

Evaluating Active and Micromode Emission Reduction Potentials

The Role of Walking and Bicycling in Reducing Emissions

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In a typical community, 20-40% of travellers cannot, should not, or prefer not to drive, yet non-auto modes only receive about 10% of total transportation infrastructure investments. More comprehensive analysis can justify more multimodal planning which ensures that non-drivers receive a fair share of resources.

Summary

This study examines the potential roles that active transportation (walking and bicycling) and micro modes (e-bikes and e-scooters) and their variants can play in reducing climate emissions and other pollutants. By helping create more compact, multimodal communities, active and micromodes can leverage large vehicle travel reductions. This analysis indicates that with integrated active mode improvements, each additional mile of average daily walking or bicycling reduces much more than one vehicle-mile. There is considerable latent demand for active and micromode travel, and for living in walkable and bikeable communities, so improving these modes directly benefits consumers. These modes provide many co-benefits, in addition to emission reductions. Conventional planning tends to overlook these effects which undervalues active and micro mode investments. This study finds that active and micromode improvements tend to be more cost effective and equitable than many other transportation emission reduction strategies. More comprehensive analysis tends to justify significantly more investments in active modes.

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Introduction

What roles can active transportation (walking and bicycling) and micro modes (e-bikes and e-scooters) and their variants play in reducing vehicle emissions? How much should jurisdictions prioritize and invest in these modes as part of their transportation emission reduction plans?

These are important and timely questions. Reducing emissions, including climate and local pollutants, are important policy goals, so most jurisdictions are developing emission reduction plans. In addition, after a century of nearly steady growth, per capita automobile travel has peaked and current demographic and economic trends are increasing demands for non-auto travel and the benefits of serving those demands. This is a good time to reassess how practitioners evaluate active and micromode impacts and benefits, including emission reductions.

This paper examines these issues. It discusses contrasting ways to think about and evaluate active and micromode impacts, and critically evaluates current planning practices which tend to undervalue these modes. It examines ways that active and micro modes can leverage vehicle travel reductions, so a mile of increased walking or bicycling reduces more than one vehicle-mile of travel. It investigates their co-benefits, and compares those with other transportation emission reduction strategies, particularly clean vehicle (e.g., hybrid and electric) vehicle subsidies. This research should be of interest to anybody involved in transportation emission reduction planning, or active and micromode advocacy.

A Paradigm Shift

The way we think about transportation problems and evaluate potential solutions is changing (Sundquist and McCahil 2021). The old paradigm assumed that our goal is to maximize mobility, the speed and distances that people can travel, and so favored faster modes and longer-distance trips over slower modes and shorter trips. The new paradigm recognizes that the ultimate goal of most travel activity is access to services and activities, and that many factors can affect accessibility including vehicle travel speeds, the quality of non-auto modes, mobility substitutes (such as telework and delivery services) transport network connectivity, geographic proximity (and therefore development density and mix), affordability and user information. The new paradigm recognizes that there are often trade-offs between these factors, and in particular, efforts to increase automobile traffic speeds often degrade other travel modes and stimulate sprawl which reduces geographic proximity, reducing overall accessibility.

Table 1 compares these perspectives.

Table 1 **Old and New Planning Paradigms (Litman 2013)**

	Old Paradigm	New Paradigm
Definition of transportation	<i>Mobility</i> – physical travel (primarily motor vehicle travel)	<i>Accessibility</i> – peoples’ ability to reach desired services and activities
Transport planning goal	Maximize travel speeds	Maximize overall accessibility
Transport system performance indicators	Roadway level-of-service (LOS), average traffic speed, congestion delay	Multi-modal LOS, time and money required by various people to access services and activities
Analysis methods	Focuses on quantitative factors such as speed	Considers qualitative factors such as convenience and comfort
Modes considered	Primarily automobile	Multiple modes (walking, cycling, public transport, carsharing, telework, etc.)
Solutions favored	Roadway expansion whenever possible	Transport demand management whenever justified
Land use consideration	Supports sprawl	Supports Smart Growth policies that increase land use accessibility
Transport funding	Dedicated funds for roads and parking facilities	Least cost planning allocates funds to the most cost-effective and beneficial option

This table compares the old and new planning paradigms.

The old paradigm assumed that increases in per capita vehicle travel are desirable; the new paradigm recognizes that increased vehicle travel may reflect a decline in overall accessibility which forces people to drive farther to reach the services and activities they desire.

The old planning paradigm considered active modes inferior and so gave them little attention. For example, conventional travel surveys collect abundant information on automobile travel demands and conditions, but little information on active travel activity or conditions. Older travel surveys undercounted shorter, off-peak and non-work trips; travel by children; and recreational travel. Many surveys ignore active mode links of motor vehicle trips; for example, a *bike-transit-walk* trip is often classified simply as a transit trip, and a motorist who walks several blocks between their parked car and destinations is classified only as an auto user. More comprehensive surveys indicate that active travel is much more common than conventional surveys indicate (Forsyth, Krizek and Agrawal 2010), so if statistics indicate that 5% of commute trips are by active modes, the total portion is probably 10-20%, reflecting overlooked trips.

The old paradigm described roadway expansions as “improvement,” although wider roads and the increased traffic they generate degrade walking and bicycling conditions, a phenomenon called the “barrier effect” (van Eldijk, Gil and Marcus 2022). Similarly, the old paradigm gave little consideration to the negative effects that automobile dependency and sprawl have on overall accessibility. The new paradigm recognizes the ways that automobile-oriented planning encourages automobile-dependency and sprawl, and the ways that active mode improvements can help create more compact, multimodal communities, which leverage additional vehicle travel reductions, as described in the following section. As a result, the new planning paradigm recognizes that active modes have unique and important roles in an efficient and equitable transportation system (Blumenberg, et al. 2016; Litman 2021).

ACTIVE TRANSPORTATION LEVERAGE EFFECTS

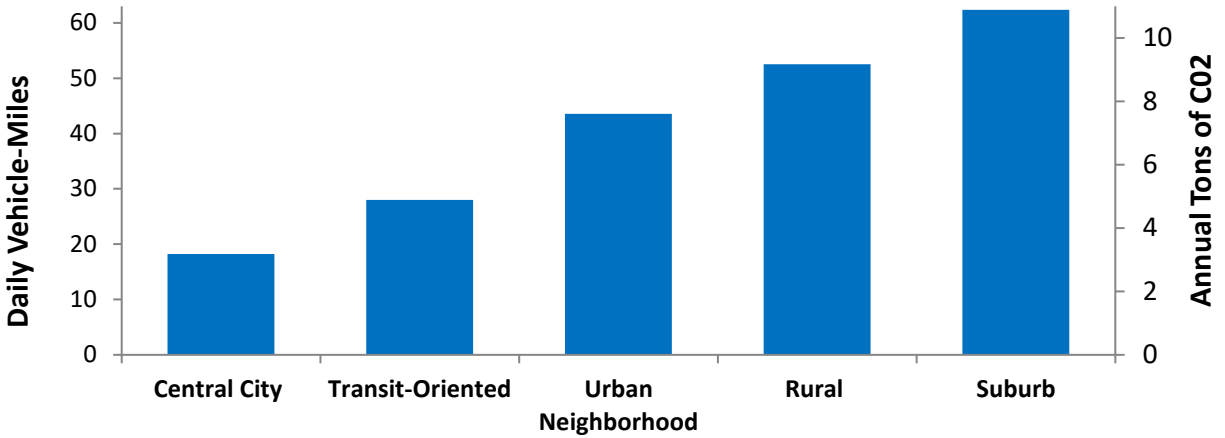
Walking and bicycling improvements can leverage additional vehicle travel reductions in various ways, so each additional average daily mile walked or biked reduces more than one vehicle-mile, due to mechanisms listed below (Guo and Gandavarapu 2010; Litman 2021).

Common Active Transportation Leverage Effects

- *Shorter trips.* A shorter active trip often substitutes for longer motorized trips, such as when people choose a local store rather than driving to more distant shops.
- *Reduced chauffeuring.* Poor walking and bicycling conditions often cause motorists to chauffeur non-drivers which generates empty backhauls (miles driven with no passenger). For such trips, a mile of walking often reduces two vehicle-miles of travel.
- *Increased public transit.* Walking and bicycling improvements can support public transit travel, since most transit trips involve walking and bicycling links.
- *Vehicle ownership reductions.* Improving alternative modes allow some households to reduce their vehicle ownership. Since motor vehicles are costly to own but relatively cheap to use, once households purchase an automobile they tend to use it, including local trips that could be made by active modes.
- *Lower traffic speeds.* One of the most effective ways of increasing active travel is to reduce traffic speeds on urban streets. This makes walking and bicycling trips more time-competitive with driving and reduces total automobile travel.
- *Land use patterns.* Active travel planning creates more compact, multi-modal communities by reducing road and parking facility land requirements which reduces travel distances.
- *Social norms.* More walking and cycling can help increase social acceptance of alternative modes.

These leverage effects result in part from local land use changes. For example, active mode improvements often create safer and more attractive streets, and reduce parking demands, which encourages more compact development, resulting in more local services. This reduces travel distances for all modes, as well as increasing the portion of trips that can be made by non-auto modes. These conditions are described as a 15-minute community, a high Walk Score neighborhood, an urban village, transit-oriented development, New Urbanism or Smart Growth (Knight Frank 2020). Regardless of the name, these factors work together to reduce vehicle travel and emissions. Residents of compact, walkable neighborhoods typically drive 20-60% fewer annual vehicle-miles than in automobile-dependent areas, as illustrated in Figure 1. Not every active mode improvement has all these effects but many small changes can help make a community more compact and multimodal, and therefore reduce total vehicle travel.

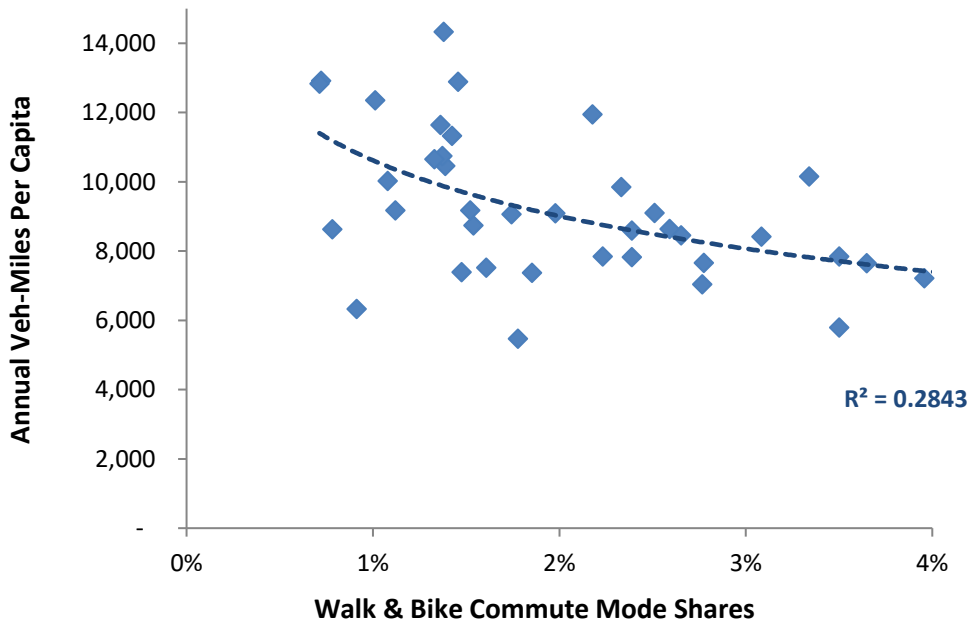
Figure 1 Household Vehicle Travel and Emissions by Location (Salon 2014)



Compact, multimodal neighborhood residents drive 20-60% less than in automobile-oriented areas.

Some of these differences may reflect self-selection, the tendency of households to locate in neighborhoods that reflect their travel preferences, but evidence described in the next section indicates that there is considerable latent demand for housing in walkable neighborhoods (Litman 2019). Although compact, multimodal neighborhoods are often described as transit-oriented development, implying that they depend primarily on high quality transit services, in practice, their travel reductions result more from improved walkability than from shifts to public transit (Chatman 2013). Figure 2 illustrates these effects, based on data from the 40 largest U.S. urban regions. Each one-percentage-point increase in walking mode share is associated with a 5-10% reduction in average vehicle-miles.

Figure 2 Active Mode Shares and Per Capita VMT (FHWA 2018)



Using detailed data on personal travel demands, Philips, et al. (2022) estimate that if most adults in England had an e-bike, personal automobile CO2 emissions would decline up to 24%, with particularly large reductions in rural areas. Chapman, et al. (2018) estimated the benefits of New Zealand's *Model Communities Programme* which funded active mode improvements and encouragement campaigns. Considering health and emission reduction benefits the estimated benefit/cost ratio was 11:1. This did not include user cost savings or road and parking facility cost savings, and so likely underestimates net benefits. It concluded that comprehensive active travel improvement and encouragement programs are likely to provide measurable, positive returns on investment.

Kraus and Koch (2022) integrated data on new bike lanes created during the Covid pandemic with counts from 736 bicycle counters in 106 European cities. They found that new bike lanes increased cycling between 11 and 48% on average. Based on the costs of these facilities, which range from €9,500 to €250,000 per kilometer, and health benefits from increased bicycling, they conclude that the bike lanes provide a positive return in investment.

Other studies have similar results. Guo and Gandavarapu (2010) found that installing sidewalks on all streets in a typical North American community would increase per capita walking and bicycling by 0.097 average daily miles and reduce automobile travel by 1.142 daily vehicle-miles, about 12 miles of reduced driving for each mile of increased active travel. Similarly, Wedderburn found that in New Zealand cities, on average, each additional daily transit trip by driving age residents increases daily walking (in addition to transit access walking trips) by 0.95 trips and 1.21 kilometers, and reduces two daily car driver trips and 45km driven (Wedderburn 2013). International data also indicate that each mile of increased active travel is associated with seven miles of reduced motor vehicle travel (Kenworthy and Laube 2000).

This suggests that an integrated set of policies that improve active modes and create more compact, multimodal communities can have order-of-magnitude leverage effects, so each additional average daily mile walked or biked in a community reduces five to 50 vehicle-miles over the long run. Conventional planning tends to ignore these indirect impacts and so underestimates the potential impacts and benefits of active mode improvements for achieving objectives such as reducing congestion, accidents and emissions.

ACTIVE AND MICROMODE DEMANDS

A key question in this analysis is the latent demand for active and micromode travel, that is, the degree that travellers will use these modes and therefore reduce their vehicle travel, emissions and costs if given the opportunity. A related question is whether there is latent demand for living and working in more compact, multimodal communities where residents drive less and rely more on non-auto modes. If there is significant latent demand, improving active mode conditions and creating more walkable and bikeable communities can provide large vehicle travel reductions and large benefits.

There is abundant evidence of latent demand for active and micro modes (Kuzmyak and Dill 2012). Consumer surveys indicate that many people want to drive less, rely more on walking and bicycling, and live in more walkable and bikeable neighborhoods (Burda 2014; NAR 2019 and 2021). Approximately a quarter of all personal trips are one mile or less, suitable for a twenty-minute walk, half of all vehicle trips are three miles or less, suitable for a twenty-minute bike ride, and most trips are less than five miles, suitable for a twenty-minute e-bike ride (Bhattacharya, Mills, and Mulally 2019). Many studies find that well-planned active transport improvements significantly increase walking and bicycling

activity (Buehler 2016; CPSTF 2017). For example, the U.S. Federal Highway Administration’s four-year Nonmotorized Transportation Pilot Program invested about \$100 per capita in pedestrian and cycling improvements in four typical communities (Columbia, Missouri; Marin County, Calif.; Minneapolis area, Minnesota; and Sheboygan County, Wisconsin), which increased walking trips 23% and bicycling trips 48%, and reduced driving about 3%, indicating latent demand for active travel (FHWA 2014).

Because they can travel farther and faster, carry larger loads, and easily climb hills, e-bikes essentially double the portion of trips that can be made by light two-wheelers, so if a community previously planned for a 5% bike mode share, it can now plan for 10% including bike and micro modes (ITDP 2019). However, e-bikes are just as vulnerable as pedal bikes, and so require safe facilities such as protected bike lanes to achieve their potential.

Current demographic and economic trends (aging population, rising fuel prices, rising poverty rates, urbanization, increased health and environmental concerns, plus improved micro modes) are increasing demands for active transport and the potential benefits from serving those demands. This indicates that active and micro modes improvements can directly benefit travellers, reduce automobile travel and provide associated savings and benefits.

Academic studies estimate that improving bicycle and e-bike conditions could approximately triple bicycle mode shares to 17% in 2030 and up to 22% in 2050, and reduce urban vehicle emissions up to 12% (McQueen, MacArthur and Cherry 2020). A major New Zealand study, *Mode Shift to Micromobility* (Ensor, Maxwell and Bruce 2021), estimated that 3-11% of all urban trips could be made by micromodes by around 2030, and would increase transit ridership by up to 9% by improving access to stops and stations. A study by the University of Washington’s Urban Freight Lab found that cargo bikes are often able to make more direct and faster trips than vans, which halved vehicle miles traveled and reduced tailpipe emissions by 30% per delivery (SCTL 2021).

SOCIAL EQUITY GOALS

Active and micromode improvements can help achieve social equity goals (Litman 2022a). Horizontal equity requires that each type of traveller receive a fair share of public resources. Vertical equity requires that public policies protect and favor disadvantaged groups, and provide affordable options. Active and micromode improvements help achieve all of these equity goals.

Figure 3 Infrastructure Spending (Litman 2020)

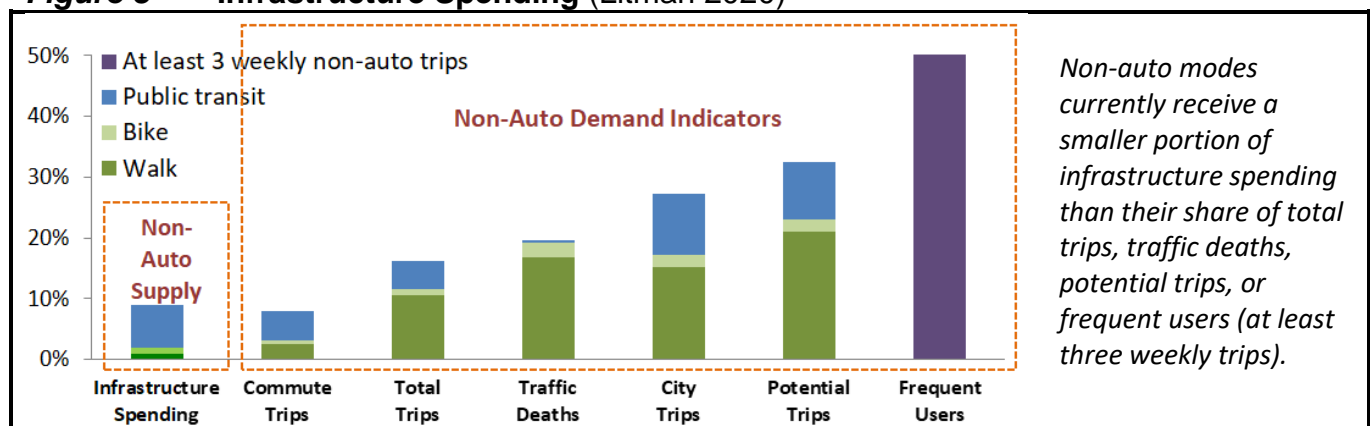


Figure 3 compares non-auto infrastructure spending with indicators of walking, bicycling and public transit demands. Non-auto modes currently receive less than 10% of total investments, which is comparable to their commute mode shares but less than their share of total trips, particularly in large cities, far less than their potential mode shares if their conditions improved, and far less than the portion of residents who at least occasionally use non-auto modes. These discrepancies are particularly large for walking: although it serves more than 10% of total trips, is the most basic and universal form of travel, has significant latent demands, and provides many benefits to users and communities, it receives less than 2% of total transportation spending. This underinvestment is unfair and inefficient.

CO-BENEFITS

Clean vehicles can conserve fossil fuels and reduce emissions but provide few other benefits, and by inducing additional vehicle travel they tend to increase external costs. For example, hybrid and electric cars operating costs are about half those of comparable fossil fuel vehicles, so they are likely to be driven 10-30% more annual miles, a rebound effect which increases traffic congestion, infrastructure cost, crashes and sprawl-related costs (Orsi 2021, Maizlish, Rudolph and Jiang 2022).

Table 2 illustrates this concept. It compares the planning objectives that are supported or contradicted by active and micromode improvements, and by clean vehicles. Because they are small, affordable and resource efficient, and reduce total vehicle travel, active and micro modes support virtually all of these objectives. In contrast, because they are large and costly, require significant resources for construction and operations, and tend to increase total vehicle travel, clean vehicles tend to contradict many objectives.

Table 2 **Comparing Impacts** (Litman 2022b)

Planning Objectives	Active and Micromode Improvements	Clean Vehicles
<i>Vehicle Travel Impacts</i>	<i>Reduced</i>	<i>Increased</i>
Congestion reduction	✓	×
Roadway cost savings	✓	×
Parking cost savings	✓	×
Consumer savings and affordability	✓	Higher purchase, lower operating
Traffic safety	✓	×
Improved mobility for non-drivers	✓	×
Fossil fuel conservation	✓	✓
Pollution reduction	✓	Reduce tailpipe but increase other emissions
Physical fitness and health	✓	×
Strategic development objectives (reduced sprawl)	✓	×

(✓= Supports objectives. ×= Contradicts objective.) Cleaner vehicles help conserve fossil fuel and reduce pollution emissions but provide few other benefits. Vehicle travel reductions and more compact, accessible community development provide far greater ranges of benefits.

Currently, electric vehicles receive substantial subsidies including cash or tax discounts to purchase the vehicles, recharging network development subsidies, plus exemptions from road user taxes charged to motorists driving fossil fuel vehicles. As a result, their emission reductions typically cost more than \$300 per tonne of CO₂e reduced, which is costly compared with other strategies (Economist

2021). Although it is difficult to calculate active and micromode emission reduction unit costs, they are probably much lower, considering all impacts including their co-benefits, and the increased external costs induced by electric vehicles. As a result, active transportation improvements can provide many times the total health benefits as electric vehicle incentives (Maizlish, Rudolph and Jiang 2022). Emission reduction plans often overlook these factors as illustrated in the next section.

EXAMPLE

To illustrate these effects consider how active and micro modes are evaluated in *Project Drawdown* (Drawdown 2020). This project identifies a dozen transportation emission reduction strategies including bicycle infrastructure, electric bicycles and walkable cities. Below are descriptions of their how their impacts are evaluated:

Bicycle Infrastructure

“We assume an increase in bicycle infrastructure will drive bicycling from under 3 percent to almost 5–6 percent of urban trips globally by 2050, displacing 2.59–2.98 trillion passenger-kilometers traveled by conventional modes of transportation and avoiding 2.73–4.63 gigatons of carbon dioxide equivalent emissions. By building bike infrastructure or converting lanes rather than constructing roads, municipal governments and taxpayers can realize US\$2.42–3.13 trillion in construction savings and US\$5.91–8.45 trillion in lifetime net operational savings.”

Electric Bicycles

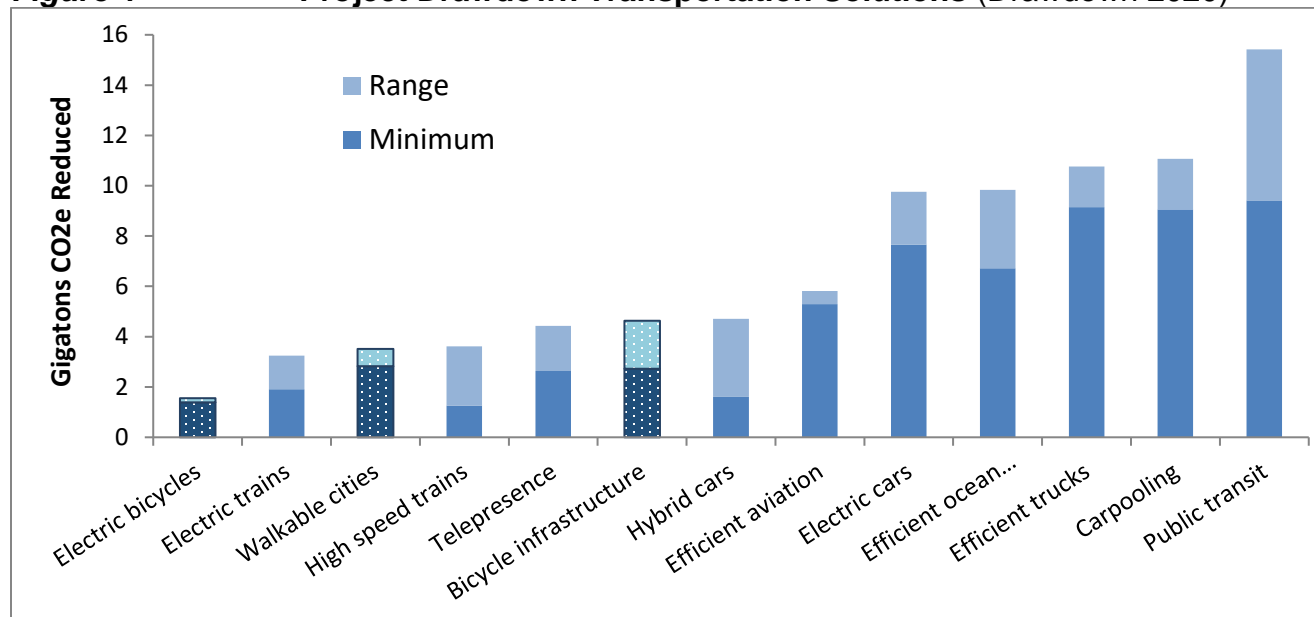
“In 2018, electric-bicycle (e-bike) riders traveled around 289 billion kilometers, largely in China. Based on market research, we project use could increase to 1.44–1.66 trillion kilometers per year by 2050. The growth will occur in Latin America, the Middle East, and Africa. This solution could reduce carbon dioxide equivalent emissions by 1.39–1.55 gigatons and save e-bike owners US\$402.06–446.01 billion in first costs and US\$1.07–1.23 trillion in lifetime operating costs.”

Walkable Cities

“As cities become denser and city planners, commercial enterprises, and residents invest in walkability, 5 percent of urban mobility can be provided by foot instead of car by 2050. That shift could result in 2.83–3.51 gigatons of carbon dioxide equivalent greenhouse gas emissions and reduce costs associated with car ownership by US\$3.18–3.94 trillion.”

Figure 4 illustrates Project Drawdown’s estimates of potential impacts of various transportation emission reduction strategies, based on these assumptions. It ranks active and micro modes relatively low.

Figure 4 Project Drawdown Transportation Solutions (Drawdown 2020)



This illustrates common omissions and biases that tend to underestimate active and micromode potential emission reductions:

- It assumes that active and micro modes can only reduce travel in cities. In fact, they can have significant impacts and benefits in rural and suburban communities, particularly as e-bikes expand feasible trip distances (Aytur, et al. 2011).
- It ignores leverage effects, and therefore greatly underestimates the emission reductions and other benefits provided by policies that create more compact, walkable and bikeable communities.
- It ignores rebound effects and therefore the increased external costs caused by clean vehicles.
- It considers few co-benefits. It accounts for roadway cost savings and user savings, but not parking facility cost savings (which are generally larger than roadway savings), health and safety benefits of more active travel, or sprawl-reduction benefits. More comprehensive analysis is likely to result in much higher returns on active mode facility improvements (Cooper and Danziger 2016; Gössling, et al. 2019).

These omissions and biases are not specific to Project Drawdown or to active and micro modes; most emission reduction plans favor clean vehicle subsidies over vehicle travel reduction strategies (McCahill 2021). A review of two dozen recent emission reduction plans found that virtually all include large clean vehicle subsidies, but most assume that transportation demand management has limited potential and high costs, and few include significant active and micro mode investments (Litman 2022b). For example, the International Energy Agency's *Net Zero by 2050: A Roadmap for the Global Energy Sector* report concludes that transportation behavior changes, "such as replacing car trips with walking, cycling or public transport, or foregoing a long-haul flight" can only achieve 4% of emission reduction targets (IEA 2021). Yet, other studies find that, because active and micro modes are inexpensive, can be developed quickly, can leverage large vehicle travel reductions, and provide large co-benefits, they can provide larger total emission reductions than clean vehicle subsidies, particularly during the next decade (Brand, et al. 2021).

CONCLUSIONS

This study finds that the assumptions and methods used to evaluate transportation emission reduction strategies are biased in ways that undervalue active and micro mode improvements. It starts with incomplete statistics, such as census mode share data which suggests that only 1-4% of total trips are made by active modes, rather than more comprehensive surveys which show that they actually represent 10-20% of trips. It applies the old mobility-based paradigm which assumed that the goal is to maximize mobility, and so favors faster modes and sprawled development to the detriment of slower modes and compact development, and so considers active and micromodes inferior and unproductive.

Although few motorists want to forego driving altogether, surveys indicate that many would prefer to drive less and rely more on non-auto modes, provided that they are convenient, comfortable and affordable. Everybody benefits if transportation planning responds to those demands, including motorists who experience reduced congestion delays, crash risk and chauffeuring burdens.

Appropriate active and micromode improvements can leverage large vehicle travel reductions, so each mile of increased walking, bicycling and micromode travel reduces an order of magnitude more vehicle-miles. This occurs because active and micro mode improvements can be a catalyst for more compact, mixed neighborhoods where residents own fewer motor vehicles, drive less, rely more on non-auto modes, and save travel time and money. These benefits are large but generally overlooked and undervalued. New, accessibility-based planning can evaluate these impacts, and therefore the full benefits of active and micromode improvements.

More comprehensive analysis tends to justify significant increases in active transport improvements. At a minimum, active and micro modes should receive funding equivalent to their potential mode shares, after all improvements are complete, which is generally several times higher than current investment levels. Such investments could provide large emission reductions in addition to other economic, social and environmental benefits. Active and micromode improvements can be considered a foundation for many other emission reduction strategies, including public transit improvements and compact development policies.

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