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How do e-bikes compete with the other modes of transport? Investigating multiple dimensions of a modal shift

Patrick Rérat, Dimitri Marincek and Emmanuel Ravalet

Academic Observatory for Cycling and Active Mobilities & Institute of Geography and Sustainability, University of Lausanne, Lausanne, Switzerland

ABSTRACT

E-bikes are increasing popular. Their health and environment benefits depend strongly on the transport modes they replace. This paper addresses the multiple dimensions of the modal shift induced by e-bikes (motivations, uses, substitution, renunciation). It is based on biographical interviews ($n = 24$) and a survey ($n = 1466$) in Lausanne, Switzerland. Results show that e-bikes are used very frequently and for a variety of reasons (mostly utilitarian). They substitute all modes (mainly public transport, walking and the car but also cycling) and may lead to giving up regional transport passes, motorized two-wheelers and cars. E-bikes are also a way to continue cycling (despite age, children, physical condition) and to avoid switching to motorized modes. The paper calls for approaching modal shift through three perspectives to understand how e-bikes (1) fit in the transport system (systemic approach), (2) within individuals' mobility biographies (life-course approach) and (3) within the everyday organization of individuals and households (lifestyle approach). It finally argues that e-bikes should be at the core of planning – along with other forms of active mobilities and public transport – as they are a readily available way to foster decarbonization of transport.

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E-bike; cycling; modal shift; sustainable mobility; E-mobility

1. Introduction

E-bikes (or electrically-assisted bicycles) combine muscular power with an electrical assistance which activates when pedalling.[1] They are increasingly popular, notably in the European Union where sales were multiplied by 10 between 2009 and 2021, to 5.1 million units (Statista 2022). Switzerland, on which this paper focuses, has one of the highest market penetration rates. In 2022, 219,000 e-bike were sold, which represents 45.2% of all new bikes (1800 in 2005; 0.6%) (Velosuisse 2022).

E-bikes share the advantages of the conventional bicycle. They are silent, space efficient and have a low ecological footprint. A comparison of the lifecycle of different transport modes shows the e-bike's low ecological footprint is only beaten by walking and the mechanical bike (or slightly by rail transport in Switzerland as it is fully electrified) (International Transport Forum 2020; OFEV 2018). The fact that e-bikes are

CONTACT Patrick Rérat Patrick.rerat@unil.ch

environmentally much more interesting than buses, motorized-two-wheelers, and cars (whatever their propulsion) highlights their importance in the transition towards a low-carbon mobility.

E-bikes consume energy through their electric assistance, but roughly half of the energy comes from the cyclist. As an active mode, they manage to provide a meaningful amount of physical activity (Bourne et al. 2018a). They bring health benefits as they are a way to incorporate physical activity in increasingly sedentary lifestyles. Even when taking into account exposure to accidents and air pollution, the benefits of e-cycling for public health remain overwhelmingly positive (Castro et al. 2019; Götschi, Garrard, and Giles-Corti 2016). Moreover, e-bikes extend cycling – and physical activity – to a wider population and reduce the barrier of topography and distance (Rérat 2021b)

However, the level of their benefits depends strongly on the modal shift they imply (Bigazzi and Wong 2020; Bourne et al. 2018b). While its definition is simple – the replacement of transportation modes – modal shift is complex to measure. This paper discusses the modal shift of e-cycling. Based on a survey (1466 e-bikers) and interviews (24) in Lausanne, Switzerland, it addresses buyers' characteristics, their motivations, their uses, and various modal shift effects (mode replacement for journeys, renunciation of ownership of vehicles/passes).

The paper concludes by arguing for the need to draw on mobilities studies and to extend the analysis of modal shift through a systemic approach (how e-bikes fit in the transport system) a longitudinal approach (how e-bikes fit in individuals' mobility biography) and a lifestyle approach (how e-bikes fit in the everyday organization of individuals). It contributes to the literature on e-bikes but also on the analysis of modal shift for other micromobilities (e-scooters, etc.). It finally argues that e-bikes should be – along with other forms of active mobilities and public transport – at the core of planning as they are a readily available way to foster decarbonization of transport.

2. Theoretical discussion

2.1. Definition of modal shift

Modal shift (or transfer) means shifting from one mode of transport to another (usually understood as from private motorized transport to sustainable modes like public transport and active mobilities). It is often measured by the number of trips a mode replaces. Modes are part of a transportation system or transportation market where they compete, but also complete each other. Héran (2017) argues for an "omnimodal" approach to address the competition between modes as their characteristics (range, speed, price, etc.) may partly overlap. Moreover, the development of one mode is often at the detriment of others, given the number of daily trips per person is stable over time (Héran 2017).

Modal shift is a key determinant of the health and environmental benefits of e-bikes (Bigazzi and Wong 2020; Fishman and Cherry 2016; Kroesen 2017). The highest benefits are obtained when motorized modes are replaced. We start our literature review on the uses of e-bikes (including buyers' characteristics and motivations) before focusing on modal shift (for an in-depth discussion see reviews by Bigazzi and Wong 2020; Bourne et al. 2020; Cairns et al. 2017).

2.2. E-bike uses

In 76 studies reviewed by Bourne et al. (2020) the mean frequency of e-bike use ranges from 1.9 to 5.1 days per week and the mean duration from 2.7 km to 24.0 km. Commuting distance accounts for 8 km among e-bikers and 5.3 km among conventional cyclists in seven European cities (Castro et al. 2019). Weekly average distance varies from 15 km to 71 km but with important variation (Winslott Hiselius and Svensson 2014). E-bikes are primarily used for utilitarian reasons, though older adults engage in recreational e-cycling (Bourne et al. 2020). In Norway, e-bike trials increased the trips and distance cycled for travel and leisure (Fyhri and Fearnley 2015). E-bikes therefore often increase the frequency and duration of cycling.

Motivations for and barriers to e-cycling are similar to those for conventional cycling (Haustein and Møller 2016; Rérat 2021b). The electric assistance helps to cycle despite steep gradients or long distances (Dill and Rose 2012; Haustein and Møller 2016) and makes it easier to complete a succession of journeys and to escort children with a trailer or child seat (Jones, Harms, and Heinen 2016). E-bikers are older compared to conventional cyclists (de Kruijf, Ettema, and Dijst 2019; MacArthur, Dill, and Person 2014; Sun et al. 2020). Some studies report a majority of retired people (Wolf and Seebauer 2014) but others show that e-bikes are spreading to younger cohorts (Peine, van Cooten, and Neven 2017). In cycle-friendly contexts, women are overrepresented (Haustein and Møller 2016), whereas men are a majority in low cycling countries (Johnson and Rose 2013; MacArthur, Dill, and Person 2014). E-bikers often live in households with above average income and education (MacArthur, Dill, and Person 2014; Wolf and Seebauer 2014).

2.3. Modal shift effect

2.3.1. Trips

The modal shift effect of e-bikes strongly depends on the context and on the primary transport mode prior to e-bike acquisition (Bigazzi and Wong 2020; Bourne et al. 2020; Castro et al. 2019; Kroesen 2017). Bigazzi and Wong (2020) carried a meta-regression on 38 observations from 24 studies. Questions usually referred to "travel mode prior to e-bike adoption ("previous mode") and hypothetical travel mode choice if e-bikes were to be unavailable ("alternative mode") and for specific purposes or trips in general. Median modal shift values are highest for public transport (33%), conventional bicycle (27%), car (24%) and walking (10%) but vary widely with interquartile ranges of 31% for cars and 44% for public transport. A greater shift is observed from public transport in China and from the car in Europe, North America, and Australia.

In their review, Bourne et al. (2020) conclude that the car and conventional bicycle were the most substituted modes after purchasing an e-bike. The proportion of trips previously made by conventional bike ranges from 23% to 72%, while those from the car range from 20% to 86%. E-bikes also substitute from 3% to 45% of public transport trips. Few studies found an impact on walking (but see Cairns et al. 2017 in the UK). In The Netherlands, e-bikes strongly reduce the use of the conventional bicycle, but also, to a lesser extent, of the car and public transport (Kroesen 2017; Sun et al. 2020). Concerns have been raised about a modal shift away from conventional cycling (Fyhri and Fearnley 2015). It has been argued that if the e-cycling only replaces cycling, there would be no benefit to the environment or public health. However, this comparison is short-sighted and does not account for possible increases in cycling trips (Fyhri and Beate Sundfør 2020), nor the possibility that e-bikes enable the continuation of cycling despite physical limitations but also distances and gradient (Marincek and Rérat 2021). Moreover, although e-bike adoption may represent a transition from conventional cycling (Bigazzi and Wong 2020), e-bikes seem to have greater potential to replace motorized modes (Kroesen 2017).

2.3.2. Vehicles and public transport passes

While most studies focus on the e-bikes' effect on trips, fewer investigate renunciation effects or the giving up of vehicle/pass ownership. In the Netherlands, e-bikes replace the ownership of conventional bicycles but do not seem to replace cars in the household (Kroesen 2017). In a longitudinal study, Sun et al. (2020) found that the purchase of an e-bike in The Netherlands was followed by a drop in the ownership of mechanical bikes (from 81.3% to 43%) higher than in the ownership of cars (from 92.5% to 86.9%). The lack of data on renunciation is a limit of the literature.

2.3.3. Mobility biographies

Broader limits stems from the focus on trips made by each mode at the time of a survey (t_0) and before adopting an e-bike (t_{-1}). Mobility biographies research highlights the importance of adopting a broader temporal approach. Mobility practices may change or stop over an individual's life course under the influence of "key events" (e.g. work, family) (Rau and Manton 2016). Modal shifts take on a different meaning when considered in the context of a person's lifelong mobility trajectory. Switching to an e-bike may for example reduce conventional cycling. However it may also represent a way to avoid giving up cycling (due to physical limitations, longer commute, escorting children, etc.) and adopting motorized modes (Chatterjee, Sherwin, and Jain 2013; Janke and Handy 2019). Living car-free can be the result of a modal shift by giving up car ownership, but also, the consequence of avoiding motorization through a combination of alternative modes such as public transport or cycling (Baehler and Rérat 2022).

This last point highlights the need for a systemic or omnimodal approach (Héran 2014). Environmental challenges call for a post-car system (Dennis and Urry 2009). Replacing the car or reducing its importance demands thinking beyond vehicles to consider policies, investment, infrastructures, rules, images, etc. (Dennis and Urry 2009.). It also requires combining and integrating walking, cycling, public transport, and shared vehicles (Baehler and Rérat 2022). Having access to a portfolio of several modes – including e-bikes – may enable travellers to opt for alternative to ownership of the private car.

3. Research approach

Lausanne is the 4th Swiss city (145,000 inhabitants). It is a low cycling city even though the share of cycling is quickly growing: it went from 0.8% of all trips in 2010, to 1.6% in 2015 and 4.4% in 2021 (vs 6.2%, 6.8% and 7.8% nationally) (OFS and ARE 2023). Automatic counters show an increase in cycling traffic of + 86% between 2017 and 2021 (Ville de Lausanne 2022). The rest of the modal split is as follows: walking 43%, cars and motorized two-wheelers 33%, public transport 20% (OFS and ARE 2023). Car-free households accounted for 34% in 2005, 46% in 2015 and 44% in 2021 while the number of households owning two cars or more decreased (respectively 13%, 12% and 8%) (OFS and ARE 2023).

The low cycling share in comparison to other Swiss major cities is due to the hilly topography (370m at the lake side, about 650 to the highest neighbourhoods), which makes the e-bike an interesting option. It is also due to traffic conditions. These are rated very negatively: 34% of bike commuters feel unsafe during their home – work journey, 14% nationally (Rérat 2021a).

The City of Lausanne has subsidized the purchase of new e-bikes in local shops since 2000. At the time of the survey this subsidy accounted for 15% of the price (up to 500 Swiss francs) and was available to any inhabitant. This subsidy is very well known, and shops inform their customers. The database therefore gathers most e-bikers (except when they bought their e-bike outside the region or before moving to Lausanne) and is not a convenience sample (non-probability sample made of people easy to contact).

We received access to the whole database (4293 subsidies; half in the four previous years). Due to the time elapsed many older addresses were not valid. In summer 2018, 3400 beneficiaries received the questionnaire (via post or email) among which 1466 usable responses were obtained (43%).

The survey assessed e-bike adoption and experiences. For this paper, we use questions about personal characteristics (gender, age, education), motivations, use (frequency, reasons for travel) and modal shift (previous modes for journeys made by e-bike; changes in the use of other modes; renunciation to vehicles/passes). The sample encompasses both types of e-bikes: pedelec (25 km/h) and s-pedelec (45 km/h); differences are mentioned when relevant. We used the Structural Survey (2017) and the Mobility and Transport Microcensus (2015) to compare e-bikers with the population of Lausanne (OFS and ARE 2017).

A sample of 24 people were recruited among respondents for biographical interviews. The long-term relationship to cycling over the life course, and the short-term period around the purchase were covered. Participants had varied profiles (14 men and 10 women, from 25 to 81 years old) and backgrounds in cycling. The goal was to understand their cycling trajectories or "thoughts, feelings, capabilities, and actions related to cycling" (Chatterjee et al. 2012, 83). We mention in this paper only results relevant to modal shift.

4. Results

4.1. Characteristics of e-bike buyers

Most e-bikes have an assistance limited to 25 kmph (84.9% vs 15.1% for s-pedelec).[2] Most models are city e-bikes (81.2%), 13.3% are mountain e-bikes and 5.5% other kinds (cargo, folding, recumbent, etc.).

Women represent 53% of e-bikers (53%); their share is higher for pedelecs (57.9%) but much lower for s-pedelecs (26.8%) (Ravalet, Marincek, and Rérat 2023) (Table 1). E-bikers aged 35 to 49 (40.3%) and to a lesser extent 50 to 65 (29.4%) are overrepresented (but only the first category for s-pedelecs; 48.3%). Adults living with children represent 48.8% of the sample while persons living alone are underrepresented (18.2% vs 47.2% of households in Lausanne). The underrepresentation of elderly people is quite usual in low-cycling contexts while price may represent a barrier for younger adults.

Table 1. Characteristics of e-bikers compared to residents of Lausanne (source: survey and structural survey).

		% survey	% Lausanne population
Sex	Female	53%	51.7%
	Male	47%	48.3%
Age (from 20)	20–35	22.2%	32.9%
	35–49	41.8%	28.6%
	50–65	29.8%	20.3%
	65 and more	6.3%	18.3%
Education (from 25)	Compulsory school and apprenticeship	20.1%	58.3%
	University or equivalent	79.1%	41.8%

E-bikers' cultural capital is high – the share of people with a tertiary education is twice as high as in the city (70.9% vs 41.8%) which may influence images, and values. The economic capital is however closer to the national value – the median of monthly income accounts for about 6000 Francs as in Switzerland (according to the Swiss Earnings Structure Survey).

The electric assistance makes cycling easier for women, "mature adults" and those with children. Over time, there is a diversification of buyers with a rejuvenation (average age: 45.7 before 2014; 43 in 2018) and a feminization (50.6% before 2014; 55.3% in 2018). E-cycling is still rather new: Two-thirds bought their e-bike in the two years before the survey.

4.2. Motivations to buy an e-bike

Respondents rated their agreement with motivations inspired by the literature (Figure 1). Two lessons can be drawn. First, the electric assistance enables to cycle more (84.5%), faster/further (72.3%), and despite the gradient (almost all agree, 95.8%) in a hilly city like

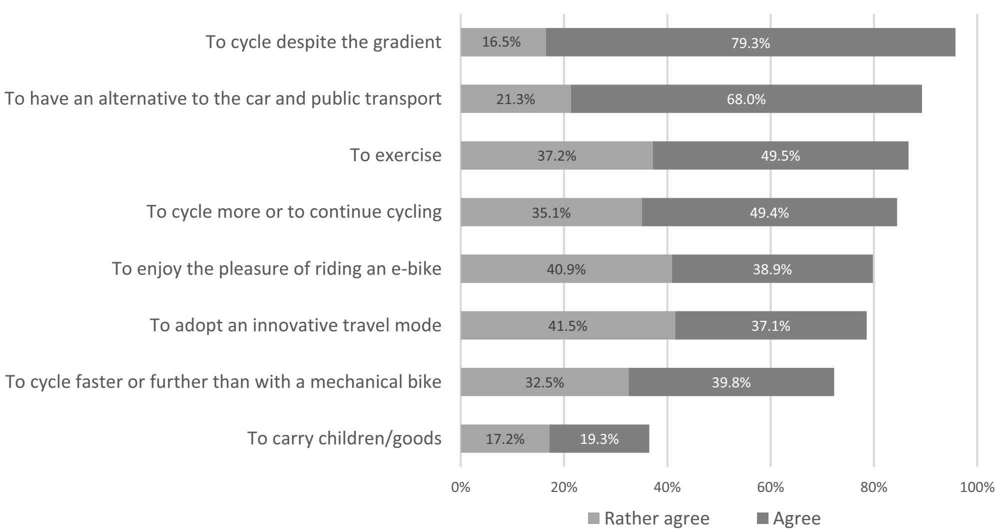

Figure 1. Motivations to buy an e-bike (source: survey).

Lausanne. Second, there is a clear objective to have an alternative to the car and public transport (addressed in the same question) (89.3%).

Alt Text: Respondents rated their agreement with 8 motivations. The electric assistance enables to cycle more (84.5%), faster/further (72.3%), and despite the gradient (almost all agree, 95.8%).

The subsidy plays a dual role (Table 2) . It triggers the purchase of an e-bike (66.9%) specifically among people with low-income, who buy their first e-bike or a less expensive model. It also encourages to buy a better performing e-bike or accessories (saddle bags, etc.) (40.4%). This upgrading effect is less frequent but important as it may consolidate the practice of e-cycling. It is more present among those with high income, who chose a more expensive e-bike or buy a new one.

In the interviews we identified two main cycling trajectories: restorative and resilient.[3] Restorative trajectories accounted for 14 users (58%) who were not cycling regularly before buying their e-bike or had even stopped. The e-bike enabled them to restore a regular cycling practice. Sub-trajectories include people "returning to cycling" (they had already cycled regularly for transport before), "starting to cycle for transport" (e.g. to reduce car use) and "reinforcing a return to cycling" (that they tried with a conventional bike).

Resilient trajectories account for 10 users (42%) who were already cycling regularly. As many chose not to own a car, cycling was their main mode of transport. The electrical assistance was a way of continuing cycling despite changes in their life (new residential location, need to carry children, advance of age, etc.) that could have led to the reduction or interruption of cycling. While some replaced conventional cycling with the e-bike completely, others alternate both types of cycling depending on the journeys, the season, etc.

E-bikes attract not only people who (re)start cycling, but also those who sustain existing practices. Restorative trajectories mainly imply a modal shift from other modes (cars and public transport) or induce new journeys (leisure/sport). Modal shift is more complex for resilient trajectories: the e-bike replaces the mechanical bike at a time when cycling was becoming fragile. The electric assistance makes it possible to avoid turning to motorized modes.

4.3. Uses of e-bikes

The frequency of use is high (Table 3): 42.1% e-cycle (almost) daily and 35.6% several times a week. One in five is an occasional user and 0.6% stopped. From a seasonality perspective, 25.3% cycle equally all year round, 47.6% less often in winter and 27.2% stop in winter (this figure increases to 50.4% for people over 60 and 67.5% for those who cycle

Table 2. Effects of the subsidy (source: survey).

		The subsidy encouraged me to buy a better performing e-bike (or accessories)		
		(Rather) no	(Rather) yes	Total
The subsidy made me decide to buy a e-bike	(Rather) no	25.0%	8.1%	33.1%
	(Rather) yes	34.6%	32.3%	66.9%
	Total	59.6%	40.4%	100%

Table 3. Frequency of e-bike use (source: survey).

Frequency	%
(Almost) everyday	42.1%
Several times a week	35.6%
A few times a month	16.7%
A few times a year	5.0%
Never	0.6%
Total	100%

only for leisure). In terms of distance, nine users out of ten (89.3%) are willing to cycle 10 km to reach an activity (excluding leisure/sport trips). This range fits the size of an urban region like Lausanne, where 304,000 people live in a 10-km radius around the town hall.[4]

The most selected reason for e-bike use is commuting (78.7%) (Table 4), much before public transport; 41.6%). The e-bike is also the most chosen to reach leisure activities (63.1%) or as a leisure in itself (68%). Lower values are found for shopping and services (36.1%). Overall, the e-bike is much more than a leisure activity (only 9.2% strictly use it for such trips) and is often used either just for utilitarian reasons (32.1%) or for a combination of leisure and transport (58.7%).

When considering all modes and trip reasons, 48.8% of respondents combine the e-bike with the car and public transport, and 18.9% with the car only. These proportions are higher for couples with child(ren) (53.4% and 20.9%) and lower for persons living alone (39.3% and 15.1%). Whereas commuting is an individual activity for which it is easier to rely only on the e-bike, going to leisure activities or for bike rides more often implies other members of the household. This is also the case for shopping and services, which explains why the car is more present (59.8%).

Respondents rated their experience of e-cycling in Lausanne. Most agreed on the lack of cycle ways (paths or lanes) (83.8%), didn't feel respected by other road users (71%) or safe when riding in traffic (69%). These difficult conditions and the lack of dedicated infrastructure limit the potential of (e-)cycling.

4.4. *Modal shift induced by e-bikes*

In comparison to the population of Lausanne, e-bikers have greater access in their households to cars (73.9% vs 53.8%), motorized two-wheelers (23.2% vs 11.3%) and bicycles (73.2% vs 41.8%). These differences are explained by the age structure of e-bikers, the overrepresentation of families, and their cultural/economic capital. When considering only households with two adults, motorization is similar between the sample and the city (car-free: 18.5% vs 20.8%). The share of national pass[6] holders is similar (10.2% vs 11.2%)

Table 4. Use of transport modes (source: survey)[5].

	Commute (job/studies)	Shopping/services	Leisure/visit	Ride (leisure/sport)
Walk	28.2%	51.6%	50.8%	68%
Conventional bicycle	9.5%	8.7%	10.1%	29%
E-bike	78.7%	36.1%	63.1%	68%
Motorized two-wheelers	9.5%	8.3%	10%	3%
Car	31.7%	59.8%	52.9%	37%
Public transport	41.6%	33.7%	51.7%	31%

but much lower for regional passes (15.1% vs 31.6%), which hints at a competition between e-bikes and regional public transport. No differences are found between pedelecs and s-pedelecs.

For two-thirds, the e-bike replaced trips previously made by public transport (Table 5). Half mentioned walking and the car, and fewer the mechanical bike (27.1%) and motorized two-wheelers (15.7% due to much lower ownership). Finally, 6.6% made new journeys by e-bike which they didn't do previously.

Since adopting an e-bike, most respondent used public transport less (−61.5%) (Table 6). The second-most reduced mode is the car (−51.3%), followed by mechanical cycling (−46%) and walking (−37.5%). Interestingly, 8% used their mechanical bicycle which may indicate a rediscovery of cycling or a better physical condition.

The question of renunciation can be interpreted as either effectively giving up a car or giving up the intention to buy one (Table 7). The most frequent renunciation concerns motorized two-wheelers (43%), likely due to their similarity with e-bikes (range, size, speed). The renunciation to a conventional bicycle is lower (33.8%) as many respondents kept their mechanical bike, while others re-started cycling thanks to the e-bike.

The e-bike led to the renunciation of an annual public transport pass for a third of respondents, who may continue using public transport, but less regularly. Renunciation of the car concerns 18.6% (44% of car-free households and 12% of households owning a single car). It is not possible to say whether this response indicates renunciation to the ownership or to the purchase of a car.

The only significant differences between households relates to couples with children. They give up less often the car (as families face more difficulties living car-free) and the conventional bicycles (that may be more adequate for family rides when children have their own bicycles).

Normal and fast e-bikes have the same renunciation effect on cars. However, fast e-bikes lead to a stronger renunciation of motorized two-wheelers (51.2% vs 41.5%), while normal e-bikes impact more conventional bikes (35.5% vs 22.8%).

Table 5. Modes previously used for journeys by e-bike (source: survey).

	Walking	Bike	Motorized two-wheeler	Car	Public transport	New journeys
No	50.1%	72.9%	84.3%	51.7%	35.2%	93.4%
Yes	49.9%	27.1%	15.7%	48.3%	64.8%	6.6%
Total	100%	100%	100%	100%	100%	100%

Table 6. Change in the use of modes since buying an e-bike (source: survey).

	Walking	Bike	Motorized two-wheeler	Car	Public transport
More	5.9%	8.1%	4.2%	2.3%	4.3%
Less	37.5%	46%	23.4%	51.3%	61.1%
No change	56.6%	45.9%	72.4%	46.3%	34.6%
Total	100%	100%	100%	100%	100%

Table 7. Renunciation to the ownership of vehicle/season ticket since buying an e-bike (source: survey).

	Bike	Motorized two-wheeler	Car	Public transport season ticket
No	66.2%	57.1%	81.4%	65.5%
Yes	33.8%	42.9%	18.6%	34.5%
Total	100%	100%	100%	100%

5. Conclusion

E-bikes are increasing popular. Their environmental and health benefits depend notably on the modes they substitute (Bigazzi and Wong 2020; Bourne et al. 2018b). We addressed e-bikes' modal shift from several angles: users (characteristics, motivations, cycling trajectories), uses (reasons for travel, frequencies) and effects (journeys and ownership of vehicles/passes) in Lausanne, Switzerland. We now wrap up the main conclusions before outlining challenges for future research.

E-bikes are used very frequently and for a variety of reasons but with a predominance of utility trips. They are contributing to the growth of cycling in Lausanne, as measured both by an increase in the modal share of cycling and by an increase in cycling traffic Their public has diversified since earlier adopters with feminization and rejuvenation (Peine, van Cooten, and Neven 2017). Buyers still stand out by having a high cultural capital which translates to a positive image of e-bikes, high environmental awareness, and greater tolerance for (perceived) price.

E-bikes compete with all the other modes and induce a multidimensional modal shift. They replace journeys previously made by public transport, car, on foot and by conventional bike (Bigazzi and Wong 2020; Bourne et al. 2020). A further – but less studied – effect which we have found is the renunciation to transport modes. This concerns firstly public transport passes and motorized two-wheelers, but also car ownership.

The impacts of e-bikes on cycling are diverse and complex. E-cycling may replace, prolong, or increase cycling. While about half respondents reduce mechanical cycling, and a similar proportion maintain it at the same level, 8% ride their mechanical bike more. Motivations for e-biking include cycling despite the gradient, continuing to cycle or cycling more, suggesting the e-bike is seen as an extension of the mechanical bike, and to have alternatives to the car and public transport. Interviews highlighted two main cycling trajectories: restorative (starting/restarting cycling) and resilient (continuing cycling despite a longer commute, the need to carry a child, age, etc.). These two trajectories reflect the difficulty of measuring modal shift, as the e-bike may replace another mode but also help to avoid switching to a motorized mode.

This study nonetheless faces some limitations. The survey was carried out in 2018, although its results are expected to be similar with more recent buyers. More attention could be given to the emerging trend of e-cargo bikes which enhance the possibility to carry goods and children. The study focused on a low-cycling city and the e-bike could have a more recreational role in rural contexts. More crucially, the survey addressed the adoption of the e-bike but further questions could have been asked on modal shift (modes that were used for the most frequent trips or that would be used without the e-bike, number of trips and distances replaced by the e-bike and made by other modes, etc.). While self-reported retrospective data are usual in mobility research, additional methods (e.g. odometer, GPS tracking) could complement this approach (Kroesen 2017).[7]

Despite these limitations, this paper draws on three concepts often used in mobilities studies – mobility biography, lifestyle and mobility system – and identifies theoretical and methodological issues for future research.

First, analyzing modal shift from a life course perspective – although challenging methodologically as it requires to know the motivations of users and their needs over a long period – is crucial to understand how the e-bike fits within mobility biographies. This would make possible to consider not only the "immediate" modal shift but also the "avoided" modal shift (e.g. adopting the e-bike to continue cycling and to avoid a motorized mode) and a "long-term" modal shift (e.g. not becoming motorized).

Second, analyzing the effects of e-bikes should address the complexity of lifestyles considered as the activities of individuals organized in space and time (e.g. Axsen, TyreeHageman, and Lentz 2012). The environmental and health impacts of new leisure journeys by e-bikes could be considered in greater detail to uncover what they replaced (e.g. sedentary activities or leisure requiring motorized vehicles). More generally, it would be important to better acknowledge multimodality (the fact that people don't rely on a sole mode of transport) and why and how the e-bike may have various effects (e.g. it may reduce the use of public transport for some but increase it for others).

Third, it is important to address modal shift from a systemic perspective rather than one mode against the other. A modal shift implied by a new mode not only produces a competition with other modes, but also the creation of a new system of mobility where new synergies and mutual reinforcement emerge. On the whole, we argue that new forms of mobility such as e-bikes (but also e-scooters or others) should not only be assessed on their ability to replace car trips in the short term. Research should also address their contribution to the implementation of a post-car system.

Methodologically, these principles call for more long-term perspectives (e.g. the need to analyse mobility trends over time) and for longitudinal approaches combining qualitative (e.g. biographic interviews) and quantitative (e.g. panel) methods. Comparative approach could also consider the diversity of regional transport systems to understand the role of e-bikes.

Politically, e-bikes are a readily available way to foster decarbonization of transport (while there are doubt whether e-cars will scale up in time and bring a sufficient contribution to meet climate goals). However, many challenges remain to realize its full potential. First, infrastructure must make e-cycling as well as cycling safe, efficient, and attractive at the scale of the urban region. Electric assistance cannot compensate for the lack of cycle ways. Attention has also to be paid to the storage of e-bikes, especially in dense, older neighbourhoods. Second, promotional measures (subsidies, trials) could help to reach a wider population (age, social class). Third, e-bikes must be thought in combination with other modes (walking, public transport, carsharing, cargo-bikes) to make it possible to live car-free. Finally, spatial planning should aim to regulate urban sprawl and promote more compact development to avoid automobile dependence, reduce distances to travel and foster trips by active mobilities.

Notes

1. They have an assistance limited to 25 kmph (pedelecs) or 45 kmph (speed-pedelecs or s-pedelecs). We exclude solely throttle-controlled bikes, which do not require to pedal.
2. This share reflects the Swiss market. S-pedelec are much more important than in the rest of Europe (4% in Belgium, 0.9% in the Netherlands, 0.5% in Germany) as they are allowed on cycle paths (Marincek and Rérat 2022; Ravalet, Marincek, and Rérat 2023).

3. Diminishing trajectories were not found among the e-bikers we interviewed. In the survey 0.6% said they didn't cycle anymore.
4. According to the site tomforth.co.uk.
5. We didn't ask for frequency and mode combination (during a journey or depending on the day) to keep the questionnaire simple.
6. It gives access to the national railway network and most city and regional networks (buses, etc.).
7. Such methods would provide data on travelled distances and could, with additional information on the type of vehicle, enable the calculation of the environment impacts of the e-bike. These are likely to be very positive in the case of Lausanne. First, the ecological footprint of e-bikes is much better than for motorized-two wheelers and cars, better than for buses (which are quite important in Lausanne) and only slightly less favorable than for trains and metros. Second, as shown by our analysis of resilient trajectories, switching from a bike to an e-bike may also be a way of continuing cycling and avoiding switching to motorized modes. Finally, buses and metros are very busy in Lausanne and should meet growing demand given sustainability policy targets. E-bike may also therefore be seen to avoid congestion in public transport and to make room for future new users.

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ORCID

Patrick Rérat http://orcid.org/0000-0001-6980-3336
Dimitri Marincek http://orcid.org/0000-0003-1851-8820
Emmanuel Ravalet http://orcid.org/0009-0002-1131-610X

Highlights

- E-bikes are used very frequently and for a variety of travel reasons
- E-bikes substitute all modes but mainly public transport, walking and the car
- E-bikes are also a way to continue cycling despite age, children, etc.
- E-bikes lead to renouncing regional passes, two-wheelers and cars
- Planning should integrate e-bikes to foster decarbonisation

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