Evaluating Active and Micro Mode Emission Reduction Potentials

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Word Count: 5,350 words + 3 tables (250 words each) = 6,100 words

12 December 2022

TRB 2023 Annual Meeting: TRBAM-23-03449

ABSTRACT

This study examines the potential roles that active modes (walking, bicycling and variants such as wheelchairs, strollers, handcarts) and micro modes (e-bikes and e-scooters) can play in reducing climate emissions. Conventional planning considers these modes unimportant and ineffective at reducing emissions. More comprehensive analysis indicates that they play unique and important roles in an efficient and equitable transportation system, and can provide large and cost-effective reductions in vehicle travel and emissions. Often-cited statistics imply that active and micro modes serve a few percent of total travel, but more comprehensive surveys show that they actually serve 10-15% of trips and their potential is far higher. By helping create more compact, multimodal communities, active mode improvements can leverage large vehicle travel reductions, so each additional mile of active and micro mode travel reduces more than one motor vehicle mile. Improving these modes provides many co-benefits in addition to emission reductions. This analysis indicates that cost-effective improvements and incentives could double or triple active mode travel, and an integrated program of active and public transport improvements, TDM incentives and Smart Growth policies can reduce emissions by 15-50%. A review of recent emission reduction plans indicates that most undervalue active and micro modes. More comprehensive analysis tends to justify far more investment in these modes.

Keywords: Active transportation, walking, bicycling, micro modes, e-bikes, emission reduction, climate action.

INTRODUCTION

Active modes include walking and bicycling, and variants such as wheelchairs, strollers, handcarts. Micromodes include e-bikes and e-scooters. They can include bike- and scooter sharing services. Micromodes are often counted as bicycles in travel surveys, and use the same facilities, such as bikelanes, paths and bike parking. Various programs and incentives encourage active and micro modes. For simplicity sake, this paper refers to "active mode improvements" to include facility improvements and program that make active and micro mode travel more convenient, comfortable, safe or common.

Conventional transportation planning tends to undercount, undervalue, and under-invest in these modes due to common practices such as those in Box 1. As a result, most communities invest less than 5% of their transportation infrastructure budgets on active modes, which is far less than their share of current or potential trips, traffic casualties, or users. More comprehensive analysis can justify more active mode investments.

Box 1 **Common planning practices that underinvest in active modes**

- Commonly-cited travel statistics, such as commute mode share, undercount active trips by ignoring shorter trips, non-commute trips, children's travel, recreational travel, and active links of trips that include motor vehicle travel. For example, a bike-transit-walk trip is often classified simply as a transit trip, and trips between parked vehicles and destinations are ignored even if they involve several blocks of walking.
- Conventional planning evaluates transportation system performance using indicators of vehicle traffic speed and delay, such as roadway level-of-service and annual delay per automobile commuter. Few jurisdictions have comparable indicators of active conditions and barriers to their use.
- Conventional planning gives little consideration to many active mode benefits such as consumer savings and affordability, independent mobility for non-drivers, road and parking infrastructure savings, public health and safety, and reduced sprawl costs; these impacts are seldom included in economic analysis.
- Most jurisdictions have large, dedicated roadway budgets, and impose parking minimums that require property owners to provide costly off-street parking facilities; in contrast active transportation improvements must compete for funding against other public expenditures.
- Active modes tend to be stigmatized.

Active and micro mode investments can provide larger emission reductions and total benefits than electric vehicle subsidies because bikes and e-bikes are much cheaper, have a higher price elasticity (each dollar of subsidy increases e-bike purchases much more than e-car purchases) and because shifts to active and micro modes cause much large emission reductions and greater total benefits than shifts from fossil fuel to electric cars (1).

Many jurisdictions are now developing emission reduction plans. This paper investigates whether such plans incorporate these biases, and how better to determine optimal active and micro mode investments. It examines ways that active modes can reduce vehicle emissions, discusses how these impacts should be considered in an evaluation process, describes how to better determine optimal investment levels, and critically evaluates the degree that these factors are currently considered in typical emission reduction plans. This research should be of interest to anybody involved in transportation emission reduction planning or active mode advocacy.

ACTIVE AND MICRO MODE TRAVEL DEMANDS

A key issue in this analysis is the demand for active travel: the amount that people would use these modes and the factors that affect this. According to commonly-cited census data, active modes serve less than 4% of commute trips and less than 2% of travel distance. This implies that active modes are unimportant and even large increases in their use could only provide small vehicle travel and emissions reductions. However, more comprehensive data, such as the National Household Travel Survey, indicate that active modes serve 10-15% of total trips (2).

There is significant potential for more active travel. Approximately a quarter of U.S. personal trips are a mile or less, suitable for a twenty-minute walk, and more than half are less than five miles in length, suitable for pedal or e-bike rides (3). There is evidence of significant latent demand for active travel. Surveys indicate that many people want to drive less, rely more on walking and bicycling, and live in more walkable and bikeable neighborhoods (4, 5).

Many studies find that appropriate improvements significantly increase walking and bicycling activity (6). For example, after the Federal Highway Administration's four-year Nonmotorized Transportation Pilot Program invested about $100 per capita in pedestrian and bicycling improvements in four typical communities (Columbia, MO; Marin County, CA; Minneapolis area, MN; and Sheboygan County, WI), walking trips increased 23%, bicycling trips increased 48%, and automobile travel declined 3% (7). A recent U.S. study found that a 10% increase in per capita bikeway-miles increases bicycle commute mode shares 2.5%, and a 10% increase in protected bicycle lanes increases bicycle mode shares 4% (8). Cities with extensive active mode networks, such has Davis, CA, Eugene, OR and Boulder, CO have more than 15% active commute mode shares, five times the national average, plus under 20 daily vehicle miles travelled per capita, 20% less than the national average (9).

Because they can travel farther and faster, carry larger loads, and easily climb hills, micro modes significantly increase potential for light two-wheeled travel (10). Academic studies estimate that bicycle and micro mode improvements could approximately triple U.S. bicycle mode shares, up to 17% in 2030 and up to 22% in 2050, and reduce urban vehicle emissions up to 12% (11). A major New Zealand study estimated that 3-11% of all urban trips could be made by micro modes by around 2030, and this would increase transit ridership by up to 9% (12). 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, halving vehicle miles traveled and reducing tailpipe emissions by 30% per delivery (13).

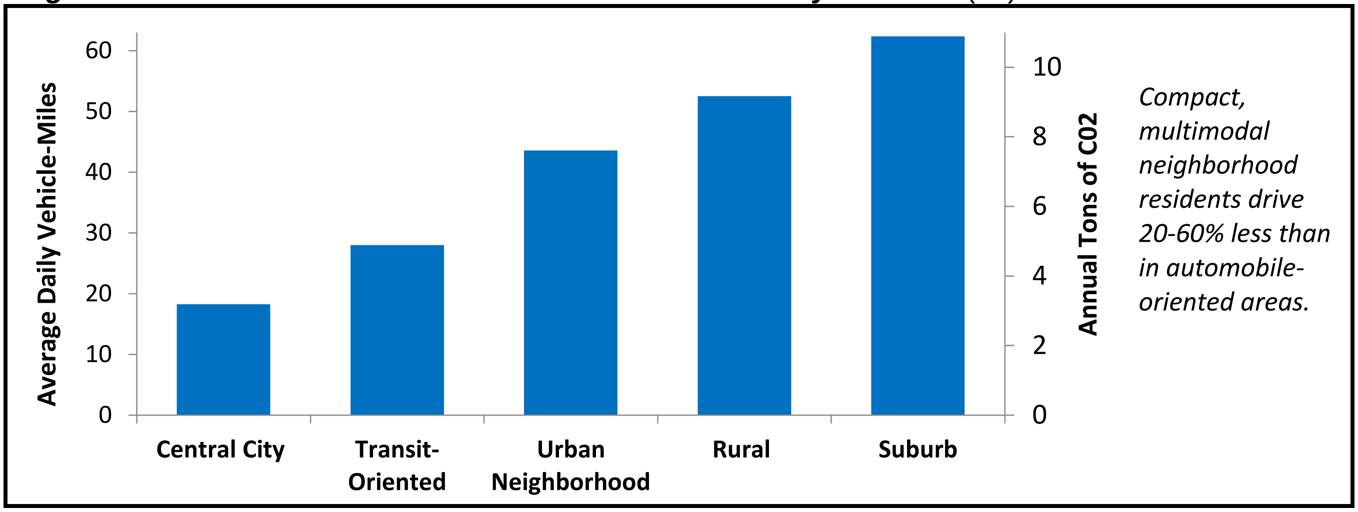
Bike, e-bike and e-scooter sharing services serve relatively small numbers of trips but these mostly occur in dense urban areas where automobile traffic imposes high congestion, crash and pollution costs, and they complement public transit, so their benefits can be large.

However, dangerous and uncomfortable riding conditions discourage many people from using both pedal- and e-bikes, so investments are needed to take advantage of their potential benefits. A recent U.S. survey found that safety concerns are the largest obstacle to micromobility use, cited by 33% of respondents (14).

HOW ACTIVE TRANSPORTATION REDUCES EMISSIONS

The amount that people drive and their vehicle emissions vary widely, from less than 20 DVMT per capita in compact, multimodal communities to more than 40 DVMT in more sprawled, automobile-dependent communities (15). There are similar differences within regions between central neighborhoods and urban-fringe areas, as illustrated below.

Figure 1 **Household Vehicle Travel and Emissions by Location** (16)



Although this may partly reflect self-selection (people who cannot or prefer not to drive choose more compact neighborhoods), studies that account for this still find that multimodal planning reduces vehicle travel (17). The table below identifies key factors affecting motor vehicle travel rates. Walking and bicycling improvements reduce vehicle travel directly, by substituting for vehicle trips, and indirectly by supporting public transit and helping create more compact, multimodal communities where households own fewer vehicles, lead less automobile dependent lifestyles, and value non-auto travel.

Table 1 **Vehicle Travel Reduction Strategies** (18, 19)

Factors Affecting Vehicle Travel	Vehicle Travel Reduction Strategies
Active travel conditions.	Improve sidewalks, crosswalks, paths and bike parking, and reduce road traffic speeds.
Public transport service quality.	Increase transit service, improve stations and vehicles, and improve connections.
Proximity between destinations (homes, services, jobs, recreational activities, etc.)	Increase development density and mix. Allow more infill in walkable neighborhoods.
Vehicle travel reduction incentives and programs.	Reduce parking supply. Increase parking fees, road tolls and fuel taxes. Support TDM programs.
The social status of non-auto modes.	Promote non-auto modes.

Various factors affect vehicle travel. Active mode improvements support vehicle travel reduction strategies.

These strategies tend to have synergistic effects – their impacts are greater when implemented together – so an integrated package of active and public transport improvements, TDM incentives, and Smart Growth development policies can significantly reduce motor vehicle travel and emissions (20).

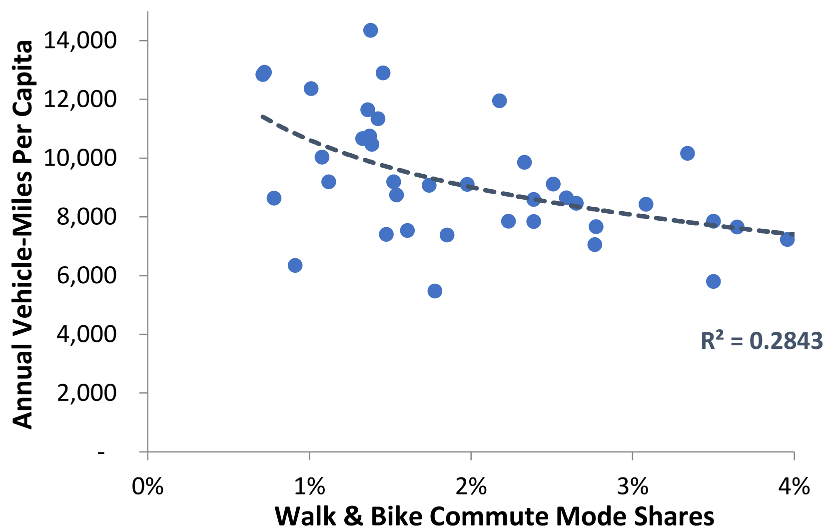
Active mode improvements can have leverage effects, so each additional mile of active travel reduces more than one vehicle-mile, in ways summarized below.

Box 2 **Common Active Transportation Leverage Effects** (21,22,23)

- *Shorter trips.* Shorter active trips often substitutes for longer motorized trips, such as when people choose a local store rather than driving to more distant shops.
- *Reduced chauffeuring*. Better walking and bicycling conditions reduces the need to chauffeur non-drivers (special trips to transport a passenger). These often require empty backhauls (miles driven with no passenger). As a result, each mile of avoided chauffeuring often reduces two vehicle-miles.
- *Increased public transit travel.* Since most transit trips include walking and bicycling links, improving these modes supports public transit travel and transit-oriented development.
- *Vehicle ownership reductions*. Active mode improvements allow some households to reduce their vehicle ownership, which reduces vehicle trip generation, and therefore total vehicle-miles.
- *Lower traffic speeds.* Active travel improvements often involve traffic speed reductions. This makes non-auto travel more time-competitive with driving and reduces total automobile travel.
- *More compact development*. Walking and bicycling help create more compact, multimodal communities by reducing the amount of land needed for roads and parking, and creating more attractive streets.
- *Social norms.* As active travel increases, these modes become more socially acceptable.

Figure 2 illustrates these effects. Although active modes only serve 1% to 4% of commute trips, increasing their share is associated with larger reductions in per-capita vehicle travel: each one-point increase is associated with a 5-10% reduction in average vehicle-miles.

Figure 2 **Active Mode Shares and Per Capita VMT** (24)



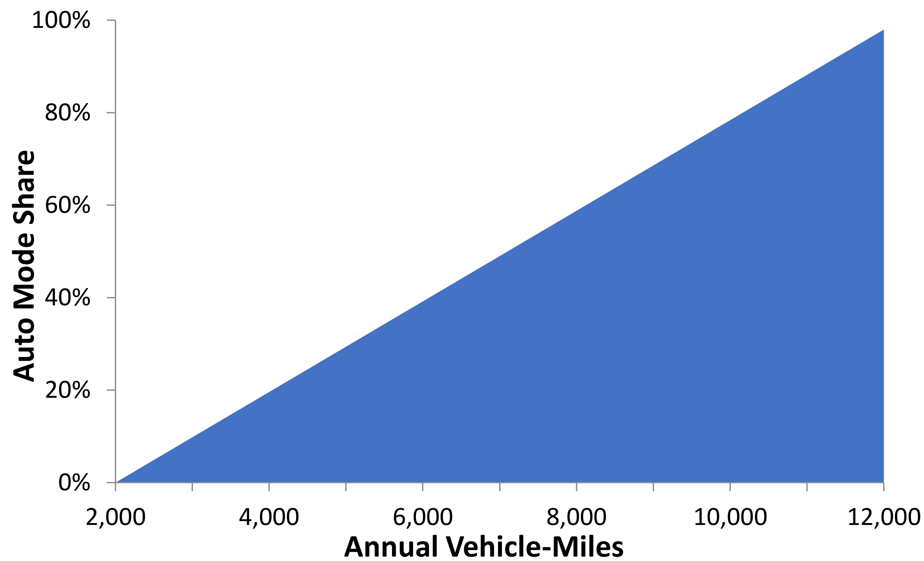
Each one-percentage-point increase in walking mode share is associated with a 5-10% reduction in average vehicle-miles.

Each dot represents one of the 40 largest U.S. urban regions.

Other studies using various analysis methods and data sets support the conclusion that with appropriate active mode improvements, each additional daily mile of walking or bicycling often reduces several motor vehicle-miles. For example, Guo and Gandavarapu found that installing sidewalks on all streets in a typical North American community increases per capita walking and bicycling by 0.097 average daily miles and reduces automobile travel by 1.142 daily vehicle-miles, about 12 miles of reduced driving for each mile of increased active travel (25). International data indicate that each mile of increased active travel is associated with seven miles of reduced motor vehicle travel (26). Frank, et al. found that increasing sidewalk coverage from 30% to 70% reduces local vehicle travel by 3.4% and emissions 4.9% (27).

These impacts can be calculated based on the observation that people tend to maintain fixed travel time budgets: most people around the world devote on average about 70 daily minutes to personal travel (28). Since motor vehicles typically travel five to ten times faster than active modes, each mile shifted from motorized to non-motorized travel tends to reduce five to ten motor vehicle-miles. People who rely entirely on active modes probably generate about 2,000 annual freight and service vehicle-miles, and people who rely entirely on driving generate about 12,000 annual vehicle-miles. The figure below illustrates this effect.

Figure 3 **Vehicle-Miles Versus Automobile Mode Share**



This figure illustrates the increase in per capita annual vehicle-mileage that results as automobile mode shares increase, assuming that non-drivers generate about 2,000 annual vehicle-miles, mainly by freight and service vehicles, and people who rely entirely on automobile travel generate 12,000 annual vehicle-miles.

Of course, not every active transportation improvement provides large emission reductions. For example, bike lanes or paths constructed where they are cheapest to build, rather than where there is significant demand, may do little to reduce automobile travel, and bike- and scooter-sharing programs may provide no net savings if their lifecycle emissions exceed their vehicle travel reduction impacts (29).

WHAT IS OPTIMAL?

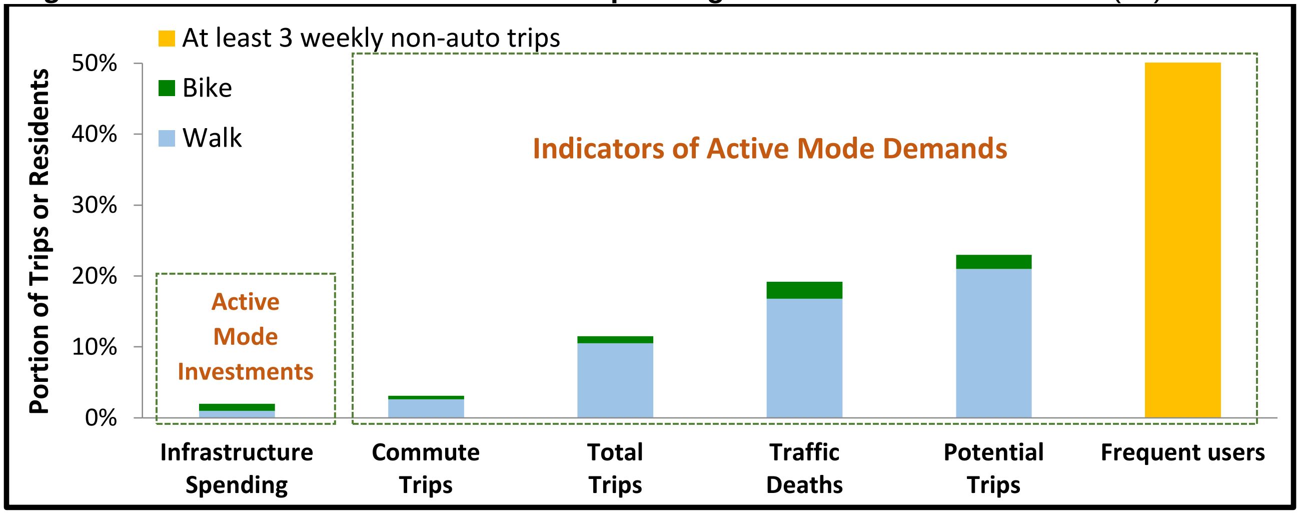
What level of active and micro mode investment is optimal? Below are factors to consider (30).

1. Fair Share Planning and Consumer Sovereignty

Fair share planning strives to give each traveller a comparable share of public resource unless additional subsidies are justified for specific reasons. This implies that active modes should receive investments at least comparable to their share of trips or portion of travellers who depend on them, and more if needed to make up for past underinvestment. *Consumer sovereignty* means that transportation planning responds to changing demands. This implies that active mode investments should increase if demand for their use increases, for example, due to rising poverty, health and environmental concerns, or if increased micro mode traffic requires larger sidewalks, bikelanes and paths.

Most communities currently spend $50 to $100 per capita on sidewalks and bicycling facilities (31, 32). Detailed studies estimate that improving all sidewalks to optimum standards in typical North American cities (e.g., Albuquerque, NM and Denver, CO) would cost between $5 and $50 annually per capita (33, 34). Washington State's *Active Transportation Plan* estimates that upgrading the state transportation system to maximize active travel safety would cost $5.7 billion, about 13% of the state transportation budget, averaging approximately $40 annually per capita over 20 years (35). Such investments are small compared with the $800 annual per capita expenditures on public roads, $200 on traffic services and $2,000 or more on government-mandated off-street parking (36). Figure 3 compares estimated active mode infrastructure expenditures with indicators of their demand, including mode share, traffic deaths, potential trips, or frequent users (people who make at least three weekly non-auto trips).

Figure 4 **Active Mode Infrastructure Spending Versus Demand Indicators** (37)



Active modes receive less than 5% of total infrastructure investments, which is less than their share of total trips, traffic deaths, potential trips or frequent users.

Similarly, most road space is devoted to automobile facilities such as higher-speed traffic lanes and on-street parking (38, 39). Few roads have bikelanes or low traffic speeds that ensure active travel safety. Many urban streets have sidewalks that use 5-15% of cross-sections (4-8 feet of a 40-60 foot width), but sidewalk networks tend to be incomplete, particularly on suburban and rural roads, so they probably occupy just 2-4% of total roadway rights-of-way.

2. Social Equity

Social equity goals means that planning favors investments that benefit disadvantaged groups. Since active modes provide basic mobility to people with disabilities and low incomes, social equity goals justify investments in those modes, particularly universal design policies that benefit people with disabilities and improvements serving disadvantaged communities.

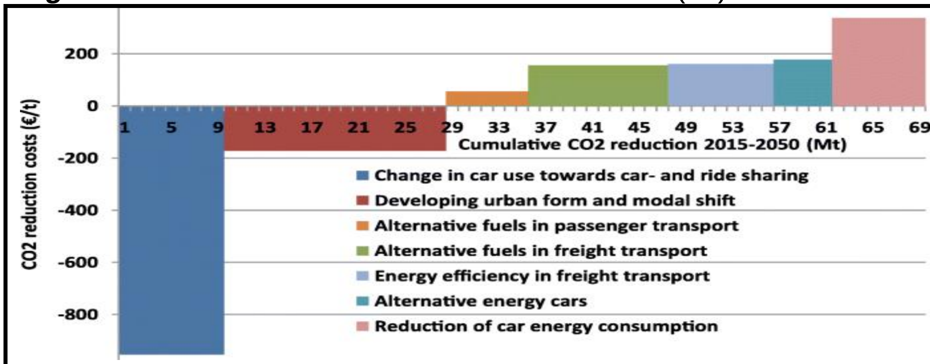
3. Cost Effectiveness

Cost efficiency invests public resources to maximize social benefits, taking into account all impacts. This implies that communities should invest in active modes whenever they cost less than automobile facilities that serve the same trips, or have benefit/cost ratios higher than other investments. Since active modes have low facility costs and provide many benefits, this tends to justify more investments in these modes. However, conventional transportation planning tends to ignore many of these impacts. For example, transportation project evaluation seldom accounts for the vehicle cost savings, traffic and parking congestion reductions, and roadway infrastructure savings provided by active mode improvements.

Active mode infrastructure is relatively inexpensive. For example, currently most communities spend $30 to $60 annually per capita on sidewalks and bikepaths, less than 5% of expenditures on roads and government-mandated parking facilities (40). Relatively modest additional investments can significantly improve active travel conditions, increase use of those modes, and reduce automobile travel. For example, studies in Albuquerque (41), Denver (42) and Los Angeles (43) indicate that $30 to $60 additional annually spending per capita could complete their sidewalk and bike networks, resulting in significant travel changes and benefits. For example, the *Nonmotorized Transportation Pilot Program* invested about $100 per capita in pedestrian and bicycling improvements in four typical U.S. communities, which improved active travel safety, increased walking trips 23% and bicycling trips 48%, and reduced total vehicle-miles about 3% (44). Guo and Gandavarapu found that completing the sidewalk networks in typical U.S. towns increases average per capita non-motorized travel 16% (from 0.6 to 0.7 miles per day) and reduce automobile travel 5% (from 22.0 to 20.9 vehicle-miles), representing about 12 miles of reduced driving for each mile of increased non-motorized travel (45).

Some studies estimate and compare unit costs of various emission reduction strategies, measured as dollars per metric tonne of emissions reduced (46). They vary widely in their methods and assumptions. Comprehensive studies that account for all impacts find that active mode improvements are among the most cost effective emission reduction strategies, with benefits that far exceed their costs. For example, the study *CO_2 Reduction Costs and Benefits in Transport: Socio-technical Scenarios*, concluded that shifting car travel to shared modes and more compact urban development provide significant net savings, while alternative fuel cars cost 175€ to 300€ per tonne of emission CO_2 reduced (Figure 5). An international study found that protected bike-lanes in Bogotá, Columbia and Guangzhou, China provide large emission reductions at much lower unit costs than most other transportation strategies (47).

Figure 5 **Emission Abatement Cost Curve** (48)



This study concluded that vehicle travel reduction strategies, such as vehicle sharing and more compact urban form, have negative costs (they provide net savings) due to their co-benefits, and so are more cost effective than alternative fuel vehicles.

4. Strategic Objectives

Strategic objectives means that individual, short term decisions should support long-term goals. Active mode improvements tend to provide a wider range of benefits than many other transportation emission reduction strategies (49).

Table 2 illustrates this concept. It compares the planning objectives supported or contradicted by active mode with those provided by clean vehicles. Because they are affordable, resource efficient, and reduce total vehicle travel, active modes support virtually all objectives. Because clean vehicles have lower operating costs than comparable fossil fuel vehicles they are likely to be driven 10-30% more annual miles, a rebound effect which increases external costs such as congestion, crashes and sprawl impacts (50, 51).

Table 2 **Comparing Impacts** (52)

Planning Objectives	**Active Modes** (walking, biking, e-bikes)	**Clean Vehicles** (hybrids, electric, hydrogen)
Vehicle Travel Impacts	*Reduced*	*Increased*
Congestion reduction	✓	×
Road and parking facility savings	✓	×
Consumer savings and affordability	✓	Higher purchase, lower operating
Traffic safety	✓	×
Improved mobility for non-drivers	✓	×
Fossil fuel conservation	✓	✓
Pollution reduction	✓	Reduce tailpipe, increases other emissions
Physical fitness and health	✓	×
Strategic objectives (reduced sprawl)	✓	×

(✓= Supports objective. ×= Contradicts objective.) Active modes help achieve many planning objectives. Clean vehicles provide fewer other benefits and by increasing total vehicle travel contradict many objectives.

Summary

This analysis indicates that significant increases in active transport investments can be justified on several grounds, including fairness, social equity, consumer sovereignty, cost efficiency, and strategic objectives. More comprehensive analysis tends to justify more support for active travel, particularly as part of integrated programs that also include public transit improvements, TDM incentives and compact development policies.

HOW MUCH CAN ACTIVE MODES REDUCE VEHICLE TRAVEL AND EMISSIONS?

Case studies such as the Nonmotorized Transportation Pilot Program indicate that in typical North American communities, modest active mode investments can increase walking by about a quarter and bicycling by half, and reduce motor vehicle travel by 3% within a few years. This suggests that a 3% VMT reduction is a lower-bound estimate, and much larger reductions are possible from comprehensive programs that also include TDM and Smart Growth policies.

The upper bound can be estimated based on North American communities that significantly improve active travel such as Davis, CA, Eugene, OR and Boulder, CO, where active travel is two to five times higher, and automobile travel 10-30% lower than in peer communities. Even larger reductions are possible if active mode improvements are implemented as part of comprehensive vehicle travel reduction programs.

This suggests that an integrated program of active travel improvements (for example, funding levels comparable to active mode shares), implemented with public transit improvements, TDM incentive and Smart Growth policies could reduce per capita vehicle travel 15-30% if implemented at the local level, and 20-50% if implemented with state and federal strategies such as fuel price increases and vehicle travel reduction policies (53).

EMISSION REDUCTION PLANS REVIEWED

Below are conclusions of a review of more than two dozen typical emission reduction plans by various governments and organizations (54):

- Most plans use simplified analysis: most ignore embodied emissions, rebound effects, leverage effects, and vehicle travel reduction co-benefits. These biases tend to exaggerate clean vehicle benefits, and undervalue vehicle travel reduction strategies including active and micro modes.
- Most invest primarily in clean vehicle strategies, with few investments in vehicle travel reduction strategies, particularly active mode improvements and incentives. Although most provide large electric vehicle subsidies, few provide micro mode subsidies.
- Some plans, such as those by the National Academy of Sciences and the International Energy Agency, imply that vehicle travel reductions are costly and difficult to achieve, and only provide small emission reductions, and so give minimal support to active mode investments.
- Sustainable development organizations such as the World Resources Institute and the United Nations Environmental Programme, give more priority to vehicle travel reductions, and consider a wider range of impacts, and so give significant support for active mode investments.
- Some jurisdictions, including California, New Zealand, and the United Kingdom, have vehicle travel reduction targets; they typically want to reduce motor vehicle travel 15-25% during the next two decades, and approximately double active and public transport travel. Some have analysis tools and policies to ensure that individual planning decisions support these targets.
- Few current plans are likely to achieve emission reduction targets.

This suggests that many emission reduction plans are biased in ways that exaggerate clean vehicle benefits and undervalue active and micro modes. More comprehensive analysis can justify significantly more investments in active modes.

DISCUSSON: EXPLAINING AND CORRECTING PLANNING BIASES

Several factors help explain why transportation planning tends to undervalue and underinvest in active travel. The table below summarizes common biases and reforms to correct them.

Table 3 **Planning Biases and Reforms** (55, 56, 57)

Bias	Reforms
1. Commonly-cited statistics (such as commute mode share) undercount active travel.	Use more comprehensive data that reflect all active travel activities and latent demands.
2. Mobility-based planning assumes that the goal is to maximize travel speed and distance, which favors faster modes over slower modes, and sprawl over compact development.	Apply accessibility-based planning, which evaluates transport system performance based on door-to-door travel speeds and financial costs, and so values slower modes and compact development.
3. Planning evaluates transportation system performance based on travel speed, ignoring other community goals.	Consider all community goals including social equity, affordability, infrastructure savings, basic mobility for non-drivers, public fitness and health, emission reductions and habitat protection
4. Planners have tools for evaluating and improving motorized traffic conditions, but not for active modes.	Develop better tools for evaluating and planning active travel, including leverage effects and indirect benefits.
5. Roads and parking facilities have dedicated funding, but active modes do not.	Dedicate funds to active modes. Apply least-cost planning, so money currently dedicated to roads and parking facilities can be invested in other modes when they are more cost effective overall.
6. Emission-reduction planning ignores embodied emissions and rebound effects, which exaggerates clean (hybrid and electric) vehicle emission reductions.	Apply comprehensive impact analysis when evaluating emission reduction options.
7. Current development policies favor automobile-oriented sprawl over compact community planning.	Implement Smart Growth development policies that create compact, multimodal communities.
8. Planning is reductionist: problems are considered individually.	Apply more comprehensive analysis which ensures that individual decisions support strategic goals.

This table lists eight common planning biases that tend to undercount, undervalue and underinvest in active travel, and reforms to correct them. These can apply to emission reduction planning.

One important reform is to establish vehicle travel reduction targets, and evaluate all major transportation and land use projects based on how they support those targets; sometimes called a shift from LOS to VMT (that is, from maximizing roadway level-of-service to minimizing vehicle-miles-travelled). This helps ensure that individual, short-term planning decisions support strategic transportation goals. It tends to justify more active mode improvements and complementary strategies, such as TDM incentives and compact development policies.

CONCLUSIONS AND RECOMMENDATIONS

This study finds that conventional planning is biased in ways that tend to undervalue active and micro modes. Many emission reduction plans incorporate similar biases; they exaggerate clean vehicle emission reductions, assume that vehicle travel reduction strategies are ineffective and difficult to implement, and overlook many active travel co-benefits. This results in underinvest in active modes compared with what is optimal

Although commonly-citied statistics imply that active modes serve less than 2% of travel, more comprehensive analysis indicates that they actually serve 10-15% of trips, have significant and growing latent demand, often leverage additional vehicle travel reductions, and provide large and diverse benefits. Active mode improvements support other vehicle travel reduction strategies such as public transit encouragement and compact community development.

Comprehensive analysis can justify much more investment in active modes. Currently, most jurisdictions spend less than 4% of their transportation infrastructure budgets on active modes. At a minimum, they should receive funding and road space equivalent to their potential mode shares, typically 15-30% of trips, and more to make up for past underinvestments. Active mode improvements should be implemented as part of integrated programs that also include public transport improvements, TDM incentives and Smart Growth development policies. These can provide large emission reductions plus other economic, social and environmental benefits.

Optimizing active travel requires a variety of planning reforms. For the last century, transport planning has prioritized speed over other goals such as affordability, health and safety, and environmental quality. Efficiency and equity require reprioritization. A useful approach is to establish vehicle travel reduction targets, typically 15-25% reductions in per capita vehicle-travel, and develop analysis tools and policies to incorporate these goals in all planning decisions. Active mode improvements are essential to achieving these goals.

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