Summarizing the Impacts of Electric Bicycle Adoption on Vehicle Travel, Emissions, and Physical Activity

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Summary

Increasing use of electric bicycles (e-bikes) could help cities achieve goals of reducing emissions and increasing physical activity. A key assumption underlying this hope is that use of e-bikes will displace a substantial amount of travel by car. This article reviews studies on e-bike adoption and summarizes the expected impacts on vehicle travel, emissions, and physical activity. Existing evidence suggests that on average each additional e-bike adoption will reduce around 2,000 vehicle-kilometers travelled per year, yielding a net reduction of 460 kg per year in CO_2 emissions and a net increase of 21 minutes per week of physical activity.

1 Introduction

E-bikes are an emerging mode of personal transportation that could potentially help cities move toward their climate goals. E-bikes offer a sustainable alternative mode of transport to private cars that can be utilized by a greater range of ages and capabilities than conventional bicycles. Limited data are available on the size of the e-bike market in Canada, but various sources suggest it is growing (Shore 2016; WATT Consulting Group 2018; Bartel 2018). E-bike adoption can be bolstered by the actions of cities, regions, and provinces such as developing e-bike friendly building codes, modifying vehicle regulations, providing purchase incentives, establishing lending programs, and improving bicycle facilities, among other strategies (Aono and Bigazzi 2019; MacArthur, Dill, and Person 2014; Dill and Rose 2012).

A variety of methods have been used to estimate the impacts of e-bike promotion policies. A common approach is to apply sales and adoption assumptions, due to a lack of available information on e-bike utilization (Mason, Fulton, and McDonald 2015). Beyond adoption, key questions for e-bike policy analysis are the broader impacts on greenhouse gas emissions, and physical activity, particularly through displaced car usage. The objective of this article is to summarize the known impacts of e-bike adoption on car travel, emissions, health, and safety.

2 E-bike Usage

More than a dozen studies over the past decade have characterized the travel habits of early e-bike adopters (Cairns et al. 2017; Popovich et al. 2014; Ling et al. 2017; Gorenflo et al. 2017; Fyhri and Sundfør 2014; Hiselius and Svenssona 2014; Wolf, Angelika 2014; Allemann and Raubal 2015; Lopez Aguirre et al. 2015; Kroesen 2017; Weinert, Jonathan, Chaktan Ma, Xinmiao Yang 2007; Montgomery 2010; Mohamed, Amr, n.d.; McQueen, MacArthur, and Cherry 2019). These studies have been focused in Europe, with a smaller number available from China and North America. The following summarize average usage in the European and North American studies, though quantities can vary greatly by location and study sample (N = number of studies, SD = standard deviation):

1. Average trip speed for e-bikes is approximately 20 km/hr (N=4, SD=7.2),
2. Average riding frequency is 3.3 days per week (N=3, SD=1.2), and
3. Average single-trip distance is 6 km and weekly total distance is 60 km (N=17, SD=4.4).

3 Displacement of Travel by Other Modes

There is less literature on displacement of travel by other modes after e-bike adoption, again concentrated in Europe, with one study from the United States (Hiselius and Svenssona 2014; Hiselius and Svensson 2017; Cairns et al. 2017; Dekker 2013; Christopher Robin Cherry 2007; Montgomery 2010; McQueen, MacArthur, and Cherry 2019). The results of these studies suggest that on average (N = number of studies, SD = standard deviation):

- 44% of e-bike trips replace car trips (N=8, SD=17.3),
- 30% of e-bike trips replace trips by conventional bicycle (N=7, SD=12.7),
- 12% of e-bike trips replace trips by public transit (N=6, SD=5.0), and
- 6% of e-bike trips replace walking trips (N=3, SD=2.0).

These percentages are illustrated in Figure 1, with the remaining trips (8%) assumed to be new (induced) trips. Past estimates of induced e-bike trips ranged from 1% to 38% in the United States and the Netherlands (Dekker 2013; Hiselius and Svenssona 2014; MacArthur et al. 2018; Hendriksen et al. 2008; Cairns et al. 2017).

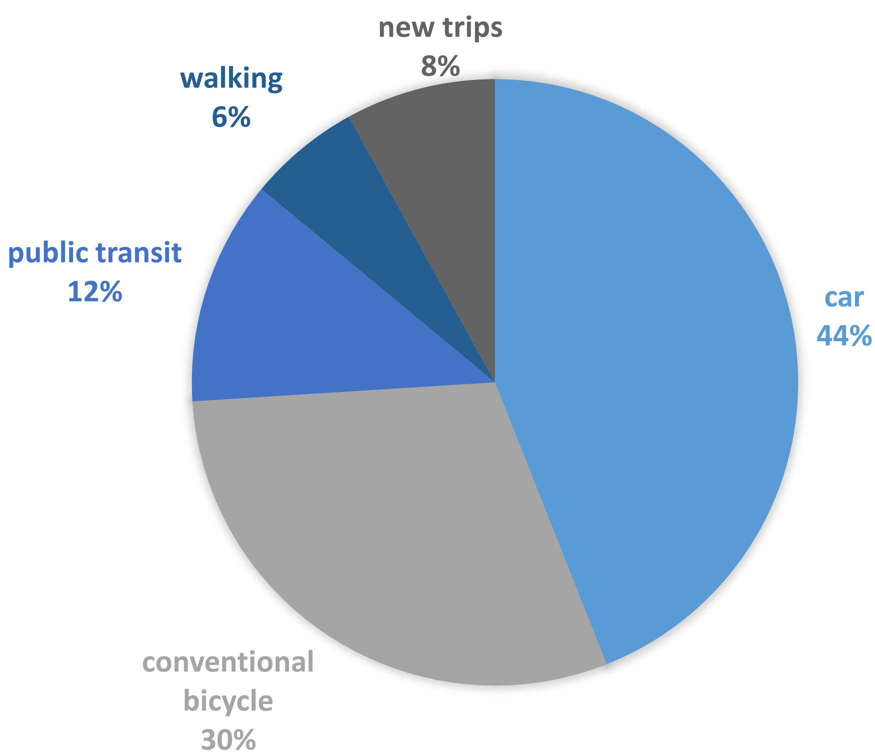

Figure 1. E-bike mode substitution summary

Several studies have reported travel distance displaced by e-bike adoption, rather than number of trips; synthesizing the findings of (Dekker 2013; Hiselius and Svenssona 2014; McQueen, MacArthur, and Cherry 2019), around 39 km of driving per week is displaced by the average e-bike adopter (ranging from 25 to 50 km). The following have similarly been reported for travel distances displaced from other transportation modes by the average e-bike adopter:

- Public transit: 9 km displaced per week,
- Conventional bicycle: 14 km displaced per week, and
- Walking: 3 km displaced per week.

In summary, the average e-bike adoption can be estimated to yield 60 km of e-bike usage, displacing 39 km of driving, 9 km of transit travel, 14 km of conventional cycling, and 3 km of walking.

4 Emissions Impacts

Several studies have investigated the environmental impacts of e-bike adoption in Europe, China, and the United States (Popovich et al. 2014; Hiselius and Svensson 2017; Engelmoer 2012; Dave 2010; Dekker 2013; Christopher Robin Cherry 2007; Christopher R Cherry, Weinert, and Xinmiao 2009). Using lifecycle CO_2 emission rates from (Engelmoer 2012) and the travel displacement estimates above, the estimated weekly travel emissions reduction attributable to e-bike adoption is summarized in Table 1. Each e-bike adoption is expected to result in approximately 460 kg CO_2 net emissions reduction per year, on average.

Table 1. CO_2 emission reductions from displacing trips by other modes

Travel	Weekly travel	Lifecycle CO_2 emissions rate (g/PKT*)	Weekly CO_2 emissions (kg)	Annual CO_2 emissions (kg)
Car (displaced)	-39 km	260	-10.1	-525
Public transit (displaced)	-9 km	100	-0.9	-47
Conventional bicycle (displaced)	-14 km	20	-0.3	-16
Walking (displaced)	-3 km	0	0	0
E-bike	60 km	40	2.4	125
Total	-12 km	NA	-8.9	-463

* PKT: Passenger Kilometers Travelled

5 Health Impacts

Common health guidelines recommend at least 150 minutes per week of moderate to vigorous physical activity (MVPA) (Department of Health 2011). A few studies have explored the relationship between electric pedal-assist and intensity of physical activity while cycling (Simons, Van Es, and Hendriksen 2009; Gojanovic et al. 2011; Sperlich et al. 2012). Based on these studies, e-bike trips are around 25% lower intensity physical activity than trips on conventional bikes. E-bike trips are at an average MET (metabolic equivalent task) of around 5, which qualifies as moderate physical activity – although intensity varies greatly with individual, trip, and environmental factors.

Incorporating information from studies of physical activity during travel by other modes (Chaix et al. 2014; Ferrer, Cooper, and Audrey 2018; Costa et al. 2015), the average amount of MVPA per PKT by car, transit, conventional bicycle, walking, and e-bike can be estimated as 0, 0.7, 2.4, 9.8, and 1.5 minutes, respectively. Table 2 summarizes the combined physical activity and travel displacement estimates, indicating a net increase of 21 minutes of MVPA per week for the average e-bike adoption. The 60 km of e-bike riding per week is estimated to achieve about 60% of the target minutes of MVPA. Physical activity levels during e-bike trips will likely be influenced by trip purpose, weather, terrain, speed, level of power assistance, and other factors.

Table 2. Estimated changes in physical activity from displacing trips by other modes

Travel	Weekly travel	Minutes MVPA per PKT	Weekly minutes MVPA
Car (displaced)	-39 km	0	0
Public transit (displaced)	-9 km	0.7	-6
Conventional bicycle (displaced)	-14 km	2.4	-34
Walking (displaced)	-3 km	9.8	-29
E-bike	60 km	1.5	90
Total	-12 km	NA	21

6 Safety Impacts

Several studies have also investigated the safety impacts of e-bike travel (Feng et al. 2010; Du et al. 2014; Hu et al. 2014; Papoutsi et al. 2014; Schepers et al. 2014). E-bike riders have been reported to have greater safety risks than conventional cyclists in China (Yao and Wu 2012; Bai et al. 2013; C. Cherry 2007; Weinert, Jonathan, Chaktan Ma, Xinmiao Yang 2007) and Europe (Schepers et al. 2014; Huertas-Leyva, P., Dozza, M., & Baldanzini 2018), but that has not been found in the United States (Rodier, Shaheen, and Chung 2003; Langford et al. 2013). A recent study in Israel found that although injury rates for e-cyclists are lower than for conventional cyclists, they suffered more severe injuries (Siman-Tov et al. 2018). In terms of perceived safety, e-bike riders in North America report feeling safer riding an e-bike compared to a conventional bicycle (MacArthur, Dill, and Person 2014; MacArthur et al. 2018). In China, women expressed that they feel safer riding on e-bikes while passing intersections (Weinert et al. 2007). Overall, there is a lack of robust evidence on the safety of e-bike riding, particularly in a Canadian context. Given this gap, we do not attempt to quantify the impacts of e-bike adoption on safety outcomes.

7 Summary of e-bike adoption impacts

Combining the information presented above, the estimated average impacts of each additional e-bike adoption are given in Table 3 for weekly, annual, and 5-year (e-bike lifespan) periods. A 5-year e-bike lifespan is assumed based on past studies (Tian et al. 2015; Montgomery 2010; Leuenberger and Frischknecht 2010; Christopher R Cherry, Weinert, and Xinmiao 2009). Note that there is significant uncertainty in these estimates, and they should be interpreted as central approximations only.

In sum, e-bike adoption is expected to provide net benefits in the forms of reduced motor vehicle travel, reduced greenhouse gas emissions, and increased physical activity. A little more than half of e-bike trips are expected to displace travel by motor vehicles (44% car trips and 12% transit trips), which is sufficient to provide significant emissions benefits. Reduced walking and conventional cycling is not expected to outweigh the added physical activity of e-biking. These expected benefits can support policies to promote e-bike adoption such as purchase incentives, e-bike lending programs, and improved bicycle infrastructure.

E-bike promotion is one tool cities can use to work toward their goals of active, healthy, and sustainable transportation systems.

Table 3. Estimated impacts of each additional e-bike

Impact	Weekly	Annually	Lifespan (5 years)
Displaced car travel (VKT)	38	1980	9900
Displaced public transit travel (PKT)	10	520	2600
Reduction in lifecycle CO_2 emissions (kg)	8.9	460	2300
Increase in minutes of moderate to vigorous physical activity (MVPA)	21	1092	5460

The impact estimates summarized here should be applied with caution. These estimates reflect average, aggregate effects and the impacts on an individual level will vary widely. Many factors influence e-bike travel behavior such as cycling infrastructure, weather, and topography in a city, as well as traveller characteristics such as age, gender, physical capability, and attitudes (Xu, Chengcheng 2019; Van Cauwenberg et al. 2018; Simsekoglu, Özlem 2019; MacArthur et al. 2018). To refine these estimates and adapt them for specific locations, more research is needed on e-bike travel behavior among different population segments and in different urban settings throughout Canada and elsewhere. E-bike research in the Canadian context is scarce, and more is needed to clarify the expected outcomes of adoption and to guide planners in designing policies to maximize the positive potential of e-bikes.

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