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The E-Bike City as a radical shift toward zero-emission transport: Sustainable? Equitable? Desirable?

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A R T I C L E I N F O

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A B S T R A C T

This think piece discusses current barriers to the rapid decarbonization of transport and ways to overcome them. Policymakers face a set of contradictory goals, leading them to ponder only incremental measures: The need to reduce carbon emissions conflicts with accessibility improvements and the resulting induced traffic. At the same time, the prevention of urban sprawl as a means of promoting sustainable mobility is fundamentally thwarted by technical advances in electric cars and autonomous driving. Unable to attract public acceptance for measures that would effectively reduce travel demand, transport policy is failing to provide convincing transition pathways toward sustainable and equitable mobility for growing urban populations.

As a possible way forward, we propose a new starting point for transport policy discussions, exploring the feasibility of urban transport systems based on sustainable, flexible, and relatively cheap modes of active mobility – the *E-Bike City*. This paper aims to outline a research agenda for testing the effects of such a policy direction. In contrast to the literature on “cycling cities”, this effort should include possibilities newly opened by the recent availability of electric micro-mobility vehicles. Also, it should aim for a balanced and realistic transition rather than a unimodal utopia.

Inspired by friendly conversations around recent urban visions like 15-Minute Cities or Superblocks, this paper is meant to begin a new discussion about alternative future directions for transport policy beyond mere optimization and technical incrementalism.

1. Introduction

The transport sector must reduce its carbon footprint by at least 59% by 2050 (IPCC, 2022). It is also under pressure to reduce its other negative externalities such as accidents, noise, and extensive usage of public space (Moreno et al., 2021). At the same time, investments in better road infrastructure generate economic value through accessibility improvements but also lead to induced traffic (Hymel et al., 2010; Great Britain Department of Transport, 1994; Hymel, 2019; Duranton and Turner, 2011). This trend is further amplified by population growth (UN, 2019) and increasing wealth (Steffen et al., 2015).

The global population in cities is expected to grow by 58% from 2018 to 2050. Most of this growth will happen in less developed regions (UN, 2019), often with weak institutional practices of spatial and transport planning. The vast majority of surface-bound passenger travel is using private cars, most often occupied by solo drivers (BFS and ARE, 2023), resulting in high energy consumption, substantial negative externalities, and carbon emissions (ITF, 2020). Globally, the mode share of private cars is estimated at 71% of passenger kilometers (PKM) in urban areas (Aguiléra and Grébert, 2014). Even in Switzerland and the Netherlands, despite a relatively robust supply of alternatives, the mode share of private cars accounts for roughly 69% and 71% of PKM respectively (BFS and ARE, 2023; KiM, 2022). Car driving is further perpetuated by building codes requiring a generous provision of (uncharged) parking, making all tenants and homeowners involuntarily pay for the car-centric transport system (Shoup, 2005). At the same time, this reduces the supply of commercial and residential space, particularly in North America, where parking typically consumes around 5% of total urban land to provide 2.5 to 3 parking spaces per vehicle (Davis et al., 2010).

Since the COVID-19 pandemic, the “new normal” has further exacerbated already existing challenges. A study in Switzerland has shown that road traffic volumes have quickly returned to their pre-pandemic levels (Molloy et al., 2021). At the same time, falling transit ridership, partially paralleled by growing car ownership, poses fiscal challenges to transit agencies (Basu and Ferreira, 2021). Recent studies suggest an increased preference for solo driving over more sustainable collective

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modes (Abdullah et al., 2021; Basu and Ferreira, 2021; Das et al., 2021). Less regular commuting may further reduce revenues from season tickets (Axhausen, 2020). Policymakers need to find new ways of securing transit financing and managing road traffic volumes.

Although much hope has been placed on the technical progress of battery-electric vehicles (BEV) to mitigate climate change, realistic scenarios show that this will not decarbonize transport quickly and strongly enough (de Blas et al., 2020; Gebler et al., 2020). BEVs still produce substantial greenhouse gas (GHG) emissions throughout their lifecycle and do not address many other negative externalities of traffic, including accidents or the excessive use of space. As of 2020, the lifecycle CO_2 emissions of private BEVs were only ~25% lower compared to vehicles with internal combustion engines (ICE) (ITF, 2020). Depending on the exact vehicle model and the location where the vehicle is charged, many BEVs in the US currently produce more emissions than equivalent hybrid-electric vehicles (Singh et al., 2023). Cox et al. (2018) estimate that future BEVs may generate lifecycle GHG emissions of 45 to 78% of today's values, although parts of the necessary technologies are still in the prototype stage (IEA, 2021).

Moreover, ongoing technical progress in electric vehicles will likely decrease the generalized cost of driving below the current levels, thus inviting additional demand (Wang et al., 2021). While the lifecycle costs of BEV and ICE vehicles are approximately equal today (Verma et al., 2022), falling battery costs will make BEVs cheaper (Schmidt et al., 2017). The emergence of autonomous vehicles will further accelerate this trend by lowering the generalized cost of car travel (Bösch et al., 2018; Steck et al., 2018), enabling a wider group of potential users and perpetuating urban sprawl (Meyer et al., 2017). As a result, a large part of the BEV sustainability benefits will be counterbalanced by induced demand, in line with *Jevon's Paradox* – see Alcott (2005) and Sorrell (2009).

The car has been a critical driver of economic growth since the early 1900s, with many jobs dependent on its supply chains. Attempting to retain this model while at the same time addressing the climate crisis, transport policy is caught in a dilemma between maximizing accessibility and making transport sustainable (Axhausen, 2020; Axhausen, 2022). This paper aims to catalyze a discussion about ways out of this dilemma.

The remainder of this paper is structured as follows: Section 2 presents an overview of behavior changes necessary for effective transition paths to sustainable mobility. Among different ways to achieve such changes, it emphasizes the potential of urban visions which positively frame future travel behaviors. Section 3 proposes the *E-Bike City* as a new starting point for urban transport policy discussions. Section 4 elaborates on changes in accessibility patterns that may emerge from such policy direction in existing cities. Section 5 outlines potential barriers and emerging avenues of research, followed by a conclusion in Section 6.

2. Behavior change for sustainability

2.1. Necessary and possible

As shown in the introduction, technical progress alone is insufficient for decarbonizing transport within the necessary time frame. A substantial body of literature concludes that there is an inevitable need for large behavior changes alongside technical progress (de Blas et al., 2020; Grubler et al., 2018; Moriarty and Honnery, 2013). Multiple studies have analyzed the potential of such behavior changes (see Creutzig, 2019; Santos, 2017; Banister, 2011; Santos et al., 2010; Zhang and Zhang, 2021). Experience from the COVID-19 pandemic shows that substantial changes in travel behavior are possible (Molloy et al., 2021). However, the following sections illustrate how difficult it is to induce them under normal conditions.

2.2. Supply-side changes

Mobility pricing: A frequently discussed way of changing travel behavior is through comprehensive pricing (Levinson, 2010). Such schemes may focus on internalizing the adverse external effects of carbon emissions, noise, usage of space, accidents, etc., and helping to maintain desirable levels of service in traffic. Successful examples from Stockholm, Milan, London, New York City, and Singapore (Croci, 2016; Schaller, 2010; Anas and Lindsey, 2011) show that such measures are, in principle, possible and effective. However, evidence from democratic countries also shows that implementing such measures is highly unpopular and politically unfeasible on a larger scale (Jakobsson et al., 2000; Gu et al., 2018; Lichtin et al., 2022). Even payment for parking is contested in many places (Shoup, 2005).

Land use and transit: In the long term, mode choices or, more generally, the amount of travel may be influenced by changing land-use patterns or providing attractive transit options. Public transport's lifecycle GHG emissions per PKM are roughly 50–70% lower compared to private cars (ITF, 2020). Its use of road space is about 16 times more efficient in terms of passengers/h on a single traffic lane (NACTO, 2016). However, the time needed to implement land-use changes and transit is too long given the urgency of the climate crisis. Also, the benefits of residential areas favoring car-free lifestyles, such as transit-oriented development (Ohland and Dittmar, 2004; Calthorpe, 1993), can vanish over time if high property values attract groups with high car ownership rates (Paul and Taylor, 2021; Steuteville, 2017).

Cycling infrastructure: A different type of behavior change could be induced by encouraging shifts to active modes with light and energy-efficient vehicles. Over the entire lifecycle, cyclists on privately owned e-bikes emit ~5 times less GHG per PKM than car users (~10 times less in the case of conventional bicycles) (ITF, 2020), and a single traffic lane can carry 5 to 12 times more passengers per hour on bicycles than in private cars (NACTO, 2016). Besides low emissions and high space efficiency, widespread cycling may also increase transit catchment areas, making demand bundling on existing infrastructure easier. Finally, in contrast to car traffic, cycling produces substantial health benefits (Garrard et al., 2021), resulting in net positive externalities (ARE, 2022). Many individuals would in principle be willing to cycle if it were safer (Dill and McNeil, 2016; Geller, 2009). Providing a safe cycling infrastructure is therefore an essential instrument for inducing the shift (Pucher and Buehler, 2008). Since the 1990s, New York, San Francisco, Portland, London, Paris, Berlin, Seville, Bogotá, and many other cities have increased their modal splits of cycling by investing in safer, dedicated infrastructure for cyclists (Pucher and Buehler, 2021). Unprecedented progress happened during the COVID-19 pandemic, with massive networks of pop-up bike lanes deployed in many prominent cities, e.g., Paris, London, Washington DC, and Boston (Buehler and Pucher, 2021; Kraus and Koch, 2021; Becker et al., 2022), many of which have remained until today. Active modes are increasingly seen as a functional solution to multiple challenges of transport policy (Fishman, 2016; Parkin, 2012; Pucher and Buehler, 2017), and the recent developments may be a starting point for discussions about more radical changes in urban transport systems in the post-COVID-19 world. However, despite the growing popularity of cycling policies, it is still unclear to what extent cycling could replace a substantial part of private car trips and what would be the consequences.

2.3. Demand-side changes

Pooling: The current average car occupancy in Switzerland is 1.53 passengers, resulting in a load factor of 31% (BFS and ARE, 2023). With 69% of car capacity unused, increasing the occupancy could substantially reduce the volume of traffic. Pooling in relatively small paratransit vehicles is popular in emerging countries (Behrens et al., 2016), as there are few alternative modes of transport. However, it remains a marginal phenomenon wherever solo driving is affordable. Evidence from the US shows that pooling is largely limited to low-income communities lacking alternatives (Shaheen, 2018) and mainly draws passengers from public transit (Shaheen et al., 2016). For similar reasons, even the large-scale potential of autonomous pooled taxis is contested (Alonso-González et al., 2021; Becker, 2020).

Working from home: Working from home can reduce the need for commuting (Delventhal et al., 2022). However, rebound effects would likely shrink the resulting benefits (O'Brien and Yazdani Aliabadi, 2020). A GPS tracking study in Switzerland during and after the initial stages of the pandemic shows that road traffic returned to its original levels within five months despite an unprecedented increase in work from home (Molloy et al., 2021). Older studies on "telecommuting" also suggest that working from home bears no substantial potential for reducing car travel, given long-term rebound effects (Choo et al., 2005; Zhu and Mason, 2014).

2.4. Urban visions as enablers for transport policy discussions?

Unlike traditional measures for controlling travel demand via pricing and restrictions, positive images such as *15-Minute Cities* (Moreno et al., 2021) or *Superblocks* (Rueda, 2019) enjoy a rather favorable discussion despite aiming for similar goals. Through their positive reception, they open ways of rethinking elements of urban planning that might otherwise not be negotiable. In such cities, sustainable mobility can enjoy a universal preference without the possibility of some groups buying themselves out. The practical complexities may only become apparent at a later point, once the public is enthusiastic about the benefits of living in such cities.

Images of modern urbanism from the beginning of the 20th century also enjoyed great popularity and shaped urban planning throughout the rest of the century. Visions like Le Corbusier's *Ville Radieuse* (Le Corbusier, 1935), Frank Lloyd Wright's *Broadacre City* (Wright, 1932), or Hans Bernhard Reichow's car-oriented city *Autogerechte Stadt* (Reichow, 1959) quickly won the favor of the public, while the resulting traffic and parking challenges only became apparent later.

Observing the normative power of such urban visions, the question arises as to whether the enthusiasm they produce could be used to open a stream of more ambitious transport policy discussions. As a starting point for this discourse, we propose to explore the feasibility of an *E-Bike City*, building on early ideas in Axhausen (2022).

3. The E-Bike City

3.1. The basic idea

The E-Bike City aims to provide a new starting point for transport policy discussions. It should mobilize research to test the feasibility of an urban transport system based primarily on active mobility and public transit, potentially opening new pathways for future transport policies. Its core idea is allocating road space in favor of transit, walking, and cycling while incorporating e-bikes as an accelerator for longer trips and wider user groups. As an initial assumption, it may dedicate approximately 50% of the existing road space to cycling while leaving the remaining space for motorized traffic, mainly in the form of one-way streets. A generous provision of dedicated infrastructure would make cycling attractive to a wide spectrum of users. Public transit would allow longer trips and complement cycling when it is not feasible. On the other hand, reducing road space for motorized traffic would make driving less attractive, further encouraging a shift to sustainable modes.

The recent mass availability of e-bikes and other micro-mobility vehicles such as cargo bikes or e-scooters massively broadens the potential appeal compared to traditional bicycles. They allow longer trips and reduce the impact of elevation differences (Rérat, 2021; Meister et al., 2023; Meyer de Freitas and Axhausen, 2023; Bourne et al., 2020; MacArthur et al., 2018). Using e-bikes helps increase cycling frequencies (Van Cauwenberg et al., 2022; Edge et al., 2018) and maintain cycling despite changing circumstances (Marincek and Rérat, 2021), and is being seen as an enabler, strengthening transition pathways (Edge et al., 2020). Giving wider user groups the capability to cover short and medium distances using micro-mobility improves the cost-effectiveness of transit systems by allowing stronger demand bundling on lower-density networks with longer stop distances.

In contrast to more extreme visions of cycling cities like *Velotopia* (Fleming, 2017) or *Bicycle Utopias* (Popan, 2019), the E-Bike City should not be seen as a unimodal utopia, but rather as a means of seeking a new balance between existing modes of transport. Its streets would still permit private car travel, although possibly at lower speeds and with some detours. The available road capacity could be priced or otherwise managed to ensure a sufficient level of service for essential trips as well as for commercial and emergency vehicles.

A conscious supply of public and private parking spaces would help manage both the demand for driving and car ownership rates. It would also help provide more space for commercial, residential, and public uses – resulting in more local businesses, affordable housing, and attractive street spaces. Fully internalizing the cost of parking to its users would relieve car-free households from the cost of car traffic and incentivize economically efficient mode choices.

Similar to the pop-up bike lanes implemented in response to the COVID-19 pandemic, the E-Bike City could be started by merely repainting existing road surfaces, at first, perhaps, as a set of temporary pilots. Experimenting at little cost and with immediate results would replace lengthy planning processes. If successful, first progress toward healthy and sustainable cities would be achievable within a few years.

The E-Bike City vision is a research agenda for a way out of the present transport policy dilemma by exploring to which extent future transport planning could utilize the potential of active mobility. The following section outlines its key challenges, together with areas of research to address them.

3.2. Addressing practical challenges

Long trip distances: Decades of car-centric lifestyles have created urban geographies that are difficult to serve by other modes than private cars (Illich, 1974). Long distances and dispersed travel patterns in sprawling cities and agglomerations are a considerable challenge for sustainable mobility transitions. However, the vast majority of trips in Western metropolitan areas are still short, well within the range of e-bikes, possibly in combination with public transit. Assuming an average e-bike speed of 22 km/h for longer trips (Lopez et al., 2017), distances of up to 11 km are attainable within a travel time of 30 min. Faster micro-mobility vehicles such as s-pedelecs with average speeds of 22–25 km/h (Schleinitz et al., 2017) could extend the viable distances even further. In the greater Zurich area (Kanton Zürich), including suburban and some rural areas, 65% of passenger car trips are within 10 km, and 75% are within 16 km (Hofer, 2017). In the major US metropolitan areas of San Francisco, Boston, Chicago, and Atlanta, 72–77% of passenger car trips are within 16 km (Federal Highway Administration, 2020). Despite concerns over range anxiety (Edge et al., 2018), entire chains of such trips are well within the range of standard e-bike batteries, typically lasting for 50–80 km (Robert Bosch GmbH, 2023c). Intercommunal cycling "super-highways" (Rich et al., 2021; Hallberg et al., 2021; Pucher and Buehler, 2017) could help maximize the distances that can be covered using micro-mobility. Longer trips could leverage public transit, mainly using existing networks even if they have low density. However, the real potential, given daily activity chains, personal capabilities, and cargo loads, remains unclear. Future research is needed to show a more accurate estimate of trips that are feasible with active modes under real conditions and constraints.

Weather: In large parts of North America and Northern Europe, cold temperatures and icy streets challenge the safety and comfort of users. Rainfall and heat also reduce the attractiveness of cycling. In an E-Bike City, users would have an alternative offered by public transit services, although the travel times might be longer and the overall cost higher for such occasional trips. Nevertheless, evidence from Germany suggests that high cycling levels are associated with lower sensitivity to weather conditions. In cities with high levels of cycling, the weather-based variation in bicycle counts during morning peak hours is under 5% (Goldmann and Wessel, 2021). To reduce the weather sensitivity further, E-Bike Cities could incorporate existing biodiversity efforts connecting green spaces (Kong et al., 2010; Parker et al., 2008) to create a primary network of cycling streets where greenery protects against rain and heat. Finally, a lasting increase in working from home could imply more flexibility in deciding when to travel, shifting travel demand to times with better weather conditions. To gain a fuller understanding of these effects, future research should explore the demand variations closer and show how they impact the usage of alternatives like public transit. If many cyclists turned to transit on rainy and cold days, research should show possible ways of operating rail and buses under such conditions.

User capabilities: Bicycle usage is limited by personal capabilities, e.g., leading to substantially lower speeds for the elderly (Schleinitz et al., 2017). However, electrification helps even less able-bodied groups to stay mobile (Leger et al., 2019; Meyer de Freitas and Axhausen, 2023). The wide range of available micro-mobility vehicles and safe infrastructure could help people with disabilities to move independently. On the other hand, electric micro-mobility vehicles of different sizes, weights, and speeds present a challenge for infrastructure design, requiring new approaches and quality measures (Kazemzadeh and Ronchi, 2022). While higher speeds may lead to more dangerous behavior (Vlakveld et al., 2021), users of electric vehicles still seem to violate traffic rules no more often than those with non-electric vehicles (Langford et al., 2015), and the overall safety of e-bike users appears to be similar to those using conventional bicycles (Jenkins et al., 2022). Given the wide variety of electric and human-powered vehicles needed to make active mobility a primary mode of transport, future research should show what infrastructure will be needed, how it can be integrated into existing streets, and how it performs in comparison to traditional car-based transport systems.

Parking: A large number of (electric) micro-mobility vehicles of different sizes would require parking facilities, and the high value of e-bikes and cargo bikes creates a need for weather and theft protection. In cases where micro-mobility replaces car trips, parking can be provided by reallocating existing car parking spaces. But if cycling replaces short transit trips, additional space for bicycle parking may be needed, particularly at central locations. Studies of travel behavior in E-Bike Cities should provide more clarity on the number and type of bicycle parking spots needed.

Charging: The batteries of private e-bikes will put some additional load on the power grid, but even a massive usage is unlikely to create relevant challenges. Typical e-bike chargers, with a power rating of 0.1–0.3 kW (Robert Bosch GmbH, 2023a) correspond to roughly one to five incandescent light bulbs, which were in wide use until the early 2000s. This is in sharp contrast to standard home chargers for BEVs, which have a power rating of up to 11.5 kW (Tesla, 2021) and 250 kW in the case of "superchargers" (Tesla, 2023). A typical e-bike battery has a capacity of 0.5–0.75 kWh (Robert Bosch GmbH, 2023b) – less than 1% of a Tesla Model S battery with up to 100 kWh (EV Database, 2023). The power consumption of a typical e-bike is approximately 0.01 kWh/km, over 90% less compared to the Tesla Model S (EV Database, 2023). Nevertheless, issues of power consumption, potentials of power storage, as well as lifecycle emissions remain a concern. Future research should deepen our understanding of these aspects in an E-Bike City, especially in comparison to other urban mobility futures.

Vehicle availability: In an E-Bike City, small micro-mobility vehicles are a crucial enabler for an achievable transition to sustainable urban mobility. But despite their growing popularity, their mass adoption faces an uptake barrier of purchase prices that are not affordable for some population groups (Jones et al., 2016; Jenkins et al., 2022). The E-Bike City may need to leverage large-scale sharing schemes to give every person access to the vehicle they need. Even though shared vehicles are associated with higher lifecycle GHG emissions (Reck et al., 2022) they may be crucial for low-income groups or could enable flexible trip chaining with public transit.

4. Accessibility effects

4.1. Changes in accessibility geographies

Accessibility refers to the possibility of reaching destinations from a particular place (Hansen, 1959) and is a crucial metric for transport and land use. Literature on equity suggests that transport systems should be designed to follow desired structures of accessibility rather than aim for free-flowing traffic (van Wee, 2011; Martens, 2016). However, accessibility is a complex measure. Depending on the question analyzed, components like travel time, comfort, or time-dependent opening hours of the different activities may be considered. In reality, each person's accessibility is also influenced by individual preferences as well as by capabilities like vehicle and license ownership, bodily fitness, or time constraints. Therefore, accessibility has no single definition and rather needs to be tailored to each analysis. Here, we focus on the accessibility components of travel time and cyclists' comfort.

The reallocation of road space in the E-Bike City would substantially change the accessibility for cyclists and drivers. While drivers would experience longer travel times and detours due to reduced road capacity, reduced speeds, and one-way streets, cyclists would enjoy an increase in comfort while using the dedicated infrastructure. The resulting accessibility difference would lead to mode shifts.

However, capabilities and preferences for changing modes vary across user groups. Depending on their degree of physical fitness or level of education, some users might be less inclined to switch to cycling, even with competitive travel times and better safety (Hudde, 2022; Meyer de Freitas and Axhausen, 2023). Also, the actual accessibility gains in cycling and public transit might not compensate for the travel time losses incurred by those currently driving. In particular, longer trips from outside of the city might be less attractive using transit and micro-mobility. On the other hand, some groups benefit from massively improved accessibility and independence once cycling became safer.

Table 1 shows estimated conceptual relationships of accessibility impacts on different user groups. We distinguish two types of urban settings representing simplified examples from industrialized nations: Cities with high density and strong public transit, and cities with low density and less attractive public transit. Within each city type, we

Table 1
Eight combinations of urban typology and population groups, together with a conceptual estimate of what accessibility changes they would experience (accessibility before → after).

	City residents		Suburban commuters	
	(1) without a car	(1) with a car	(3) without a car	(3) with a car
(H) High-density city with attractive public transit	**H1** + → + + (gain)	**H2** + + + → + + (loss)	**H3** - → o (gain)	**H4** + → o (loss)
(L) Low-density city with unattractive public transit	**L1** - → + (large gain)	**L2** + + → + (loss)	**L3** - - - → - - (gain)	**L4** o → - (loss)
Accessibility scale:				
+ + +	Highest			
+ +	Excellent			
+	Good			
o	Fair			
−	Poor			
- -	Bad			
- - -	Lowest			

consider city residents and suburban commuters, both with and without a car, all resulting in a 2 × 4 matrix of cases. The conceptual relationships are strongly simplified, representing the average situation of the exemplary groups, without considering cases under exceptional circumstances, such as cities where driving is already restricted to a minimum while allowing safe cycling. The following paragraph uses terminology from the scale below the table to describe the different levels of accessibility.

In dense cities with attractive public transit, urban residents without cars (H1) currently have “good” accessibility, greater than car-free residents in the suburbs, but less than their urban counterparts with cars. In an E-Bike City, their accessibility would increase through safer and faster cycling alternatives for shorter trips. On the other hand, those owning a car and enjoying the highest accessibility levels would experience longer travel times. Although the attractiveness of cycling would increase for this group as well, switching to cycling and transit would still likely result in slightly less accessibility for this group. Suburban commuters without a car (H3) currently have “poor” accessibility, less than all other groups. The E-Bike City's transit, optimized for fast travel across longer distances and safer last-mile cycling within the city, would increase their accessibility. Those with a car presently have substantially higher accessibility (H4) and would incur losses similar to group H2, reaching accessibility equivalent to their neighbors without a car.

In cities with low density and less attractive public transit, those without a car (L1) currently experience substantially lower levels of accessibility than their counterparts in high-density cities. In an E-Bike City, they would enjoy substantial gains due to attractive cycling and faster transit. On the other hand, those with a car (L2) would experience a loss, resulting in accessibility levels similar to those without a car. Suburban commuters without a car (L3), who currently experience the lowest accessibility among all groups, would experience gains similar to their counterparts in high-density cities, but their accessibility would remain “bad”. Those with a car (L4), on the other hand, would incur longer travel times, but driving would likely still provide them better accessibility in comparison to the previous group.

Overall, the groups already using sustainable modes of transport would gain accessibility, while those driving would lose some. Large gains would be experienced by residents living in low-density cities without a car, possibly correlating with low-income communities. However, the exact losses for car owners might vary strongly depending on how the future conception of transit systems provided alternative travel options over longer distances. Also, those switching from driving to cycling might experience additional losses due to discomfort. Further research is needed to better understand the expected changes in accessibility structures and how they correlate with existing lines of division in society.

4.2. Distributive justice and equity

The previous section outlined the conceptually expected accessibility changes and introduced a set of questions to be explored in future research. This section focuses on possible implications for distributive justice and social equity.

The *Production of Space* (Lefebvre, 1991) calls for a definition of space through social relations rather than its physical characteristics. Along these lines, a city is a place of social exchange to which every person should be entitled; see also *The Right to the City* (Lefebvre, 1972). Theories of transport justice frame this right through the concept of accessibility, combined with theories from political philosophy. According to *Spheres of Justice* (Walzer, 1983), some goods should be excluded from a free exchange due to their special meaning in society. Applying Lefebvre's point, social interaction is one such good. The *Capability Approach* (Sen, 2009) identifies the mere possibility of accessing destinations as essential, regardless of whether they are reached. The *Difference Principle* (Rawls, 1999) marks the importance of redistributing resources to those who are worst off (such as those with low accessibility). And finally, the theory of auctions and insurance schemes in Dworkin (2000) justifies partial compensations for those incurring unjust accessibility deficits.

Building on these theories, Pereira et al. (2017) propose that distributive justice concerns over transport and social exclusion should primarily address accessibility as a human capability. Following this argument, the social equity of transport policies is mainly a question of groups experiencing the lowest accessibility to key locations. *Transport Justice* (Martens, 2016) introduces an analytical method of evaluating the social equity of real transport-land use systems. In Martens' view, transport planning must aim to provide every population group with at least a basic level of accessibility above a sufficiency threshold. In contrast to these accessibility-centric theories, Gössling (2016) adopts a wider view of transport injustices in three dimensions: exposure to traffic risks and pollutants, distribution of space, and the valuation of travel time. He concludes that pedestrians and cyclists are the most sustainable participants in urban contexts, yet are particularly often affected by the negative effects of motorized traffic, which is a clear case of injustice.

Taking the perspective of Gössling (2016), the E-Bike City would mitigate the injustices in today's Western cities: It would reduce the pollution faced by cyclists and pedestrians and improve their safety. From the perspective of transport justice, it would reduce the accessibility disadvantage typically experienced by people who don't have access to cars. A notable instance of the E-Bike City improving the lowest accessibility levels would be the effects on car-free residents in low-density cities and suburban areas.

However, while reducing the injustice faced by some groups, the E-Bike City might also exacerbate the disadvantage of other people. Especially where living costs in dense urban areas are not affordable and property ownership is increasingly determined by inheritance (Adkins and Konings, 2020), underprivileged groups could face inequitable car dependency due to their involuntary choice of residential location. Reducing road capacity in favor of cyclists might deepen their inequitable disadvantages unless balanced in other ways.

The anticipated changes in accessibility structures could also challenge the relationship between urban and rural communities. While the former would benefit from fewer negative externalities from motorized traffic, the latter would face higher generalized costs on their trips into the city. Although such changes would correct existing injustices in terms of Gössling (2016), their distributive effects might create substantial controversies over different groups' “right to the city”.

In summary, the E-Bike City could help weaken existing injustices between different population groups and their modes of transport. It could also benefit those groups experiencing the lowest accessibility because of no car ownership. However, its pure form in existing car-centric cities might increase injustices based on involuntary residential location choice and increase tensions between urban and rural communities unless addressed. To explore the feasibility and effects of an E-Bike City, further research is needed to understand its impacts on transport justice given the existing spatial structure, social networks, and market conditions in real cities.

5. Getting there: Equitable and desirable?

A transition to a more sustainable transportation system is crucial for mitigating climate change. However, getting there in existing car-centric cities poses considerable challenges. In addition to improving sustainability, the proposed transition must avoid creating new injustices and be capable of gaining political acceptance. This section discusses a series of further issues that may be crucial to acquiring democratic acceptance of E-Bike Cities and implementing them.

The E-Bike City would favor those already using sustainable modes while producing losses for those presently driving. Designing proposals for real cities must involve tools for a precise understanding of the expected changes in accessibility patterns, how they relate to different population groups, and perhaps even to voting districts. Fine-tuning the exact road space allocation, changing public transit services, or adjusting the boundaries of areas where the transformation should be applied might play a key role in developing a proposal that is desirable for the majority.

The radical character of the proposal might also trigger fears of change. It might spur anxieties about the need for (unwanted) reorganization of everyday behaviors and changes in real-estate values (Liu and Shi, 2017; McDougall and Doucet, 2022). To address these concerns, the E-Bike City must emphasize its core vision and provide a locally embedded taste of it. Also, it must be transparent about the expected effects. Akin to Wright and Le Corbusier, the concept must be presented “not in dry formulas, but through three-dimensional models” (Fishman, 1982), creating strong positive images that will shape the planning process and the public discussion. As put by Banister (2005), sustainability policies must build on high levels of information, empowerment, and consistent policy direction to reach the required acceptance and impact.

6. Conclusion

Making urban mobility sustainable will demand a deep rethinking of transport policies, far beyond relying solely on technical progress. Behavior changes toward sustainable mode choices are an inevitable part of realistic pathways for addressing the climate crisis. The E-Bike City proposed in this think piece is intended to provoke a discussion about new directions for policymaking and inspire supporting research. It is meant to provide a taste of a sustainable mobility future, serving as a conceptual anchor for future work. Like Le Corbusier's and Wright's visions from the early 20th century, or the more recent 15-Minute Cities and Superblocks, the E-Bike City is designed to motivate scholars, policymakers, and the public to work toward a sustainable, equitable, and desirable urban future.

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CRediT authorship contribution statement

Lukas Ballo: Conceptualization, Writing – original draft, Writing – review & editing. **Lucas Meyer de Freitas:** Conceptualization, Writing – review & editing. **Adrian Meister:** Conceptualization, Writing – review & editing. **Kay W. Axhausen:** Conceptualization, Writing – review & editing.

Declaration of Competing Interest

None.

Data availability

No data was used for the research described in the article.

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