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Evaluating Non-Motorized Transportation Benefits and Costs

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Abstract
This report describes methods for evaluating non-motorized transport (walking, cycling, and their variants) benefits and costs, including direct benefits to users from improved walking and cycling conditions, and various benefits to society from increased non-motorized travel activity, reduced automobile travel, and support for more compact land use development. It identifies various types of benefits and costs, and describes methods for measuring them. It discusses non-motorized transport demand and ways to increase non-motorized travel activity. This analysis indicates that non-motorized travel provides significant benefits, many of which are overlooked or undervalued in conventional transport economic evaluation.

This report updates and expands on the article,
"Bicycling and Transportation Demand Management,"
Transportation Research Record 1441, Transportation Research Board, 1994, pp. 134-140.

Contents

Executive Summary

Non-motorized transport (*NMT*, also called *active transport* and *human powered transport*) refers to walking, cycling, and variants such as wheelchair, scooter and handcart use. Non-motorized transport plays an important and unique role in an efficient transport system. It provides basic mobility, affordable transport, access to motorized modes, physical fitness and enjoyment. Improving non-motorized conditions benefits users directly, and by reducing automobile travel can benefit society overall, including benefits to motorists. By helping to create more accessible, multi-modal communities, non-motorized improvements can leverage additional motor vehicle travel reductions, so a mile of increased non-motorized transport reduces several motor-vehicle miles, particularly if NMT improvements are integrated with complementary transport and land use policies.

Table ES-1 (following page) summarizes various benefits and costs to consider when evaluating transport system changes that affect non-motorized transport. Different types of policies and projects have different sets of impacts, depending on whether they improve non-motorized travel conditions, increase NMT activity, reduce automobile travel, and affect land use development patterns. This report describes the types of impacts that should be considered for various types of policies and projects. It describes methods for quantifying and *monetizing* (measuring in monetary units) these impacts, and provides default values that can be used or adjusted to reflect specific conditions.

Conventional transport project evaluation methods tend to overlook and undervalue non-motorized transport. Conventional travel statistics imply that only a small portion of total travel is by non-motorized modes (typically about 5%), but this results, in part, from travel survey practices which overlook many short and non-motorized trips. NMT represents a relatively large portion of total trips and travel time (typically 10-20% in urban areas), and many of the trips it serves are high value, and would be costly to perform by motorized modes. More comprehensive evaluation considers these additional non-motorized transport impacts and benefits.

Some benefits are relatively easy to measure. Transport economists have developed monetized estimates of traffic congestion, road and parking, vehicle operation, crash damage, and pollution costs, which can be applied to non-motorized travel impacts, such as improved pedestrian safety and reduced automobile travel. Values used to evaluate traffic deaths and injuries can evaluate the fitness and health benefits of active transport. Affordability can be quantified by measuring cost savings to lower income users. Other impacts may be more difficult to monetize, but at a minimum should be described. These include user enjoyment, option value, support for equity objectives, more compact and accessible land use development (smart growth), economic development, improved community livability, and additional environmental benefits such as habitat preservation.

There are many possible ways to improve and encourage non-motorized travel. Although most communities are implementing some of these strategies, few are using all that are justified. Most only affect a portion of total travel so their impacts appear modest and they are seldom considered the most effective way of solving a particular problem. However, these methods provide multiple and synergistic benefits. When all Impacts are considered, many communities can justify much more support for walking and cycling.

Table ES-1 **Summary of Non-Motorized Transport Benefits and Costs**

Impact Category	Description
Improve NMT Conditions	*Benefits from improved walking and cycling conditions.*
User benefits	Increased user convenience, comfort, safety, accessibility and enjoyment
Option value	Benefits of having mobility options available in case they are ever needed
Equity objectives	Benefits to economically, socially or physically disadvantaged people
Increase NMT Activity	*Benefits from increased walking and cycling activity*
Fitness and health	Increased physical fitness and health
Reduced Vehicle Travel	*Benefits from reduced motor vehicle ownership and use*
Vehicle cost savings	Consumer savings from reduced vehicle ownership and use
Avoided chauffeuring	Reduced chauffeuring responsibilities due to improved travel options
Congestion reduction	Reduced traffic congestion from automobile travel on congested roadways
Reduced barrier effect	Improved non-motorized travel conditions due to reduced traffic speeds and volumes
Roadway cost savings	Reduced roadway construction, maintenance and operating costs.
Parking cost savings	Reduced parking problems and facility cost savings.
Energy conservation	Economic and environmental benefits from reduced energy consumption.
Pollution reductions	Economic and environmental benefits from reduced air, noise and water pollution.
Land Use Impacts	*Benefits from support for strategic land use objectives*
Pavement area	Can reduce road and parking facility land requirements
Development patterns	Helps create more accessible, compact, mixed, infill development (smart growth)
Economic Development	*Benefits from increased productivity and employment*
Increased productivity	Increased economic productivity by improving accessibility and reducing costs
Labor productivity	Improved access to education and employment, particularly by disadvantaged workers.
Shifts spending	Shifts spending from vehicles and fuel to goods with more regional economic value
Support specific industries	Support specific industries such as retail and tourism
Costs	*Costs of improving non-motorized conditions*
Facilities and programs	Costs of building non-motorized facilities and operating special programs
Vehicle traffic impacts	Incremental delays to motor vehicle traffic or parking
Equipment	Incremental costs to users of shoes and bicycles
Travel time	Incremental increases in travel time costs due to slower modes
Accident risk	Incremental increases in accident risk

This table summarizes various benefits and costs that should be considered when evaluating transport system changes that affect non-motorized transport.

Introduction

Non-motorized transport (*NMT*, also called *active transport* and *human powered transport*) refers to walking, cycling, and variants such as wheelchair, scooter and handcart use.[1] It includes both utilitarian and recreational travel activity, plus stationary uses of pedestrian environments such as standing on sidewalks and sitting at bus stops.

Non-motorized travel plays important and unique roles in an efficient transport system:

- Walking is a nearly universal human activity that provides mobility, exercise and pleasure.
- Typically 10-20% of trips are entirely by non-motorized modes, and most motorized trips involve non-motorized links, to access public transit, and for travel between parked cars and destinations. Parking lots, transport terminals, airports, and commercial centers are all pedestrian environments. Better non-motorized conditions can improve motorized travel.
- Walking and cycling provide affordable, basic transportation. People who are physically, economically and socially disadvantaged often rely significantly on non-motorized modes, so non-motorized improvements can help increase social equity and economic opportunity.
- Active transport is the most common form of physical exercise. Increasing walking and cycling is often the most practical way to improve public fitness and health.
- Non-motorized modes support land use planning objectives, such as urban redevelopment and compact, mixed-use community design.
- Pedestrian environments (sidewalks, paths and hallways) are a major portion of the public realm. Many beneficial activities (socializing, waiting, shopping and eating) occur in pedestrian environments, and so are affected by their quality. Shopping districts and resort communities depend on walkable environments to attract customers.
- Walking and cycling improvements can support strategic land use development objectives by helping to create more compact, mixed, multi-modal, "smart growth" communities, where residents drive less and rely more on alternative modes.
- Walking and cycling are popular recreational activities. Improving walking and cycling conditions provides enjoyment and health benefits to users, and it can support related industries, including retail, recreation and tourism.

Non-motorized transport can provide various types of benefits and costs, as summarized in Table 1. These include the direct user benefits that result from improved walking and cycling conditions, as well as various benefits to society from increased walking and cycling activity, reduced automobile travel, and from more compact, mixed land use development patterns that support, and are supported by, non-motorized modes. Since physically and economically disadvantaged people often depend on walking and cycling, improving these modes tends to increase social equity and economic opportunity.

[1] In this report, *pedestrian*, *walker*, *cyclist*, *active transport users*, and *non-drivers* refer to people who use non-motorized modes, while *motorist* and *driver* refer to automobile users. Of course, most people fall into multiple categories at various times.

Table 1 **Non-Motorized Transportation Benefits and Costs**

	Improved NMT Conditions	Increased NMT Transport Activity	Reduced Automobile Travel	More Walkable Communities
Potential Benefits	• Improved user convenience and comfort • Improved accessibility, particularly for non-drivers • Option value • Increased local property values	• User enjoyment • Improved public fitness and health • Increased community cohesion (positive interactions among neighbors)	• Reduced traffic congestion • Road and parking facility cost savings • Consumer savings • Reduced traffic crashes • Energy conservation • Air and noise pollution reductions	• Improved accessibility, particularly for non-drivers • Transport cost savings • Reduced sprawl costs • Habitat preservation • More livable communities
Potential Costs	• Facility costs • Traffic speed reductions	• Equipment costs (shoes, bikes, etc.) • Increased crash risk	• Increases in travel times	• Increases in some development costs

Non-motorized transport can provide various types benefits and impose various costs.

Conventional planning often evaluates transport system performance using *mobility-based* indicators, as discussed in the following box. This favors faster modes and longer trips over slower modes and shorter trips, and so tends to undervalue non-motorized transport. Although non-motorized modes provide only a small portion of total travel, they play a critical role in providing accessibility. As a result, accessibility-based performance indicators better recognize the value of non-motorized modes.

Mobility Versus Accessibility (Litman 2003a)
Mobility refers to physical movement. *Accessibility* refers to people's ability to reach desired goods and activities. Accessibility is affected by *mobility* (the ease of physical travel), *transport system diversity* (the variety of modes available), *network connectivity* (the quality of connections among roads, paths and modes), *land use accessibility* (density and mix), and *mobility substitutes* such as telecommunications and delivery services. Accessibility is the ultimate goal of most transport, excepting the small portion of travel without destination, such as walking purely for exercise and automobile cruising.

Current transport planning often evaluates transport system performance using mobility-based indicators such as traffic speed, congestion delay, and vehicle operating costs. This assumes that faster travel and longer trips are always better than slower, shorter trips, and so considers slower modes inferior. These indicators ignore other factors that affect accessibility, such as land use patterns, transport system connectivity, and mobility substitutes. These practices tend to undervalue non-motorized travel.

Accessibility-based evaluation expands the impacts and options considered in planning. For example, this perspective recognizes that accessibility can often be improved by increasing transport system connectivity (such as better connections between bicycling and public transit) and creating more compact, mixed, walkable neighborhoods. It also recognizes ways that wider roads, increased vehicle traffic, and more dispersed land use development can reduce accessibility, particularly by non-motorized modes.

Conventional travel surveys often undercount non-motorized trips, because they do not count shorter trips, off-peak trips, non-work trips, travel by children, recreational travel, and non-motorized links of automobile and public transit trips (Stopher and Greaves 2007). More comprehensive surveys indicate that non-motorized travel is three to six times more common than conventional surveys indicate (Rietveld 2000; Forsyth, Krizek and Agrawal 2010). This issue is discussed in more detail later in this report.

Because non-motorized transport benefits are diverse and often outside traditional transport planning objectives, and because non-motorized travel is often undercounted, conventional planning tends to undervalue non-motorized transport impacts, as illustrated in Table 2. For example, when evaluating highway expansion projects, conventional transport project benefit/cost analysis considers the increased motor vehicle traffic speeds, but ignores additional delays to pedestrian and cyclists from wider roadways and increased vehicle traffic speeds.

Table 2 **Consideration of Non-Motorized Transport Benefits** (Litman 2007)

Usually Considered	Often Overlooked
Government costs	Downstream congestion impacts
Travel speed (congestion delays)	Delay to non-motorized travel (barrier effect)
Vehicle operating costs (fuel, tire wear, etc.)	Parking costs
Per-kilometer crash rates	Vehicle ownership and mileage-based depreciation costs
Per-kilometer pollution emission rates	Project construction traffic delays
Project construction environmental impacts	Generated traffic impacts (additional accidents, energy consumption and pollution emissions)
	Strategic land use impacts (e.g., sprawl)
	Transport diversity and equity (mobility for non-drivers)
	Impacts on physical activity and public health
	Some travelers' preference for alternative modes

Many non-motorized transportation benefits tend to be overlooked or undervalued in conventional transport project evaluation.

This report describes ways to evaluate planning decisions that affect non-motorized transport. It discusses the steps between a particular planning decision; travel activity changes; economic, social and environmental impacts; and valuation of these impacts. Because non-motorized travel is diverse, some analysis in this report only applies to certain conditions, modes or trips. For example, some analysis applies primarily to walking, others primarily to cycling, some to certain users (such as people with disabilities), and some to certain conditions (such as non-motorized access to public transit). Users should use judgment to determine what is appropriate for their analysis.

Evaluation Framework

Table 3 illustrates the various steps between transport policy or planning decisions and their ultimate impacts, and describes the types of information needed to quantify them. Active transport evaluation should account for each of these steps.

Table 3 **Evaluation Framework**

Steps From Decisions To Economic Valuation	Information Requirements
Public Policy And Planning Decisions (infrastructure funding and pricing, facility design, facility management, land use development, encouragement programs, etc.) ↓	Types of policy and planning decisions, their design, duration, integration (with other transport and land use policies), level of community support, and responsiveness to user demands.
Change in Travel Conditions (better footpaths, paths and bike lanes, traffic speed reductions, higher fees for driving, closer destination, etc.) ↓	Multi-modal transport system performance evaluation, using indicators such as level-of-service (LOS) which measures the quality of travel by each mode under particular conditions.
Travel Activity Changes (more walking and cycling, more public transit travel, less driving, etc.) ↓	Multi-modal transport modeling that predicts how changes in walking and cycling conditions affect total travel activity. This should be disaggregated by demographic factors (who changes), trip type (what types of travel would change, etc.), and location (where do changes occur).
Land Use Changes (less land devoted to roads and parking facilities, more compact and mixed development patterns) ↓	Integrated transport and land use modeling that indicates how changes in travel conditions and activity affect development patterns. This should include analysis of demand for more walkable and bikeable locations.
Impacts (changes in traffic congestion, road and parking facility costs, user costs, accident rates, pollution emissions, physical activity and health, mobility for non-drivers, etc.) ↓	Quantify travel including congestion delays, facility costs, user time and financial costs, accidents, pollution emissions, physical fitness and health, accessibility and affordability for disadvantaged people, etc. This should be disaggregated by demographic factors (identify who enjoys benefits or bears costs).
Economic Valuation (financial costs to consumers, businesses and governments, monetized value of changes in health and travel time, sum of all monetised values)	Apply accounting and monetisation techniques to calculate the dollar value of transport impacts.

This table summarises the various steps between a policy or planning decision and its ultimate economic impacts, and the information needed to quantify each step.

Non-Motorized Transport And Transport Diversity

Many communities are, to various degrees, *automobile dependent*, meaning that their transport systems patterns are designed for automobile access and provide relatively poor access by other modes. The alternative is not necessarily a car-free community, rather, it is a community with a diverse, multi-modal transport system, which provides good quality walking, cycling, public transit, automobile, taxi, telework and delivery services.

Because transport demands are diverse (different people, areas and trips have differing travel needs and abilities), a multi-modal transport system tends to be most efficient and equitable, because it allows each mode to be used for what it does best and provides relatively good accessibility for non-drivers (people who, for any reason, cannot rely on automobile transport). For example, it would be inefficient if, due to poor non-motorized travel conditions, physically able people who enjoy walking and cycling are forced to drive for short trips; or if, due to inadequate public transit services and inefficient road and parking pricing, people drive on congested urban corridors where it is not cost effective to expand roads and parking facilities due to high costs. A diverse transport system allows non-motorized modes to be used for short trips by physically able people, public transit to be used on congested urban corridors where expanding roads and parking facilities is costly, and automobiles to be used for longer trips to more dispersed destinations.

Non-motorized modes play important roles in a diverse transport system. Walking is generally the second most common mode of transport (after automobile). Improving walking and cycling conditions allows non-motorized modes to be used for more local errands. Although cycling has a small mode share in most communities, it is efficient and cost effective, and if given suitable support can serve a significant share of travel, typically 5-15% in communities with good facilities. Walking and cycling provide access to public transit; often the best way to improve and encourage public transit travel is to improve local walking and cycling conditions.

Increasing walkability involves creating more compact, mixed land use patterns, with more connected transport systems (more connected roads and paths, and better connections between different modes, such as bicycle parking at transit stations). Improved walkability also expands the range of parking spaces that can serve a destination, reducing the number of parking spaces needed in an area, which allows more compact land use development. These land use patterns help create more accessible, multi-modal communities.

For these reasons, a key step in creating more diverse, efficient and equitable transport systems is to improve non-motorized travel conditions and create more walkable and bikeable communities. Even modest shifts to non-motorized travel (for example, if walking and cycling increase from 10% to 15% of total trips) can provide large benefits to users and society. The additional non-motorized travel is likely to include many high value trips, including more mobility for non-drivers, public transit access trips (and therefore an increase in public transit travel), and as a substitute for costly automobile trips (for example, for short trips in congested urban conditions, or requiring drivers to chauffeur non-drivers).

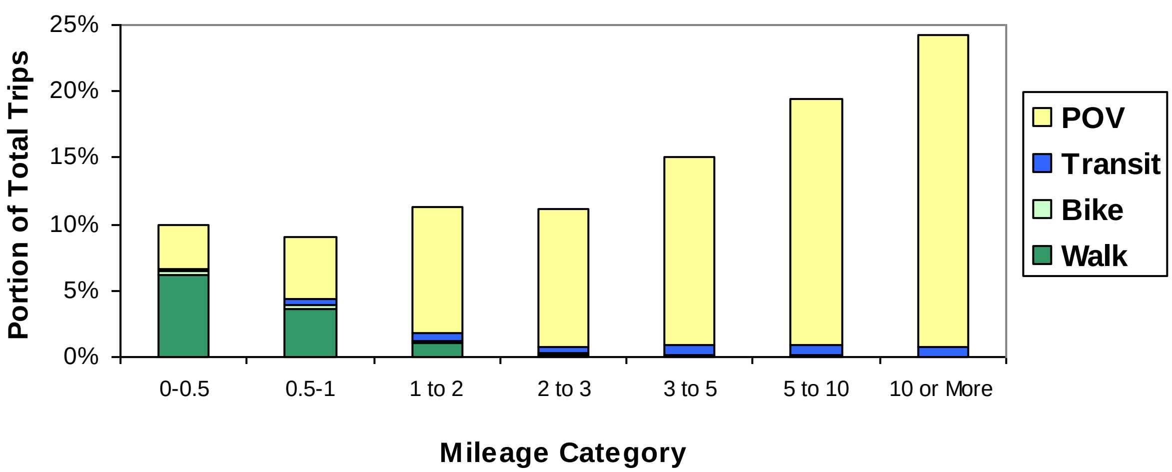
Non-Motorized Transport Demand

Transport demand refers to the amount and type of travel people would choose in specific conditions. Many factors affect non-motorized travel demand including demographics and economics, walking and cycling conditions, the quality and price of alternatives, and land use patterns (Dill and Gliebe 2008). *Transport modeling* refers to methods used to predict how specific transport system changes will affect travel activity (Krizek, et al. 2006).

Walking and cycling activity is more common than most travel statistics indicate because conventional travel surveys undercount shorter trips (those within a *traffic analysis zone* or TAZ), off-peak trips, non-work trips, travel by children, and recreational travel (ABW 2010; Stopher and Greaves 2007). Many surveys ignore non-motorized links of motor vehicle trips, for example, a *bike-transit-walk* trip is usually classified simply as a transit trip, and a motorist who walks several blocks from their parked car to a destination is simply considered an automobile user. More comprehensive surveys indicate that non-motorized travel is three to six times more common than conventional surveys indicate (Rietveld 2000; Forsyth, Krizek and Agrawal 2010; Pike 2011), so if statistics indicate that only 5% of trips are non-motorized, the actual amount is probably 10-30% (Litman 2010).

According to the 2009 U.S. *National Household Travel Survey*, 10.9% of personal trips are by walking and 1.0% are by bicycle, a 25% increase since 2001. Figure 1 shows the mode share for various trip lengths. For the 14% trips less than a half-mile mile in length, 46% are by non-motorized modes. For the 27% of trips less than a mile, 31% are non-motorized. For the 49% of trips under three miles, 19% are non-motorized. About half of walking and cycling trips are just for recreation and about half are for transport, and only about 5% is for commuting (Gallup 2008). This indicates that for each non-motorized *commute* trip there are about nine other utilitarian non-motorized trips and about ten recreational trips.

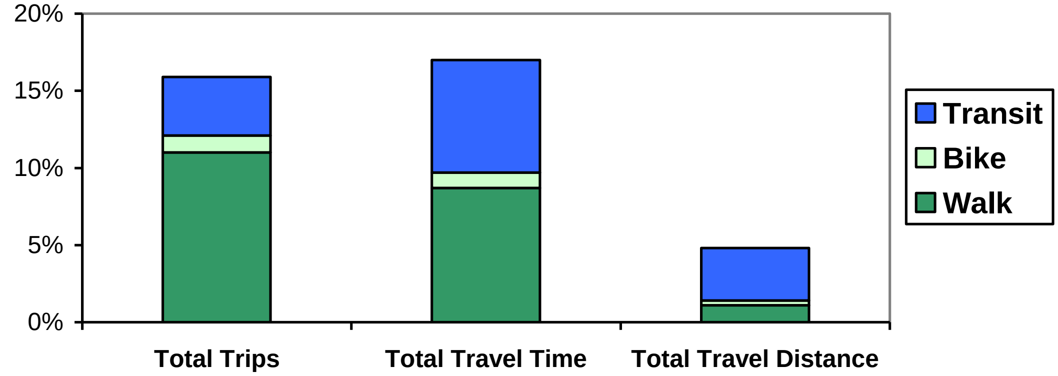
Figure 1 **Mode Split By Mileage Category** (Litman 2010)



This figure illustrates the share of total trips by mode and trip distance category. "POV" refers to Private Owned Vehicle, which includes cars, vans, SUVs, light trucks and motorcycles.

Although non-motorized modes are a small portion of total travel *distance*, they represent a much larger portion of share of *travel time* and *trips*. For example, the NHTS indicates that walking represents only about one percent of total mileage but more than ten percent of personal trips and travel time, as shown in Figure 2.

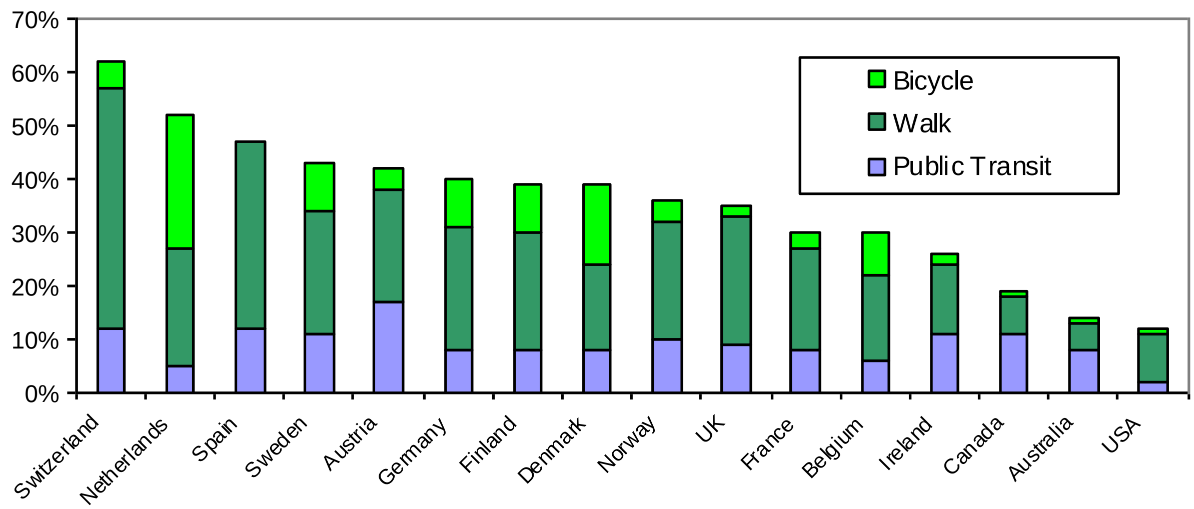
Figure 2 **Mode Share By Distance, Time and Trips** (Litman 2010)



Non-motorized modes serve a small portion of travel distance but a larger share of trips and travel time.

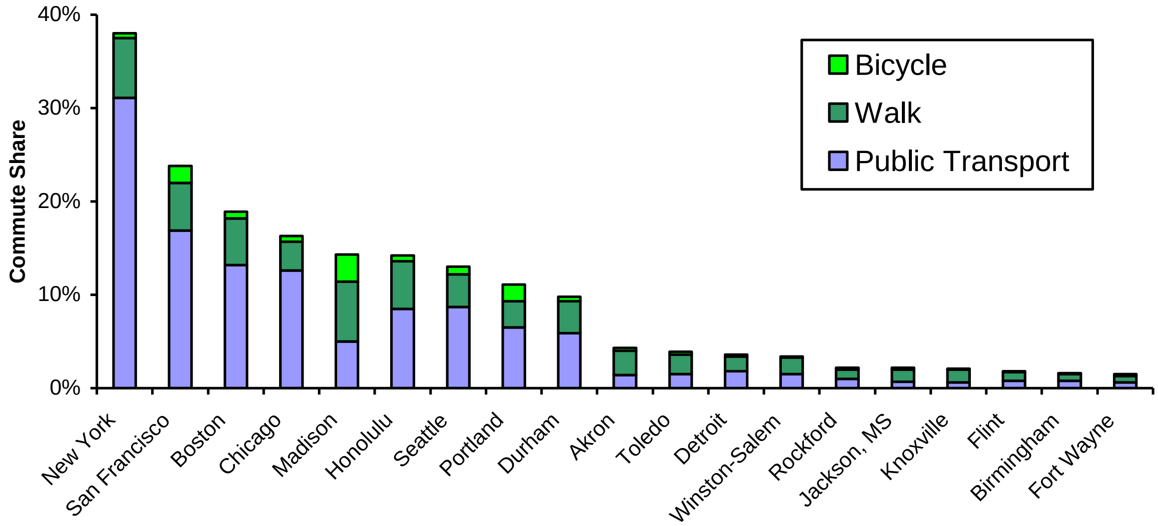
Non-motorized transport activity varies widely between different countries and cities, as illustrated in figures 3 and 4. These differences in non-motorized activity reflect policy and planning factors more than geography or climate. For example, Scandinavian countries, Switzerland, and the Netherlands have cold, wet climates, and San Francisco, Boston, and Seattle are cold, wet and hilly, but all have high non-motorized mode share due to supportive transport and land use policies and community attitudes (ABW 2010). Public transit and non-motorized travel tend to complement each other, so communities with high transit use also tend to have high rates of walking and cycling (Bassett, et al. 2010).

Figure 3 **Mode Split By Country** (Bassett, et al. 2011)



Non-motorized travel varies significantly between wealthy countries.

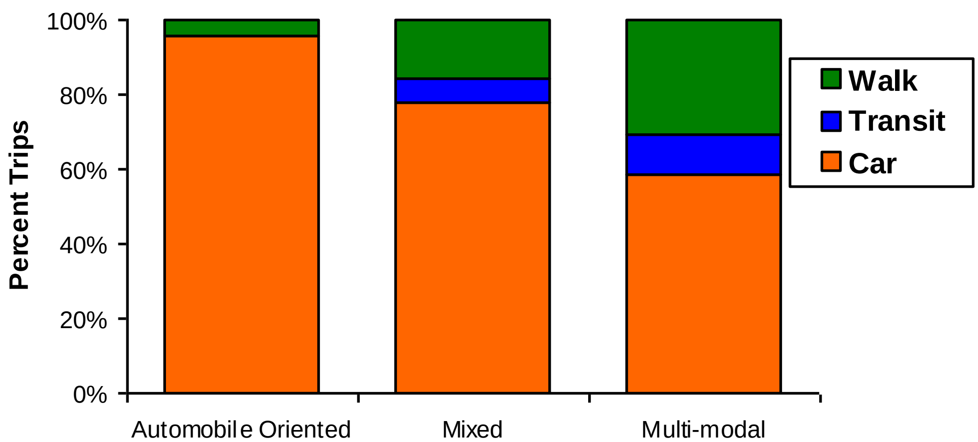
Figure 4 **U.S. Urban Region Commute Mode Share** (U.S. Census 2007)



This figure shows the ten U.S. cities with highest and lowest alternative mode commute share.

Even greater variation can occur between neighborhoods (Litman 2008). Multi-modal neighborhoods often have ten times as much walking and cycling activity as automobile-oriented neighborhoods, as illustrated in Figure 5. Although this partly reflects self-selection (non-drivers tend to choose more urbanized home locations), people who move from automobile-oriented to multi-modal communities usually shift a portion of travel to non-motorized modes (Cao, Handy and Mokhtarian 2006; Cervero 2007).

Figure 5 **Portland Neighborhood Mode Share** (Lawton 2001)



As an area becomes more urbanized the portion of trips made by transit and walking increases.

There is evidence of significant latent demand for non-motorized travel; many people want to walk and bicycle more than they currently do, but face obstacles (ABW 2010). One US survey found that 38% of respondents want to walk to work, and 80% want to walk more for exercise (STPP 2003). Similarly, there appears to be significant latent demand for housing in more walkable communities (Belden, Russonello & Stewart 2004). According to a survey of 2,000 representative home-buying U.S. households 27% would like to be able to walk to more places from their homes and rated either *important* or *very important* jogging/bike trails (36%), sidewalks (28%), and shops within walking area (19%) (NAR & NAHB 2002). Non-motorized facility improvements often lead to significant increases in walking and cycling activity (Living Streets 2011). Current demographic and economic trends (aging population, rising fuel prices, urbanization, growing traffic congestion, and increased health and environmental concerns) are increasing demand for non-motorized transport and the potential benefits from accommodating this demand (Litman 2006).

To evaluate some impacts it is important to know the automobile travel substitution rates, that is, the amount that non-motorized travel reduces motor vehicle travel. In a detailed before-and-after study of five U.S. communities that implemented non-motorized transport improvements, Krizek, et al. (2007) found that 30% to 40% of walk and bike commute trips, and about 95% of non-motorized trips to other destinations, would have been made by driving. Some of the automobile travel avoided may be ridesharing, in which passengers use an otherwise unoccupied seat in a vehicle that would make the trip anyway, but others generate additional vehicle travel, including chauffeured trips in which a driver makes a special trip to carry a passenger, which often generates an empty return trip. The researchers estimate that in these five communities the NMT improvements reduced approximately 0.25 to 0.75 mile of daily driving per adult, 1-4% of total automobile travel. The Australian *TravelSmart* program, which uses various incentives to encourage residents to use alternative modes typically reduces automobile trips 5% to 14%, about half resulting from shifts to non-motorized travel (TravelSmart 2005).

Non-motorized travel can leverage additional vehicle travel reductions (increased walking and cycling causes much larger motor vehicle travel reductions) by helping create more compact, multi-modal communities where residents own fewer vehicles and travel shorter distances. A shorter non-motorized trip can often substitute for longer motorized trips, such as when people choose a local store rather than driving to more distant shops (Cairns et al. 2004), and longer trips can shift to non-motorized-and-transit trips (Mackett 2001). Guo and Gandavarapu (2010) found that building sidewalks on all neighborhood streets in a typical North American community would increase walking and cycling by 0.097 average daily miles per capita, and reduce automobile travel by 1.142 daily vehicle-miles per capita, about 12 miles of reduced driving for each mile of increased non-motorized travel. International data also indicate that each mile of increased non-motorized travel is associated with seven miles of reduced motor vehicle travel, illustrated in Figure 6.

Of course, not every mile of walking and cycling has such impacts. Much of these effects are indirect, resulting from changes in vehicle ownership, land use patterns, and social attitudes, and so depend on other factors such as supportive development policies. For example, if residents want to reduce their driving and rely more on alternative modes but cannot due to poor walking and cycling access, improving non-motorized conditions and supportive land use policies can significantly reduce automobile travel. However, if there is minimal demand, there may be little change in travel activity and minimal benefits.

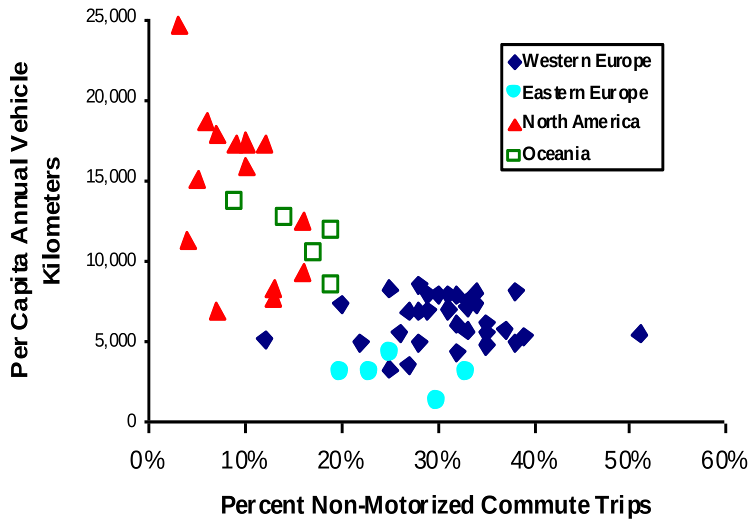
Non-motorized Indirect Travel Impacts
This analysis indicates walking and cycling improvements often leverage additional reductions in vehicle travel. Direct travel impacts consist of a mile of motor vehicle travel that shifts to a mile of walking or cycling. Indirect impacts result from the following factors:

- *Increased public transit.* Walking and cycling improvements can support public transit travel, since most transit trips involve walking and cycling links.
- *Vehicle ownership reductions*. Improving alternative modes can 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 some relatively low-value trips.
- *Land use patterns*. Walking and cycling improvements help create more accessible, multi-modal communities by reducing road and parking facility land requirements, and encouraging more compact, mixed development patterns.
- *Traffic speeds.* Non-motorized improvements sometimes reduce traffic speeds (traffic calming, streetscaping, traffic speed enforcement, etc.) which tends to reduce total vehicle travel.
- *Social norms.* More walking and cycling can help increase social acceptance of alternative modes.

Not every non-motorized improvement has all these effects, but many small changes can contribute to making a community more multi-modal, and therefore reducing total automobile travel. Consumer preference surveys indicate significant latent demand for travel by alternative modes and living in more accessible, multi-modal home locations (Litman 2009b), which suggests that walking and cycling improvements can help reduce vehicle travel.

Conventional planning analysis often ignores these indirect impacts and so underestimates the potential of non-motorized transport improvements to achieve objectives such as reduced traffic congestion, accidents and pollution emissions.

Figure 6 **Non-motorized Vs. Motorized Transport** (Kenworthy and Laube 2000)



International data show that vehicle travel tends to decline as non-motorized travel increases.

Research by Bassett, et al. (2011) using comparable travel surveys in Germany and the U.S. indicates that transport and land use policies can significantly affect walking and cycling activity. Between 2001 and 2008, the proportion of "any walking" was stable in the U.S. (18.5%) but increased in Germany from 36.5% to 42.3%. The proportion of "any cycling" in the U.S. remained at 1.8% but increased in Germany from 12.1% to 14.1%. In 2008, the proportion of "30 minutes of walking and cycling" in Germany was 21.2% and 7.8%, respectively, compared to 7.7% and 1.0% in the U.S. Virtually all demographic groups in Germany walk and cycle much more than their counterparts in the U.S.

Conventional travel models can be improved to better reflect non-motorized travel (Krizek, et al. 2006; "Model Improvements," VTPI 2009), and specialized models are available that focus on non-motorized travel (Barnes and Krizek 2005; TRB 2006; McDonald, et al. 2007). For example, such models can predict how changes in sidewalk and path conditions, land use patterns, and transport prices would affect walking and cycling activity, how much of this substitutes for automobile travel for different types of trips and user groups. Table 4 summarizes factors considered in a typical bicycle travel model. The *TDM Effectiveness Evaluation Model* (TEEM) evaluates the travel impacts and economic benefits of specific bicycle and pedestrian improvements (Loudon, Roberts and Kavage 2007). It evaluates how well existing infrastructure accommodates these modes, predicts the change in walk and bicycle commute mode shares that would result from improving index values, and estimates the benefits and costs of such improvements.

Table 4 **Factors Affecting Bicycle Travel Demand** (Based on Levitte 1999)

Factors	Bicycle Travel Impacts
Age	Bicycle use increases into middle age and then decreases. Cyclists tend to have lower average age than non-cyclists.
Gender	Men tend to cycle more than women.
Education	Bicycle use increases slightly with education.
Students	Students tend to bicycle. Schools, colleges and universities are major bicycle trip generators.
Vehicles	People without a car available are more likely to cycle.
Drivers licenses	People who cannot drive are more likely to cycle.
City size	A population of less than 100,000 appears to offer a better environment for cycling, and so may have higher rates of cycling than larger cities.
Employment status	Higher unemployment is associated with more cycling.
Professional status	Among employed people, professionals and managers appear more likely to cycle than blue collar and sales workers.
Household income	Utilitarian cyclists tend to have lower average incomes compared with non-cyclists. Recreational cyclists tend to have higher than average incomes.
Trip length	Cycling is most common for short (<5 mile) trips.
Parking fees	Commuters who must pay for parking may be more likely to bicycle.
Facility conditions	Bicycle facilities (paths and lanes) and roadway conditions considered favorable to cycling tend to increase bicycle travel.
Trip distance	Cycling tends to be used for moderate (<5 km) trips.
Travel costs	Market trends or policies that increase vehicle travel costs mayincrease bicycling.
Bicycle parking	Secure bicycle parking may encourage cycling.
Community values	Some communities support utilitarian cycling more than others.

Evaluating Non-Motorized Travel Conditions

Performance indicators are widely used to evaluate problems, prioritize improvements and measure progress ("Performance Evaluation" VTPI 2009). Below are examples of non-motorized transport performance indicators:

- *Level-of-Service* (*LOS*, also called *Service Quality*) rates performance from *A* (best) to *F* (worst). Until recently, only motor vehicle LOS ratings were available, but in recent years rating systems have been developed for non-motorized modes (TRB 2008; *Walkability Tools Research Website*, www.levelofservice.com). These include:

    1. *Cycling LOS* considers the availability of parallel bicycle paths, the number of unsignalized intersections and driveways, outside through lane and bike lane widths, motor vehicle traffic volumes and speeds, portion of heavy vehicles, the presence of parallel parked cars, grades (hills), and special conflicts such as freeway off-ramps.
    2. *Pedestrian LOS* considers pedestrian facility crowding, the presence of sidewalks and paths, vehicle traffic speeds and volumes, perceived separation between pedestrians and motor vehicle traffic (including barriers such as parked cars and trees), street crossing widths, extra walking required to reach crosswalks, average pedestrian road crossing delay, and special conflicts.

- *WalkScore* (www.walkscore.com) calculates a location's proximity to services such as stores, schools and parks, as an indication of the ease of walking to such destinations. It provides no information on walking condition quality.

- *Neighborhood Bikeability Score* (www.ibpi.usp.pdx.edu/neighborhoods.php) is a rating from 0 (worst) to 100 (best) that indicates the number of destinations (stores, schools, parks, etc.) that can be reached within a 20-minute bike ride, taking into account the quality of cycling infrastructure (McNeil 2010).

- The *Walkability Checklist* and *Bikeability Checklist* developed by the Pedestrian and Bicycle Information Center (www.walkinginfo.org) includes ratings for road and off-road facilities, user behavior, and ways to improve walking and bicycling conditions.

- Surveys that ask users to rate walking conditions, the barriers they face, and the degree that walking and cycling improvements would affect their travel activity (Leather, et al. 2011).

- Before and after studies of walking and cycling improvements that measure changes in non-motorized travel activity (Turner, et al. 2011).

- *Acceptable Walking Distance*. The distance people willingly walk is an important factor in transport and land use planning. It determines the optimal size of a commercial district or urban village, the area served by public transit, and the acceptable distance between parking facilities and destinations. The table below indicates pedestrian access LOS.

Table 5 **Level of Service By Walking Trip Distance (in Feet)** (Smith and Butcher 1997)

Walking Environment	LOS A	LOS B	LOS C	LOS D
Climate Controlled	1,000	2,400	3,800	5,200
Outdoor/Covered	500	1,000	1,500	2,000
Outdoor/Uncovered	400	800	1,200	1,600
Through Surface Lot	350	700	1,050	1,400
Inside Parking Facility	300	600	900	1,200

This table rates acceptable walking distance for various conditions.

NMT Improvement and Encouragement Strategies

There are many possible ways to improve and encourage non-motorized transport (Alta Planning 2005; FHWA 2004; VTPI 2010). Non-motorized transport improvement and encouragement programs tend to have synergistic effects (total impacts are greater than the sum of their individual impacts), so it is generally best to implement and evaluate integrated programs. Experts generally recommend that non-motorized plans include *Four Es*: engineering, encouragement, education and enforcement. Below are examples:

- *Walking and cycling facility improvements.* Improved sidewalks, crosswalks, paths, bikelanes, bicycle parking and changing facilities. Apply *universal design*, which refers to design features that accommodate all possible users, including wheelchair and handcart users, and people who cannot read local languages.
- *Non-motorized transport encouragement and safety programs.* Special programs that encourage people to walk and bicycle for transport, and teach safety skills.
- *Public bikes* (easy-to-rent bikes distributed around a community).
- *Roadway redesign, including traffic calming, road diets, and traffic speed controls.* Traffic calming changes roadway design to reduce traffic speeds. Road diets reduce the number of traffic lanes, particularly on urban arterials. Traffic speed controls can involve driver information, changes in posted speed limits, and increased enforcement.
- *Improved road and path connectivity*. More connected roadway and pathway systems allow more direct travel between destinations. Walking and cycling shortcuts are particularly effective at encouraging motorized to non-motorized travel shifts.
- *Public transport improvements*. Public transport complements active transport: Public transit improvements often involve pedestrian and cycling facility improvements (such as better sidewalks and bicycle parking), and it can reduce vehicle traffic and sprawl.
- *Commute trip reduction programs*. This includes various programs that encourage use of alternative modes, particularly for commuting to work and school. These often include features that encourage non-motorized travel such as improving bicycle parking or financial rewards such as *parking cash out*.
- *Pricing reforms.* This includes more efficient road, parking, insurance and fuel pricing (motorists pay directly for costs they impose).
- *Smart growth (also called new urban, transit-oriented development, and location-efficient development) land use policies.* More compact, mixed, connected land use, and reduced parking supply tends to improve walking and cycling conditions and encourage use of active modes by reducing the distances people must travel to reach common destinations such as shops, schools, parks, public transit, and friends.

Table 6 summarizes the travel impacts of these strategies. Some strategies only affect a portion of total travel (for example, Commute Trip Reduction programs only affect commute travel at participating worksites). A combination of these strategies can have significant impacts, improving non-motorized travel conditions, increasing non-motorized travel, and shifting 10-30% of motorized travel to non-motorized modes.

Table 6 **Travel Impacts of Strategies to Encourage Non-motorized Travel**

Strategy	Improves Non-motorized Conditions	Increases NMT Travel	Reduces Automobile Travel
Walking & cycling facility improvements	Significant	Significant	Moderate
Encouragement and safety programs	Moderate	Moderate	Moderate
Public bikes	Moderate	Moderate	Moderate
Roadway redesign	Moderate	Moderate	Small
Improving road and path connectivity	Significant	Significant	Significant
Public transport improvements	Moderate	Moderate	Moderate
Commute trip reduction	Moderate	Moderate	Significant
Transportation price reforms	Small	Moderate	Significant
Land use policy reform	Significant	Significant	Significant

("Small" = less than 1%; "Moderate" = 1-5%; "Significant" = greater than 5%)
This table summarizes the potential impacts of various mobility management strategies. Although many strategies have modest individual impacts, their effects are cumulative and often synergistic (total impacts are greater than the sum of individual impacts). An integrated program that combines several appropriate strategies can significantly improve non-motorized conditions, increase non-motorized travel and reduce automobile travel.

Conversely, various planning decisions can degrade active transport conditions and discourage use of alternative modes. These include roadway expansion, increased traffic volumes and speeds, automobile travel underpricing, and sprawled land use development.

Network and Synergistic Effects
Transport systems tend to have network effects: their impacts and benefits increase as they expand. For example, a single sidewalk or bicycle lane generally provides little benefit since it will connect few destinations, but a network of sidewalks and bicycle lanes that connect most destinations in an area can be very beneficial. Similarly, a single sidewalk or bicycle path that connects two networks (i.e., it fills a missing link) can provide very large benefits.

Transportation improvement strategies often have synergistic effects, that is, their total impacts are greater than the sum of their individual impacts. For example, developing bike lanes alone may only increase bicycle commute mode share by 5-points, and a commute trip reduction program alone may only increase bicycle mode share by 5-points, but implemented together they may increase bicycle mode share by 15-points because of their synergist effects.

Conventional transport planning often evaluates projects and programs individually, and so tends to overlook these network and synergistic effects. This tends to undervalue non-motorized transport improvements, particularly early in the development period. The first few sidewalks, bike lanes or encouragement programs in a community will seldom offer a high economic return if evaluated individually, although once completed the network may provide very large benefits. It is therefore important to use comprehensive and systematic evaluation of non-motorized benefits.

Non-Motorized Planning Resources

AASHTO (2004), *Guide for the Planning, Design, and Operation of Pedestrian Facilities*, American Association of State Highway and Transportation Officials (www.aashto.org).

Nelson\Nygaard (2009), *Abu Dhabi Urban Street Design Manual*, Urban Planning Council (www.upc.gov.ae); at www.upc.gov.ae/guidelines/urban-street-design-manual.aspx?lang=en-US.

ABW (2010), *Bicycling and Walking in the U.S.: 2010 Benchmarking Report*, Alliance for Biking & Walking (www.peoplepoweredmovement.org/site/index.php/site/memberservices/C529)

Alta Planning (2005), *Caltrans Pedestrian and Bicycle Facilities Technical Reference Guide*, California DOT (www.dot.ca.gov/hq/traffops/survey/pedestrian/TR_MAY0405.pdf).

Bicycle Information Center (www.bicyclinginfo.org), provides nonmotorized planning information.

Bicyclepedia (www.bicyclinginfo.org/bikecost), bicycle facility benefit/cost analysis tool.

Complete Streets (www.completestreets.org), provides information on multi-modal road planning.

FHWA Bicycle and Pedestrian Program Office (www.fhwa.dot.gov/environment/bikeped) promotes bicycle and pedestrian accessibility, use and safety.

Fietsberaad (www.fietsberaad.nl), the Dutch *Centre of Expertise on Bicycle Policy* develops and disseminates practical knowledge and experience for improving and encouraging cycling.

GTZ (2009), *Cycling-inclusive Policy Development: A Handbook*, Sustainable Urban Transport Project (www.sutp.org/index.php?option=com_content&task=view&id=1462&Itemid=1&lang=uk)

David Harkey and Charles Zegeer (2004), *PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System*, Pedestrian and Bicycling Information Center (www.walkinginfo.org); at www.walkinginfo.org/library/details.cfm?id=10.

ITE (2010), *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach*, Institute of Transportation Engineers (www.ite.org/css); at www.ite.org/emodules/scriptcontent/Orders/ProductDetail.cfm?pc=RP-036A-E.

PBIC (2009), *Assessing Walking Conditions With An Audit*, Pedestrian and Bicycle Information Center (www.walkinginfo.org); at www.walkinginfo.org/problems/audits.cfm.

PROWAC (2007), *Accessible Public Rights-of-Way: Planning and Designing for Alterations*, Access Board (www.access-board.gov); at www.access-board.gov/prowac/alterations/guide.htm.

VTPI (2010), Online TDM Encyclopedia, Victoria Transport Policy Institute (www.vtpi.org/tdm).

Walk Friendly Communities (www.walkfriendly.org) is a USDOT program that encourages communities to create safer walking environments.

WFC (2010), *Walk Friendly Community Assessment Tool*, Walk Friendly Communities (www.walkfriendly.org).

Charles V. Zegeer, Laura Sandt and Margaret Scully (2009), *How to Develop a Pedestrian Safety Accident Plan*, National Highway Traffic Safety Administration, U.S. Federal Highway Administration; at http://safety.fhwa.dot.gov/ped_bike/docs/fhwasa0512.pdf.

Benefit and Cost Categories

This section describes various non-motorized impact categories and methods for measuring them.

Non-motorized transportation can provide various types of benefits and costs. Some result from improved NMT conditions, others from increased NMT activity, others from reduced automobile travel, and others from land use changes, as indicated in tables 1 and 7. Table 7 summarizes the categories of benefits and factors that tend to affect their magnitude.

Table 7 **Categories of Non-Motorized Transport Benefits and Costs**

Category	Examples	Factors Affecting Their Magnitude
Improved walking and cycling conditions.	Direct benefits to existing and new users from having convenient and safe walking and cycling conditions, plus option value and equity benefits	Degree of improvement. Number and type of potential users. Whether it improves basic mobility for disadvantaged people.
Increased walking and cycling activity	User enjoyment and health benefits	Amount walking and cycling increases. Number and type of users. Whether it helps currently sedentary people achieve physical activity targets.
Reduced automobile travel	Congestion reduction, road and parking facility cost savings, consumer savings, accident reductions, energy conservation and emission reductions	Amount and type of automobile travel reduced (reductions in urban-peak travel tend to provide large benefits).
Land use impacts.	More compact and accessible land use development ("smart growth"). Support for planning objectives such as downtown redevelopment or greenspace preservation.	Degree that a policy or project supports land use planning objectives.
Economic development	Increased economic productivity and support for specific industries.	Degree that a policy or project supports economic development objectives.
Costs	Program costs, consumer costs, increased travel time and accident risk	Project costs. Vehicle traffic delays. Users' incremental financial, time and risk costs, and whether users have good alternatives.

This table summarizes the major categories of benefits and costs to consider when evaluating non-motorized policies and projects.

Some of these impacts overlap. For example, many of the economic benefits result from the transport cost savings that occur when people reduce their vehicle travel or more accessible land use supports local businesses. It would be inappropriate to simply add all of these costs together, since that could result in double-counting, but it would also be inappropriate to overlook economic benefits simply because they are indirect or difficult to quantify.

Monetization Methods

Some NMT impacts involve *non-market goods*, that is, goods not generally traded in a competitive market. For example, improved pedestrian environments, cleaner air, and reduced traffic risk are not generally purchased directly by consumers. Various methods can be used to *monetize* (measure in monetary units) such impacts (van Essen, et al. 2007; "Quantification Techniques," Litman 2009):

- *User savings.* Non-motorized improvements that allow people to reduce their transport costs (vehicle ownership and operation, parking costs, etc.) can be considered worth at least those monetary savings.
- *Social cost savings.* Non-motorized improvements that reduce costs to government or businesses (such as reduced road or parking facility costs) can be considered worth that amount to a community.
- *Control costs.* A cost can be estimated based on prevention, control or mitigation expenses. For example, if industry is required to spend $1,000 per ton to reduce emissions of a pollutant, we can infer that society considers those emissions to impose costs at least that high. If both damage costs and control costs can be calculated, the lower of the two are generally used for analysis on the assumption that a rational economic actor would choose prevention if it is cheaper, but will would accept damages if prevention costs are high.
- *Contingent valuation surveys* ask people the amount they would willingly pay for a particular improvement, or the amount they would need to be compensated for loss, such as the closure of a path or trail (Carleyolsen, et al. 2005). Most communities spend approximately a hundred dollars annually per capita on local parks and recreation centers. This suggests that walking and cycling improvements that significantly improve people's ability to enjoy recreational walking and cycling provide benefits of comparable value.
- *Revealed preference studies* observe how much people pay in money or time to access services or facilities. For example, if somebody spends 20 minutes and two dollars for fuel to drive to a trail to walk or bike, this suggests they value trail use more than those costs, and they might be willing to pay to help develop a closer trail that is cheaper to access.
- *Hedonic pricing studies* observe how walking and cycling improvements affect nearby property values. For example, Cortright (2009) found that in typical U.S. metropolitan regions a one point increase in Walkscore (www.walkscore.com) is associated with a $700 to $3,000 increase in home values, indicating the value consumers place on walkability.
- *Compensation Rates*. Legal judgments and other damage compensation can be used as a reference for assessing nonmarket values. For example, if crash victims are compensated at a certain rate, this can be considered to indicate damage costs. However, some damages are never compensated, and it would be poor public policy to fully compensate all such damages, since that could encourage some people (those who put a relatively low value on their injuries) to take excessive risks or even cause crashes in order to receive compensation. As a result, compensation costs tend to be lower than total damage costs.

In some situations a combination of methods should be used. For example, the total value of health benefits may include a reduction in government, business and consumer healthcare costs; reduced worker disability costs and improved productivity; users' willingness-to-pay for reduced illness and longevity; minus any increase in medical costs associated with walking and cycling.

User Benefits

Improving non-motorized conditions (better sidewalks, crosswalks, paths, bike parking, traffic speed reductions, etc.) can provide direct benefits to *existing users* (people who would walk or bicycle even without improvements) and *new users* (people who increase walking or cycling in response to improvements) by increasing the convenience, comfort and safety of walking and cycling. User benefits can be large for the following reasons:

- Non-motorized travel is a critical component of the transport system. It is typically the second most common mode of transport (after automobile travel), and provides access to and connections among other modes. As a result, improving walking and cycling conditions can improve overall transport system diversity and efficiency.
- Although non-motorized travel represent a relatively small portion of total travel, it is a relatively large portion of travel time (typically 15-30%), which is how users experience transport, so NMT travel conditions significantly affect people's travel experience.
- Non-motorized modes provide enjoyment and exercise. Even utilitarian trips often provide such benefits. Surveys indicate that walking and cycling are among the most common forms of recreation, and that many people would like to use these modes more, provided that NMT conditions improve (ABW 2010).
- Non-motorized transport provides basic mobility, alone and in conjunction with public transport. In a typical community, 20-40% of residents cannot drive due to age, disability or poverty, and so depend on non-automobile modes, or are forced to rely on motorists for rides. As a result, the quality of NMT affects mobility disadvantaged people's ability to access critical goods and activities, and their independence.
- Pedestrian environments serve many functions and are a critical part of the public realm (public spaces where people naturally interact). On sidewalks and paths people stand, wait, socialize, play, eat, work and window-shop, and these facilities are an important part of the landscape. Improving pedestrian environments (for example, widening sidewalks, providing landscaping and shade, removing trash, improving security, etc.) can improve the utility and enjoyment of these activities, and create more attractive communities.

Evaluation methods: Various methods can be used to measure the value to users of walking and cycling improvements:

- *Avoided costs* (user savings from reduced expenditures on motorized travel or exercise equipment). Walking and cycling improvements reduce consumer expenditures on automobiles, taxi and public transit fares, exercise equipment or gym memberships. In some situations (for example, where non-motorized improvements reduce the need for households to own vehicles) savings can total hundreds or thousands of dollars annually per capita.
- *Contingent valuation* (user surveys). Area residents or potential users can be surveyed to determine their willingness-to-pay for specific facilities or improvement. This method is often used to estimate park and trail values (Carleyolsen, et al. 2005).
- *Hedonic pricing* (effects of walking and cycling improvements on nearby property values). Various studies indicate that walkability improvements tend to increase local property values (Bartholomew and Ewing 2011; Krizek et al. 2006; LGC 2001; Cortright 2009).

Buchanan (2007) found 5.2% higher residential property values and 4.9% higher retail rents in London neighborhoods with good walking conditions. Song and Knaap (2003) found that, all else being equal, house prices are 15.5% higher on average in walkable neighborhoods. Eppli and Tu (2000) found 11% higher property values in New Urbanist neighborhoods compared with otherwise similar homes in conventional, automobile-dependent communities.

Cortright (2009) found that a one-point Walkscore is associated with a $700 and $3,000 increase in home values, so a 10-point increase raises annualized housing costs approximately $350-$1,500. Pivo and Fisher (2010) found that office, retail and apartment values increased 1% to 9% for each 10-point WalkScore increase. Assuming a 10-point Walkscore increase causes average daily walking to increase one-mile per household (0.4 miles per capita), this indicates that consumers willingly pay $1 to $4 in higher housing costs per additional mile walked. Of course, other factors may partly explain the additional value consumers place on living in areas with higher Walkscores.

Residential property values also tend to increase with proximity to public trails (NTTP 2005; Racca and Dhanju 2006). Karadeniz (2008) found that each foot closer to Ohio's Little Miami Scenic Trail increases single-family property sale prices $7.05, indicating that values increase 4% if located 1,000 feet closer to the trail (this paper provides a good overview of the literature on this subject). Some studies indicate that proximity to trails and bike paths reduces the value of abutting properties, due to concerns over reduced privacy and increased crime (Krizek 2006). However, Racca and Dhanju (2006) conclude, "The majority of studies indicate that the presence of a bike path/trail either increases property values and ease of sale slightly or has no effect." Paths and trail benefits are likely to be largest in communities where walking and cycling are widely accepted and supported, and if residents can self-select, so people who value walking and cycling can locate near such facilities, while people who dislike such facilities can move away.

In general, the greater the improvement, the greater the benefit per user, and the more users the greater the total benefits. This benefit can be worth as much as $0.50 per user-mile (i.e., one person walking or bicycling one mile under improved walking and cycling conditions) where walking and cycling conditions improve from very poor to very good, based on evidence from hedonic pricing studies and avoided cost analysis (such as savings to parents who avoid the need to chauffeur children to school). In most cases, NMT improvement user benefits will be somewhat smaller, perhaps $0.25 per passenger-mile.

Option Value

Option value refers to the value people may place on having an option available that they do not currently use, such as the value ship passengers place on having lifeboats available for emergency use ("Transport Diversity," Litman 2009). Because walking and cycling can serve various roles in a transport system, including basic mobility for non-drivers, affordable transport, recreation and exercise, their potential option value is high.

Evaluation methods: Option value can be quantified using contingent valuation surveys which ask people how much they would be willing to pay for walking and cycling facilities and services that they do not currently use. The UK Department for Transport developed specific guidance for evaluating option value (DfT 2003). The "Transport Diversity Value" chapter of *Transportation Cost and Benefit Analysis* (Litman 2009) estimates that improvements in affordable alternative modes can be valued at 7¢ per passenger-mile, although this value can vary significantly depending on conditions and assumptions.

Equity Benefits

Most communities are to various degrees *automobile dependent*, meaning that transport systems are designed primarily for automobile travel and provide relatively poor mobility and accessibility options for non-drivers. This is horizontally inequitable (it favors some groups over others) and since many physically, economically and socially disadvantaged people are non-drivers, this situation also tends to be vertically inequitable (it harms disadvantaged groups). Described more positively, improving non-motorized travel conditions can help achieve equity objectives by providing a fair share of resources to non-drivers and providing basic mobility for physically, economically and socially disadvantaged people (Litman 2004c). Although most walking and cycling improvements provide equity benefits, the following tend to be particularly effective:

- *Universal design*. This refers to special transport system design features to serve all possible users, including people with disabilities and other special needs.
- *Basic mobility*. This refers to transport that provides access to essential services and activities, such as healthcare, education, employment, basic shopping, and social activities.
- *Economic opportunity*. This refers to helping lower-income people access services and activities that support their economic development, including education and employment.
- *Affordability*. This refers to people's ability to afford basic goods and services, and opportunities for savings to lower-income households. Walking, cycling and public transit improvements tend to increase transport system affordability.
- *Respect and dignity.* Because alternative modes tend to be stigmatized, programs that improve their social status tend to benefit disadvantaged people who rely on these modes.

Evaluation methods: Various objectives and impacts can be considered in transport equity analysis (Forkenbrock and Weisbrod 2001; Forkenbrock and Sheeley 2004; Litman 2004c):

- *Egalitarian equity* (everybody receives equal shares) suggests that non-motorized transport should receive an approximately proportional share of transport resources, measured either as mode share or per capita. For example, if non-motorized mode share is 12%, it would be fair to spend that portion of total transport budgets on non-motorized improvements; and if governments spend $500 annually per motorist on road, parking facilities and traffic services, a comparable amount should be spent for each person who depends primarily on walking and cycling. Of course, there are many possible ways to measure these factors, which can result in different conclusions concerning what is fair.
- *Cost allocation equity* (each user group should pay their share of costs) suggests that public expenditures on non-motorized facilities should be comparable to what users pay in taxes.
- *Impact compensation* (people should compensate the harms they impose on others). To the degree that motor vehicle traffic imposes delay, risk or discomfort on non-motorized modes, there is a horizontal equity justification for motorists to finance non-motorized facilities to mitigate such impacts. To the degree that sidewalks, crosswalks and pedestrian overpasses are needed to protect pedestrians and cyclists from motor vehicle traffic impacts, it is fair that motorists should bear the costs of these facilities.
- *Vertical equity* (policies should favor disadvantaged people) suggests that special effort to improve non-motorized conditions is justified to the degree that disadvantaged people rely on walking or cycling. Since non-motorized modes provide basic mobility for physically, economically and socially disadvantaged people, walking and cycling improvements are likely to help achieve this objective, particularly if directed to areas or users who tend to be disadvantaged. To the degree pedestrians and cyclists are physically, economically or socially disadvantaged compared with motorists, policies that reduce these impacts increase vertical equity. For example, traffic calming and speed control, and funding cycling facilities with motor vehicle user fees, help achieve vertical equity objectives by reducing the negative impacts that automobile traffic imposes on non-motorized travelers.

Various methods can help determine the value that a community places on social equity objectives, and the degree that a particular policy or project helps achieve these objectives. For example, contingent valuation surveys can determine the amount community members are willing to pay to improve travel conditions for people who are disabled or have low incomes. Census and survey data can identify where disadvantaged populations live and travel.

Transit subsidies can indicate society's willingness-to-pay to provide mobility for non-drivers. Such subsidies average about 60¢ per transit passenger-mile, about half of which are justified to provide basic mobility for non-drivers (the other half is intended to reduce congestion, parking and pollution problems), indicating that basic mobility is worth at least 30¢ per passenger-mile to society.

Physical Fitness and Health

Non-motorized travel provides physical exercise which can provide physical fitness and health benefits (Pucher, et al. 2010). Even small increases in physical activity can improve public health (Sallis, et al. 2004). Experts recommend that adults spend at least 150 minutes per week (22 minutes per day) in moderate physical activity, with additional health benefits if the exercise is more rigorous and longer duration (CDC 2010).

Diseases Associated With Inadequate Physical Activity

- Heart disease
- Hypertension
- Stroke
- Depression
- Diabetes
- Osteoporosis (weak bones and joints)
- Cancer
- Dementia

Although there are many ways to be physically active, walking and cycling are among the most practical and effective, particularly for inactive and overweight people (Sevick, et al. 2000; Pucher and Beuhler 2010; Bassett, et al. 2011). Residents of more multi-modal communities exercise more and are less likely to be overweight than residents of automobile-oriented communities (Ewing, Schieber and Zegeer 2003; Frank 2004). Commuters who walk or bicycle tend to be more productive and take fewer sick days (Queensland Transport 1999). Increased walking appears to reduce long-term cognitive decline and dementia (Erickson, et al. 2010). The U.S. Center for Disease Control's *Healthy People 2020* program includes specific objectives to increase walking and cycling (www.healthypeople.gov, PAF 10 and PAF 11).

Rojas-Rueda, et al. (2011) quantified the overall health impacts to users from shifting urban driving to cycling, including increases in accident risk, air pollution exposure and improved public fitness. In this case study, the 181,982 Barcelona Bicing public bike rental system users are estimated to experience 0.03 additional annual traffic accident deaths, 0.13 additional air pollution deaths, and 12.46 fewer deaths from improved fitness, resulting in 12.28 deaths avoided and a 77 benefit:risk ratio. This does not account for the additional health benefits from reduced accident risk to other road users or reduced air pollution emissions to other residents. The authors conclude that public bicycle sharing schemes can help improve public health and provide other benefits.

Rabl and de Nazelle (2012) estimate of the health impacts due to a shift from car to bicycling or walking, considering four effects: changes in physical fitness and ambient air pollution exposure to users, reduced pollution to other road users, and changes in accident risk. For a driver who switches to bicycling for a commute of 5 km (one way) 230 annual days the physical activity health benefits are worth about 1300 € annually, and in a large city (>500,000) the value of reduced air pollution is on the order of 30 €/yr. For the individual who makes the switch, the change in air pollution exposure and dose implies a loss of about 20 €/yr under our standard scenario but that is highly variable with details of the trajectories and could even have the opposite sign. Changes in bicyclists' accident risk are vary; data for Paris and Amsterdam imply that the loss due to fatal accidents is at least an order of magnitude smaller than physical activity health benefit.

Evaluation methods: Some studies monetize the health benefits of improved walking and cycling ("Safety and Health," Litman 2009; Boarnet, Greenwald and McMillan 2008; SQW 2007; Cavill, et al. 2008; NZTA 2010). Cavill, Cope and Kennedy (2009) estimated that an integrated program that increases walking in British towns provides benefits worth £2.59 for each £1.00 spent, considering just reduced mortality. Including other benefits (reduced morbidity, congestion and pollution) would increase this value. The Department for Transport found even higher economic returns (DfT 2010). The *Active Transport Quantification Tool* (ICLEI 2007) provides a methodology for valuing the active transportation benefits, including savings from avoided driving, increased happiness, and reductions in coronary heart disease, diabetes risk, congestion, pollution and crash risk.

Guo and Gandavarapu (2010) conclude that the incremental costs of residential sidewalk construction is usually repaid by the health benefits of increased physical fitness and reduced vehicle air pollution. They estimate that building sidewalks on all city streets would increase residents' average daily non-motorized travel by 0.097 miles and reduce average automobile travel 1.142 vehicle-miles. The increased walking and cycling would provide an average of 15 kcal/day per capita in additional physical activity. They estimated that this intervention could offset weight gain in about 37% of the population, providing substantial healthcare cost savings.

Gotschi (2011) estimated that Portland, Oregon's 40-year $138-605 million bicycle facility investments provide $388-594 million healthcare savings, $143-218 million fuel savings, and $7-12 billion in longevity value, resulting in positive net benefits. Sælensminde (2002) estimates that each physically inactive person who starts bicycle commuting provides €3,000-4,000 annual economic benefits. Meta-analysis by de Hartog, et al. (2010) indicates that people who shift from driving to bicycling enjoy substantial health benefits (3 to 14 month longevity gains), plus additional benefits from reduced air pollution and crash risk to other road users. The New Zealand Transport Agency's *Economic Evaluation Manual* provides monetary values for active transport, as summarized in the table below (NZTA 2010, Vol. 2, p. 8-11). These reflect health and congestion reduction benefits.

Table 8 **Active Transportation Health Benefits** (NZTA 2010)

	2008 $ NZ/km	2008 USD/mile
Cycling	$1.40	$1.92
Walking	$2.70	$3.70

This table indicates New Zealand's estimated value of increased walking and cycling.

Vehicle Savings

Automobile travel reductions provide vehicle cost savings summarized in the table below. Operating costs tend to be relatively high for short urban trips due to cold starts (engines are inefficient during their first few minutes of operation) and congestion. Households tend to shed cheaper, lower-annual mileage vehicles when they reduce their vehicle ownership, but savings still average thousands of annual dollars (Polzin, Chu and Raman 2008). Reduced vehicle ownership can reduce residential parking costs or allow a garage to be used for other productive purposes. In some situations, walking and cycling improvements reduce expenditures on taxi and public transit fares.

Table 9 **Vehicle Costs** ("Vehicle Costs," Litman 2009)

Category	Description	How It Can Be Measured	Typical Values
Vehicle Operating Costs	Fuel, oil and tire wear.	Per-mile costs times mileage reduced.	10-15¢ per vehicle-mile. Higher in congested conditions
Mileage-Related depreciation	Mileage-related depreciation, repair costs and lease fees.	Per-mile costs times mileage reduced.	5-15¢ per vehicle-mile, depending on vehicle type.
Special cost	Tolls, parking fees, etc.	Specific market conditions.	Varies.
Vehicle Ownership	Reductions in fixed vehicle costs.	Reduced vehicle ownership times vehicle ownership costs.	$2,000 to $3,000 per vehicle-year.
Residential Parking	Reduced residential parking costs	Reduced vehicle ownership times costs per space.	$100-1,200 per vehicle-year.

Reducing automobile travel can provide a variety of consumer savings.

Evaluation methods: Savings can be estimated using values from Table 9. Savings tend to be particularly large for reductions in short urban trips, and additional savings can occur if non-motorized improvements help create more accessible, multi-modal communities, which leverage additional reductions in vehicle travel, ownership and parking costs.

Avoided Chauffeuring

Chauffeuring refers to extra vehicle travel to transport a passenger, as opposed to *ridesharing* in which a passenger is carried in a vehicle that would travel anyway. Chauffeuring is particularly inefficient because it often requires empty return trips, so transporting a passenger 5 miles generates 10 vehicle-miles. Improving alternative modes can reduce chauffeuring by providing mobility to non-drivers. This reduces driver travel time, vehicle and external costs. Non-drivers gain independence. Experts believe that walking and bicycling (for example, to school and neighborhood activities) helps children develop emotionally and socially (O'Brien 2001), and non-drivers often express unhappiness being dependent on friends and family for transport (PPI 2002). Chauffeuring can have positive value, for example, when it allows drivers and passenger to converse, but this can also occur with non-motorized travel. Chauffeur trips sometimes impose high costs, for example, when a driver must interrupt important activities to chauffeur, or when chauffeuring responsibilities cause domestic conflicts.

Evaluation methods: Reduced chauffeuring benefits include previously described vehicle cost savings (including reduced vehicle ownership costs if non-motorized improvements allow some households to reduce the number of vehicle they must own), driver travel time savings which are typically estimated at 30-50% of average wage rates, and reduced external costs (congestion, accident risk and pollution). Assuming that a typical chauffeuring trip involves 5 miles of vehicle travel at 25¢ per mile in vehicle costs, and 20 minutes of travel time valued at $9.00 per hour, this totals $4.25 per trip or $0.85 per vehicle-mile. The previous sections on Option and Equity values describe methods for valuing increased independence to non-drivers.

Congestion Reduction

Traffic congestion costs consist of the incremental travel time, vehicle operating costs, stress and pollution emissions that a vehicle imposes on other road users (Litman 2009). Walking and cycling improvements can help reduce traffic congestion in several ways. Poor walking and cycling conditions force people to drive for even short trips. In urban areas a significant portion of automobile traffic (often 10-30%) consists of short trips that could shift to non-motorized travel (Litman 2010). In addition, walking and cycling improvements reduce traffic congestion by supporting public transit travel.

Since both non-motorized travel and traffic congestion tend to increase with city size and density, simplistic analysis can imply that increased non-motorized travel increases congestion. Increased density tends to increase congestion intensity (measured by roadway level-of-service rating), but by reducing travel distances and improving alternative modes, it tends to reduce per capita congestion delay ("Congestion Costs," Litman 2009). Comparing similar size cities indicates that per capita congestion delays decline as non-motorized mode share increases, as summarized in the following table. For example, New York City with 6.8% NMT mode share has about half the per capita congestion delay as Los Angeles with 3.4% NMT mode share. Philadelphia with 4.3% mode share has much less per capita congestion delay than Miami, which also has lower NMT mode share. Of course, other factors, such as public transit service quality, may affect these differences, but since non-motorized and public transport are complements, improving NMT helps reduce congestion both directly, and indirectly by supporting transit use (Litman 2004).

Table 10 **Congestion Delay** (TTI 2007 and American Community Survey Data)

	New York	Los Angeles	Philadelphia	Miami	Boston	Dallas
Population	17,799,861	11,789,487	5,149,079	4,919,036	4,032,484	4,145,659
NMT mode share	6.8%	3.4%	4.3%	2.2%	5.7%	1.3%
Per Capita annual congestion delay	46 hrs.	72 hrs.	38 hrs.	50 hrs.	46 hrs.	58 hrs.

Of comparable size cities, those with more NMT tend to have less per capita congestion delay.

Non-motorized travel can contribute to traffic congestion, although this is generally minimal. Only at intersections or if roads lack sidewalks does walking cause traffic delay, and these impacts are generally less than if the same trips were made by automobile. In some situations bike lanes substitute for vehicle traffic lanes, which may increase traffic congestion if they receive little use, but in other cases bike lanes increase total roadway capacity. For example, New York City's Prospect Park West carried more people after a "road diet" converted a traffic lane to a bike path (NYDOT 2010).

To analyze bicycle congestion impacts, road conditions are divided into four classes:

1. *Uncongested roads and separated paths*. Bicycling in these conditions causes no traffic congestion.
2. *Congested roads with space for bicyclists*. Bicycling on a road shoulder (common on highways), a wide curb lane (common in suburban and urban areas), or a bike lane contributes little traffic congestion except at intersections where turning maneuvers may be delayed. Table 11 summarizes these impacts.

Table 11 **Passenger-Car Equivalents for Bicycles by Lane Width** (AASHTO 1990)

	< 11 ft. Lane	11-14 ft. Lane	> 14 ft. Lane
Riding With Traffic	1.0	0.2	0.0
Riding Against Traffic	1.2	0.5	0.0

3. *Narrow, congested roads with low speed traffic.* Bicycling on a narrow, congested road where cyclists can keep up with traffic (common on urban streets) probably causes less congestion than an average car due to bicycles' smaller size.
4. *Narrow, congested roads with moderate to high speed traffic*. Bicycling on a narrow, congested road where the rider cannot keep up with traffic and faster vehicles cannot easily pass can cause significant congestion delay.

Congestion is reduced when motorists shift to bicycling under the first three conditions. Only under condition 4 does a shift fail to reduce congestion. This represents a small portion of cycling travel because most bicyclists avoid riding under such conditions if possible, and bicycling is forbidden altogether on urban freeways.

Traffic congestion tends to maintain equilibrium; it becomes severe enough to cause some peak-period travelers to shift time, route, mode or destination. A small reduction in vehicle trips may do little to reduce long-term congestion since reduced vehicle trips will be filled by latent demand. However, improving travel by alternative modes can reduce the point of congestion equilibrium. If alternatives are slow, inconvenient or costly, travelers will drive even if congestion is severe. If alternatives are good travelers will more readily shift mode. Although most research on this subject concerns public transit service, non-motorized modes can have similar impacts, alone and in conjunction with transit (Litman 2004; Aftabuzzaman, Currie and Sarvi 2010). As a result, improving non-motorized travel can help reduce congestion costs.

Evaluation methods: Reductions in urban-peak automobile travel tend to reduce traffic congestion. Various studies estimate that congestion costs average 10¢ to 35¢ per urban-peak vehicle mile, with lower values under urban off-peak and rural travel conditions (Litman 2009; TTI 2007). SQW (2007) estimates that a traveler shifting from driving to cycling 160 annual trips averaging 3.9 kms reduces congestion costs to other road users £137.28 (£0.22 per km) in urban areas and £68.64 (£0.11 per km) in rural environments.

Barrier Effect

The *barrier effect* (also called *severance*) refers to the travel delay that vehicle traffic imposes on non-motorized modes ("Barrier Effect," Litman 2009). It is equivalent to traffic congestion imposed on non-motorized vehicles (most congestion cost estimates ignore non-motorized travel impacts). This reduces non-motorized accessibility, and causes shifts from non-motorized to motorized travel which increases external costs such as traffic and parking congestion. Various transport planning decisions affect the barrier effect:

- Highway expansion increases the barrier effect by widening roadways and increasing vehicle traffic volumes and speeds.
- Traffic calming, road diets, and traffic speed reductions tend to reduce the barrier effect.
- Mobility management strategies that reduce total vehicle traffic volumes, such as more efficient road, parking, insurance and fuel pricing, tend to reduce the barrier effect.
- Non-motorized improvements, such as paths and sidewalks separated from roadway, improved crosswalks, and sometimes pedestrian overpasses, can reduce the barrier effect.
- Land use changes that reduce the need for pedestrians and cyclists to cross major roadways (such as locating schools and shops within residential neighborhoods rather than where residents much cross or travel along a busy highway) can reduce barrier effects.

Conventional transport planning generally ignores these impacts. For example, roadway widening is often described simply as a transport *improvement*, which recognizes the reduced delay to motorists but ignores the additional delay that wider roads and increased motor vehicle traffic imposes on non-motorized travel. More comprehensive, multi-modal evaluation recognizes the tradeoffs involved in such decisions.

Evaluation methods: The barrier effect imposes direct costs on pedestrians and cyclists, and indirect costs by reducing walking and cycling activity and increasing motorized travel. Analysis methods in this report can quantify the incremental costs of such changes. For example, reducing the barrier effect allows more children to walk and bicycle to school rather than being chauffeured by parents, which increases physical fitness and health, reduces vehicle and chauffeuring costs, and reduces traffic congestion, road and parking facility costs, accident risk and pollution emissions.

Swedish, Danish and UK Department for Transport roadway evaluation models quantify the barrier effect for specific situations by estimating walking and cycling demand assuming no barrier exists, based on location trip generators (homes, schools, shops, parks, transit stops, etc.). These models then calculate the delay imposed on non-motorized travelers taking into account roadway width, traffic volumes and speeds, share of trucks, and quality of pedestrian crossings ("Barrier Effect," Litman 2009; DfT 2009; TRB 2008).

Increased travel costs can be monetized using the same methods and travel time values used to calculate motorized traffic congestion costs. Barrier effect costs are typically estimated to average 0.5¢ to 1.5¢ per urban automobile vehicle-mile. These costs are much higher if more comprehensive analysis is applied, which considers the total costs of increased vehicle ownership and use. For example, if a busy road between homes and schools makes non-motorized travel so difficult that households purchase second cars to chauffeur children (even though they would prefer to walk or bicycle), the additional costs may total thousands of dollars annually, including vehicle expenses and external costs.

Roadway Costs Savings

Roadway facility costs average about $700 annually per capita in the U.S., about half of which is funded through general taxes rather than user fees (FHWA 2008; Subsidy Scope 2009). Although roads are used by both motorized and non-motorized modes, walking and cycling require less road space and impose less wear, and so cost less per mile of travel. Sidewalks and paths are relatively inexpensive to build and maintain. Most cities have about similar miles of roads and sidewalks/paths, but spend 5 to 10 times as much money on motorized than non-motorized facilities. Providing non-motorized lanes sometimes require wider roads, but in most cases bicycle lanes can be developed using existing curb or shoulder space, parking lanes, or by narrowing traffic lanes. As a result, shifting travel from motorized to non-motorized modes generally reduces total roadway costs.

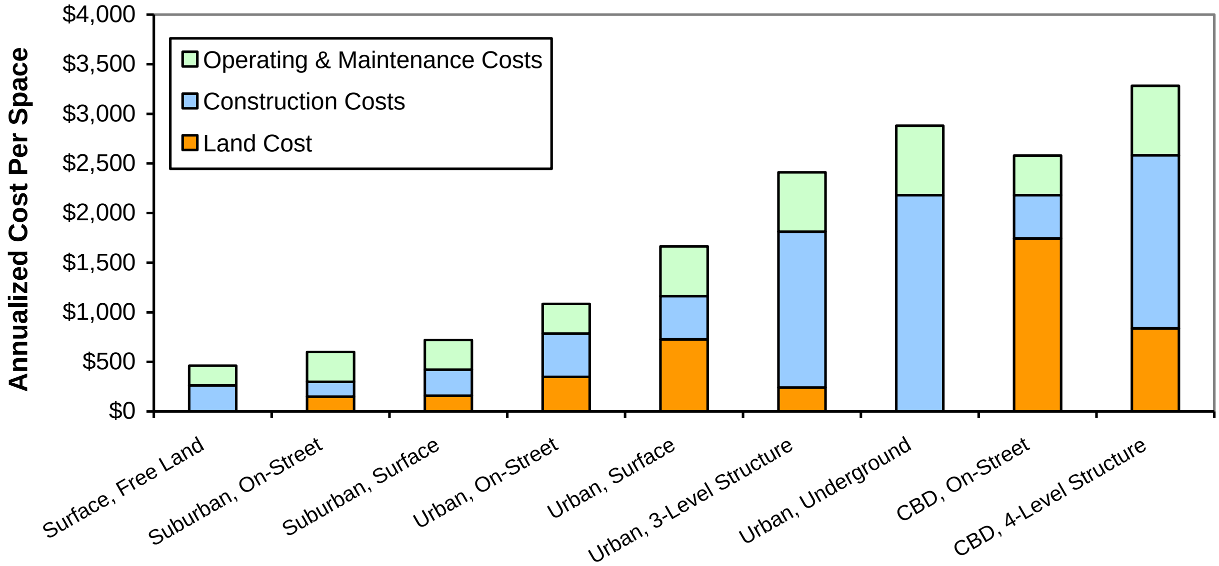
Evaluation methods: Roadway construction and maintenance costs are a function of vehicle size, weight, speed, and, in some regions, studded tire use, as described in roadway cost allocation literature (FHWA 1997). Roadway costs average about 4¢ per mile for automobiles, and more for heavier vehicles (FHWA 1997; "Roadway Costs," Litman 2009). Cycling generally imposes much smaller roadway costs. Shifts from driving to walking or bicycling provide roadway facility and traffic service cost savings of approximately 5¢ per mile for urban driving and 3¢ per mile for rural driving, including indirect travel reductions leveraged by non-motorized transport improvements.

Parking Cost Savings

Vehicle travel requires parking facilities at origins and destinations. In typical North American urban areas there are estimated to be more than three off-street parking spaces (one residential and two non-residential) and several on-street spaces per vehicle ("Parking Cost" Litman 2009). Spaces per vehicle tend to be higher in suburban and rural areas, where each destination supplies all its own parking, and lower in urban areas where parking tends to be shared. A typical urban parking space has land and construction costs worth $5,000 to $50,000, resulting in annualized costs (including land, construction and operating expenses) ranging from about $500 to more than $3,000, as illustrated in the graph below.

Bicycle parking costs much less. Typically 10-20 bicycles can be stored in the space required for one automobile, and bicycles are often stored in otherwise unused areas. Pedestrians require no parking facilities (except umbrella stands and coat racks).

Figure 7 **Typical Parking Annualized Costs per Space** (Litman 2009)[2]



This figure illustrates estimated annualized costs per parking space. These costs can vary significantly depending on factors such as local land values.

In the short run, reductions in automobile travel may simply result in unoccupied parking spaces, but eventually most parking facilities have opportunity costs: reduced parking demand allows property owners to avoid expanding parking supply, or they can rent, sell or convert parking facilities to other uses.

Evaluation methods: Parking costs are not generally affected by trip length, so this cost is measured per trip rather than per mile. Shifting from automobile to non-motorized travel is estimated to provide parking savings of $2-4 per urban-peak trip (a typical commute has $4-8 per day parking costs), $1-3 per urban off-peak trip, and about $1 per rural trip ("Parking Costs," Litman 2009).

[2] *Parking Cost, Pricing and Revenue Calculator*, VTPI (www.vtpi.org/parking.xls).

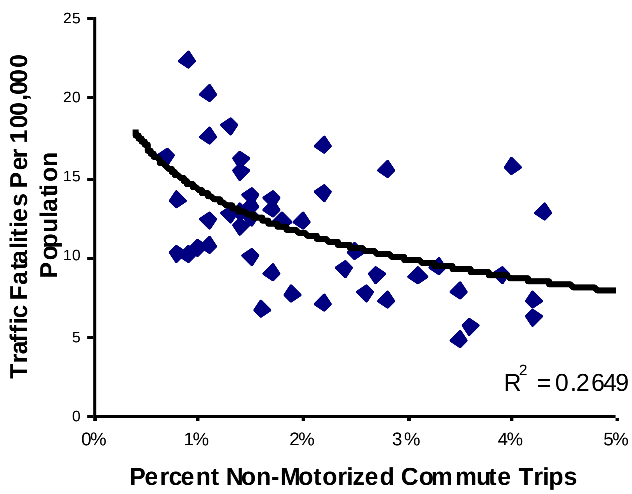
Traffic Safety Impacts

Crashes are among the largest transportation costs ("Crash Costs," Litman 2009; Vermeulen, et al. 2004). Although walking and cycling have higher per-mile casualty rates than automobile travel, shifting travel from automobile to non-motorized modes tends to reduce total crash costs due to the following factors (WHO 2008):

1. Non-motorized travel imposes minimal risk to other road users.
2. In automobile-dependent communities walking and cycling casualty rates are relatively high because many users are children and people with disabilities, who tend to have high risk factors. A pedestrian or cyclist who takes basic precautions such as observing traffic rules and wearing a cycling helmet tends to have much lower than average risk.
3. Per-mile and per capita traffic casualty rates tend to decline as walking and cycling activity increases in a community, because drivers become more cautious and communities invest more in non-motorized safety improvements where there are more pedestrians and cyclists.
4. As non-motorized travel increases, total per capita mileage declines. A local walking trip often substitutes for a longer automobile trip. People who rely on non-motorized modes tend to travel fewer total annual miles than motorists.
5. Some walking and cycling promotion programs include education and facility improvements that reduce participants' per-mile pedestrian and bicycle crash rates.
6. The substantial health benefits of walking and cycling (described earlier) more than offset any increase in crash risk, so longevity tends to increase with non-motorized transport.

Empirical evidence indicates that shifts from driving to non-motorized modes tend to reduce total per capita crash casualty rates in an area, as indicated in figures 8 and 9. For example, walking and cycling travel rates are high in Germany and the Netherlands yet the per capita traffic death rates are relatively low (Pucher and Dijkstra 2000; Fietsberaad 2008; ABW 2010). Pedestrian fatalities per billion km walked are less than a tenth as high, and bicyclist fatalities are only a quarter as high, as in the United States.

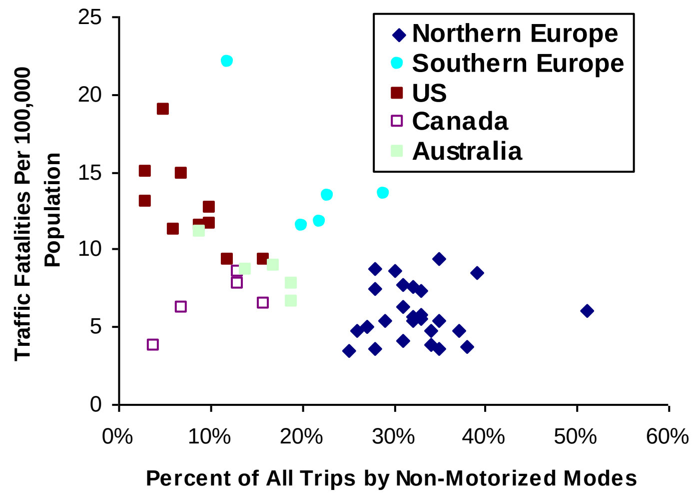
Figure 8 **Traffic Fatalities Vs. Non-Motorized Transport** (US Census 2000)



Per capita traffic fatality rates tend to decline as non-motorized travel increases. This is called "safety in numbers," (Jacobsen 2003)

Jacobsen (2003) found that overall collision rates decline with increased non-motorized travel. He calculates that the number of motorists colliding with pedestrians and cyclists increases at roughly 0.4 power of the number of people walking or cycling (e.g., doubling NMT travel in a community will increase pedestrian/cycling injuries by 32%), and the risk of a pedestrian being hit declines 34% if walking and cycling double in an area. Robinson (2005) found similar results using Australian data: doubling bicycle travel reduces cyclist risk per kilometer by about 34%; and conversely, halving bicycle travel increases risk per kilometer about 52%.

Figure 9 **Traffic Fatalities Vs. Non-Motorized Transport** (Kenworthy and Laube 2000)



Per capita traffic fatalities tend to decline as the portion of non-motorized urban travel increases.

The *Copenhagen Center for Prospective Population Studies* found a substantial decrease in the risk of death among those who spent 3 hours per week commuting to work by bicycle compared to those who did not commute by bicycle (Andersen, et al. 2000). This and other studies indicate a net increase in longevity as walking and cycling activity increases (Cavill, et al. 2008).

Evaluation methods: Various studies indicate that motor vehicle external accident costs average 2¢ to 12¢ per automobile mile, depending on driver and travel conditions, and the scope of costs considered ("Crash Costs," Litman 2009; van Essen, et al. 2007; Vermeulen, et al. 2004). Net safety benefits of shifts from automobile to non-motorized travel (reductions in motor vehicle risk minus increases in risks to non-motorized travelers) are estimated to average 5¢ per urban peak mile, 4¢ per urban off-peak mile, and 3¢ per rural mile. Targeted safety improvements can reduce walking and cycling risk, for example by separating non-motorized and motorized traffic, teaching and enforcing traffic safety rules, reducing vehicle traffic speeds, and reducing total vehicle travel.

Energy Conservation
Motor vehicle production and use consume large amounts of natural resources, particularly energy such as petroleum and coal (Chester and Horvath 2008). This consumption imposes various external costs, including economic and national security impacts from dependence on imported petroleum, plus environmental and health damages from pollution. As a result, resource conservation can provide various benefits (NRC 2009).

Non-motorized transport can provide relatively large energy savings because it tends to substitute for short urban trips that have high emission rates per mile due to cold starts (engines are inefficient during the first few minutes of operation) and congestion. As a result, each 1% shift from automobile to non-motorized travel typically reduces fuel consumption 2-4% (Komanoff and Roelofs 1993). In addition, as previously described, non-motorized transport tends to have leverage effects, so comprehensive programs to improve walking and cycling can provide additional energy conservation benefits.

Evaluation methods: Petroleum consumption external costs are estimated to be 1-4¢ per vehicle-mile ("Resource Consumption External Costs," Litman 2009; NRC 2009). Relatively high values are justified because non-motorized travel substitutes for short urban trips in which motor vehicles are fuel inefficient due to cold starts and congestion.

Pollution Reduction
Motor vehicle production and use produce air, noise and water pollution which harm people, agricultural and the natural environment (Chester and Horvath 2008). Some pollutants, such as noise, carbon monoxide and particulates, have local impacts so their costs vary depending on where emissions occur, while others, such as ozone, methane and carbon dioxide, have regional and global impacts (Litman 2009). Walking and cycling produce virtually no pollution. Per mile emission reductions tend to be relatively large when non-motorized modes substitute for short urban trips which have high emission rates due to cold starts and congestion. Pedestrians and cyclists are exposed to vehicle pollution, although no more than motor vehicle occupants (Frank, et al. 2010).

Estimated Benefits: Various studies quantify and monetize motor vehicle pollution damages, but many of these estimates include only a limited portion of total pollution costs. For example, some consider ozone, CO and NOx damages but ignore particulate and air toxic damages, so total costs are higher than most published estimates (van Essen 2004). Automobile air, noise and water pollution costs are typically estimated to average 2¢ to 15¢ per vehicle-mile, with lower-range values in rural conditions and higher values under congested urban conditions, but relatively high values can be justified to reflect the tendency of walking and cycling to reduce short urban trips (Delucchi 2007; Litman 2009; Vermeulen, et al. 2004). A British study estimates that shifts from driving to non-motorized modes provide air pollution reduction benefits of £0.11 in urban areas and £0.02 in rural areas, with higher values for diesel vehicles (SQW 2007). A reasonable estimate is 10¢ per mile for urban-peak driving, 5¢ for urban off-peak and 1¢ for rural driving.

Land Use Impacts

Transportation planning decisions often affect land use patterns. Decisions that favor automobile travel generally increase transport infrastructure land requirements (particularly roads and parking) and encourage lower-density, dispersed development (*sprawl*). Decisions that favor walking, cycling and public transit generally reduce transport land requirements and lead to more compact, mixed development (*smart growth*). These land use patterns have many economic, social and environmental impacts (CTE 2008; "Land Use Impacts," Litman 2009).

Many communities have planning objectives such as community redevelopment, urban infill, reduced impervious surface coverage, more compact and mixed development, and openspace (habitat, park and farmland) preservation. Table 12 lists various smart growth benefits.

Table 12 **Smart Growth Benefits** (Burchell, et al. 2002; Litman 1995)

Economic	Social	Environmental
Reduced development and public service costs Consumer transportation cost savings Economies of agglomeration More efficient transportation	Improved transport options, particularly for nondrivers Improved housing options Community cohesion	Greenspace and habitat preservation Reduced air pollution Energy conservation Reduced water pollution Reduced "heat island" effect

This table summarizes various benefits to society of smart growth development patterns.

Non-motorized improvements tend to support smart growth. This occurs because walking and cycling require less space than motorized travel, and because as slower modes they encourage compact and mixed development. Improving walking and cycling conditions tend to enhance the *public realm* (public spaces where people naturally interact) and increase *community cohesion* (positive interactions among residents), creating more secure and livable communities (Appleyard 1981; Forkenbrock and Weisbrod 2001). Rogers, et al. (2010) use a case study approach to evaluate the impacts of walkable social capital. Residents living in neighborhoods of varying built form and thus varying levels of walkability in three communities in New Hampshire were surveyed about their levels of social capital and travel behaviors. The results indicate that levels of social capital are higher in more walkable neighborhoods.

The space requirements of different modes can be compared using *time-area*: the product of area and times. Space requirements tend to increase with vehicle size and speed since faster vehicles need more *shy distance* (clearance from other objects). For example, at 30 miles-per-hour (mph) an automobile requires about 12.5 feet of lane width and 80 feet of lane length, totaling about 1,000 square feet, but at 60 mph this increases to 15 feet of width and 150 feet of length, totaling 2,250 square feet. Table 13 compares time-area requirements of various modes for a 20-minute commute with 8 hours of parking for automobiles and bicycles. This indicates that driving requires approximately 15 times as much space as bicycling, and about 100 times as much as walking. In practice, automobile transport does not always increase roadway land requirements 15-100 times (even cities built before the automobile often had wide roads to accommodate wagons and provide sunlight), but non-motorized transport does tend to significantly reduce transport facility land requirements.

Table 13 **Time-Area Requirements Per Commuter** (based on Bruun and Vuchic 1995)

Mode	Standing/ Parking	8 hr. Parking	Road Space	Per 20-minute Trip	Total (Parking & 2 Commutes)
	Sq. Ft.	*Sq. Ft.-Min.*	*Sq. Ft.*	*Sq. Ft.-Min.*	*Sq. Ft.-Min.*
Pedestrian	5	*0*	20	*400*	800
Bicycle	20	*9,600*	50	*1,000*	11,600
Bus	20	*0*	75	*1,500*	3,000
Automobile – 30 mph	300	*144,000*	1,000	*20,000*	184,000
Automobile – 60 mph	300	*144,000*	2,250	*45,000*	214,000

This table compares time-area requirements for parking and road space measured in square-foot-minutes (square feet times number of minutes) for 20-minute commutes by various modes.

Evaluation methods: These impacts are potentially large. More compact, mixed, connected land use development can provide thousands of dollars in per capita annual savings and benefits, including infrastructure savings, transport cost savings, economic productivity, social benefits, and improved environmental quality (CTE 2008; "Land Use Impacts," Litman 2009). However, land use impacts can be difficult to evaluate because they are numerous (analyses often focus on a few but overlook others), some are difficult to quantify and monetize; and there are often several steps between a planning decision and its ultimate land use impacts. To evaluate these impacts:

1. Identify how a planning decision affects land use patterns, including direct impacts of transport facilities, and indirect impacts from changes in development patterns. This requires defining a base case (what would otherwise occur, if the proposed policy or project is not implemented).

2. Second, describe, and to the degree possible, quantify these land use changes, including differences in impervious surface coverage and associated stormwater and heat island effects, impacts on farming and wildlife habitat, changes in accessibility and travel activity (such as more vehicle travel), and resulting changes in energy consumption and pollution emissions.

3. Third, to the degree possible, monetize these impacts. For example, estimate economic and environmental costs of increased pavement and reduced openspace. Some effects can be monetized by assigning a dollar value per hectare of habitat lost to development, or each additional motor vehicle-mile generated by sprawl.

This type of analysis requires making numerous assumptions about impacts and values, and the results may overlook some impacts, such as community cohesion and agglomeration economies, because they are difficult to quantify. Such assumptions should be documented. It may be better to incorporate some impacts qualitatively, through descriptions and community involvement, rather than assigning a single total dollar value to total land use impacts (Louis Berger Inc. 1998).

Economic Development

Economic development refers to progress toward community economic goals such as increased employment, income, productivity, property values and tax revenues. Non-motorized transport can affect economic development in several ways (Buis 2000; Litman 2011; NCDOT 2004; Living Streets 2011; Walk Boston 2011):

- *Transport efficiency*. Walking and cycling improvements can increase transport system efficiency by reducing costs such as traffic congestion, road and parking facility costs, and accident damages, as described previously in this report. To the degree that this reduces costs to commuters, businesses and governments it reduces production costs, which increases economic productivity and competitiveness.
- *Labor productivity.* Walking and cycling improvements (alone and with public transit improvements) tends to improve access to education and employment opportunities, particularly by non-drivers, increasing the quantity and quality of the lower-wage labor pool, which can reduce business costs and increase productivity and competitiveness. Active transport can also increase labor productivity by increasing worker fitness.
- *Land use efficiency.* As previously described, walking and cycling can support more accessible and compact land use patterns, which can provide various accessibility benefits, agglomeration efficiencies, and resource cost savings
- *Consumer expenditures.* Impacts on consumer spending, particularly vehicles and fuel expenditures, which affect regional economic activity.
- *Supports specific industries*. Certain industries benefit from improved walking and cycling conditions, including bikeshops, tourism (Beeton 2003; Tourism Vermont 2007; Grabow, Hahn and Whited 2010), retail activity, construction (Garrett-Peltier 2010), and real estate development that highlights livability (NBPC 1995; LAB 2009).

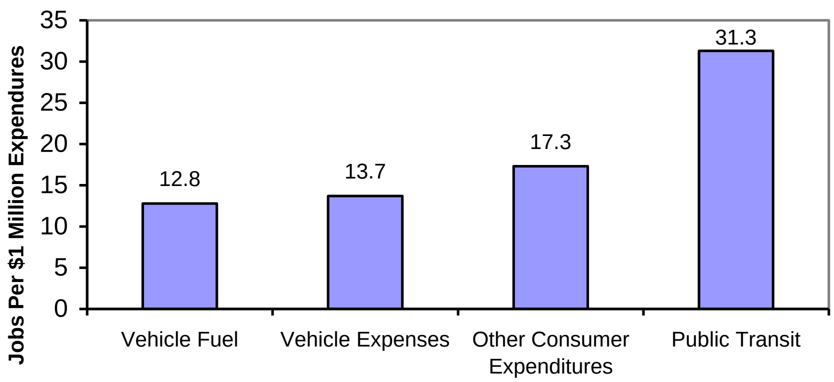
Improving walking and cycling conditions can help create more efficient transport system and more accessible land use development patterns, particularly in conjunction with complementary strategies such as public transit improvements and smart growth development policies. By improving accessibility and providing savings to commuters, businesses and governments, they tend to increase economic productivity. For example, businesses benefit if shifts to walking, cycling and public transit reduce freight and service vehicle delays, or the costs to businesses of providing employee and customer parking.

In automobile-dependent areas, non-drivers may lack access to jobs, and commuting costs typically increase by $100-300 per month, which drives up wages. Improving affordable transport options tends to expand the labor pool and reduce high commuting cost wage premiums, increasing productivity and competitiveness, particularly for industries that require numerous lower-wage employees, such as offices, hospitality and light manufacturing. Businesses also benefit from non-motorized commuting by improved employee fitness and health, which increases worker productivity, reduces sick leave, and lowers healthcare costs. A meta-analysis of employee wellness programs, indicates an average benefit/cost ratio of 6.3/1 (Chapman 2005), suggesting large potential benefits to businesses from improved walking and cycling.

High quality walking and cycling conditions tends to attract retail customers (Hass-Klau 1993; European Commission 1999). Improved walking and cycling conditions tends to increase local property values and support local development (Bartholomew and Ewing 2011; Cortright 2009; Krizek et al. 2006; LGC 2001). Pivo and Fisher (2010) found that office, retail and apartment values increased 1% to 9% for each 10-point increase in the 100 point WalkScore index. Buchanan (2007) found 5.2% higher residential property values and 4.9% higher retail rents in London neighborhoods with good walking conditions. Property values also tend to increase with proximity to public trails (NTTP 2005; Karadeniz 2008; Racca and Dhanju 2006). Retailers sometimes oppose non-motorized improvements, such as streetscaping and bicycle lanes, because they assume that motorists are better customers than pedestrians and cyclists, but this is often untrue (Sztabinski 2009; TA 2006). Bicycle parking is space efficient and so generates about five times as much spending per square meter as car parking (Lee and March 2010).

Although automobile and fuel production are major domestic industries, a large and growing portion of these products are imported. Since they are capital intensive with relatively little labor input, overall national employment and business activity increase as consumers shift expenditures from vehicles and fuel to other common consumer goods, as indicated in Figure 10. As a result, reducing vehicle and fuel spending tends to support economic development.

Figure 10 **Employment Impacts per $1 Million Expenditures** (Chmelynski 2008)



Fuel and vehicle expenditures produce fewer domestic jobs than most other consumer expenditures, and far less than spending on public transit.

Because non-motorized facility construction is relatively labor intensive it tends to create more employment and regional business activity than other capital projects. For example, analysis by Garrett-Peltier (2010) found that a $1 million spent to build bike lanes directly creates 11.0 to 14.4 total jobs, compared with approximately 7.0 total jobs created by the same expenditure on roadway projects.

Some of these impacts are economic transfers, in which one group benefits at another's expense, so their analysis depends on perspective and scale. For example, improvements in one commercial center may attract customers from other commercial centers without increasing total regional economic activity. However, some impacts are true efficiency gains: resource savings that increase overall economic productivity.

Evaluation methods: Non-motorized transport economic impacts depend on specific conditions. In many situations, non-motorized improvements can provide significant economic development benefits, in addition to the other benefits described in this report. The following factors tend to maximize non-motorized economic development benefits:

- Where there is significant demand for non-motorized travel.
- Where non-motorized improvements are integrated with complementary strategies, such as public transit improvements, efficient pricing, and smart growth land use policies, which increase overall transport system efficiency, reduce congestion and parking costs, and reduce consumer expenditures on vehicles and fuel.
- Where non-motorized improvements, in conjunction with other strategies, increase the labor pool for businesses that require large numbers of lower-wage employees.
- Where non-motorized improvements respond to local business needs, such as creating more attractive commercial centers and supporting bicycle tourism.

Table 14 indicates methods that can be used to evaluate these impacts, and ways that non-motorized improvements can maximize economic development benefits.

Table 14 **Economic Impact Analysis** (Litman 2011)

Economic Impact	Evaluation Methods	Maximizing Benefits
Transport efficiency –transport cost savings, such as reduced congestion, facility costs, and accident damages.	Measure cost savings, as described in this report, and estimate the degree these savings benefit producers (commuters, businesses and governments).	Integrate non-motorized improvements with complementary strategies such as public transit improvements, efficient pricing, and smart growth land use policies.
Labor productivity – improved worker access to education and employment opportunities.	Degree that improved affordable modes improve access to education and employment.	Improvements targeting disadvantaged workers in areas where industries require large numbers of lower-wage employees. Improve other affordable modes, particularly public transit.
Land use efficiency – impacts on development patterns, and their effects on accessibility and sprawl-related costs.	Analyze land use impacts (changes in density, mix, connectivity, etc.), and resulting costs or savings to businesses and governments.	Integrate non-motorized improvements with smart growth land use policies.
Consumer expenditure impacts – impacts on consumer expenditures, particularly on vehicles and fuel.	Estimate vehicle ownership and travel changes, and resulting consumer expenditure changes. Use Input/Output analysis to quantify economic impacts.	Non-motorized improvements help reduce the need to own and use motor vehicles. Integrate with complementary strategies such as public transit improvements, efficient pricing, and smart growth land use policies.
Support for specific industries – retail centers, bikeshops, adventure tourism, etc.	Identify ways that non-motorized improvements help support local and regional industries.	Non-motorized improvements implemented in response to local business needs.

Non-motorized transportation planning decisions can affect economic development in various ways. Evaluation should consider, and if possible quantify, all of these impact categories. Non-motorized planning can be designed to maximize economic development benefits.

Non-Motorized Versus Automobile Access – Economic Development Impacts

Planning decisions sometimes involve tradeoffs between non-motorized and automobile access:

- *Streetscaping* and *road diets* often reduce general traffic lanes to provide bike lanes and wider sidewalks.
- Traffic calming and speed control programs reduce motor vehicle traffic speeds, in part to increase non-motorized travel safety and comfort.
- Some bike lanes and sidewalk widening require eliminating automobile parking lanes.

Local merchants sometimes fear they will lose business if automobile access and parking is reduced. Such projects are often described as good for the environment but bad for the economy, but this is not necessarily true. In many cases, improving access by alternative modes and streetscaping supports local economic development overall.

During the 1970s several North American cities had negative experiences with pedestrianized city center streets; they became unattractive to customers and business activity declined. However, appropriate pedestrian improvements can increase retail area attractiveness, particularly in urban commercial districts and resort areas ("Streetscaping," VTPI 2009). A study of ten commercial districts in London, England found street design improvements typically increase residential and commercial property values about 5%, reflecting the value people place on an attractive street environment and the contribution it makes to local commercial activity (CABE 2007). In a survey of urban retail business owners, Drennen (2003) found that 65% consider a local traffic calming program to provide overall economic benefits and support program expansion, compared with 4% that consider it overall negative. Conversion of San Francisco's Central Freeway into pedestrian- and bicycle-friendly Octavia Boulevard significantly increased local commercial activity and property values (CNU 2009).

In some cases, total roadway capacity increases after general traffic lanes are converted to bus or bike paths due to a combination of smoother traffic flow after a road diet, and a significant increase in bicycle travel (NYDOT 2010). Because bicycle parking is space efficient it generates about five times as much spending per square meter as automobile parking (Lee and March 2010). In urban areas, a significant portion of retail customers arrive by walking and cycling (TA 2010). A study of customers to urban retail businesses in Toronto, Canada found (Sztabinski 2009):

- About 90% of patrons arrive by walking, cycling or public transit.
- Patrons arriving by foot and bicycle visit the most often and spend the most money per month.
- Patrons would prefer a bike lane to widened sidewalks at a ratio of almost four to one.
- Even during peak periods no more than 80% of metered parking spaces on the street are occupied.
- The reduction in on-street parking supply from a bike lane or widened sidewalk could be accommodated in the area's off-street municipal parking lots.

Negative impacts can often be addressed. Improved parking management can often off-set a loss of parking spaces, for example, by indicating where additional automobile parking is available nearby, and by encouraging local commuters and customers to arrive by alternative modes.

This indicates that in many situations, walking and cycling improvements are cost effective investments that support local economic development, particularly if implemented in conjunction with complementary transport and land use improvements.

Costs

Various costs associated with non-motorized transportation are discussed below.

Facility Costs

Bicyclepedia (www.bicyclinginfo.org/bikecost) and the report, *Guidelines for Analysis of Investments in Bicycle Facilities* (Krizek, et al. 2006), provide information on the costs of facilities such as paths, bike lanes, intersection improvements and bicycle parking. The table below summarizes some of these costs, although more specific cost data should be used when available. Dutch cities typically spend €10 to €25 annually per capita on cycling facilities, which is considered high but increases cycling activity (Fietsberaad 2008).

Table 15 **Typical Facility Costs** (FDOT 2003; Zegeer, et al 2002; Krizek, et al. 2006)

Measure	Typical Costs (2000 U.S. Dollars)
Bike lanes	$10,000-50,000 per mile to modify existing roadway (no new construction).
Bicycle parking	$50-500 per bicycle for racks and lockers
Center medians	$150-200 per linear foot
Curb bulbs	$10,000-20,000 per bulb
Marked crosswalk	$100-300 for painted crosswalks, and $3,000 for patterned concrete.
Path (5-foot asphalt)	$30-40 per linear foot
Path (12-foot concrete)	$80-120 per linear foot
Pedestrian refuge island	$6,000-9,000, depending on materials and conditions.
Sidewalks (5-foot width)	$20-50 per linear foot
Speed humps	$2,000 per hump
Traffic signals	$15,000-60,000 for a new signal
Traffic signs	$75-100 per sign.
Traffic circles	$4,000 for landscaped circle on asphalt street and $6,000 on concrete street.

This table summarizes examples of non-motorized transport facility costs. Of course, costs may differ significantly from these values depending on specific conditions.

Vehicle Traffic Impacts

Some non-motorized improvements can cause vehicle traffic delays. For example, traffic calming and speed reductions, converting traffic lanes to bike lanes or wider sidewalks, and more pedestrians and bicyclists crossing roadways, can reduce vehicle travel speeds. Similarly, converting parking lanes to bike lanes or wider sidewalks can reduce the ease of finding a parking space.

Evaluation methods: These costs can be estimated using the methods used to calculate other congestion delays, as described earlier in this report. These costs may be partly offset by direct benefits to motorists (traffic calming and speed reductions tend to reduce automobile accident risk), and indirect benefits if walking and cycling improvements cause mode shifts from driving to alternative modes, which reduces vehicle traffic and parking congestion.

Equipment and Fuel Costs
Walking and cycling may require extra equipment and fuel. Functional shoes typically cost $100 per pair and last about 1,000 miles (about a year of normal use), or 10¢ per walk-mile, and the marginal cost is often smaller, since consumers often replace shoes before they wear out for aesthetic reasons. A $500 bicycle ridden 3,000 annual miles requires about $100 annual maintenance and lasts 10 years, which averages about 5¢ per mile cycled. Walking and cycling require food for fuel, which is more costly than gasoline per calorie, but the amounts are generally small (a 150 pound person burns 80 calories per mile of walking, about the energy in a slice of bread, and half that when cycling), and most people enjoy eating and consume too many calories, in which case food energy consumption is a benefit rather than a cost.

Evaluation methods: Walking and cycling equipment and fuel costs can be estimated based on typical shoe, bicycle and food costs. Many consumers have shoes and bicycles that are underused (people who walk to work do not necessarily spend more on shoes than people who drive, and many people have bicycles that could be ridden more annual miles with little additional cost) so the incremental cost of increased walking and cycling is often small. Because such analysis is not standardized, it is important to specify the assumptions used, such as types of shoes, bicycles and foods.

User Travel Time Costs
Travel time is one of the largest transportation costs, and since non-motorized modes tend to be slower than motorized modes, some analysts argue that walking and cycling are costly and inefficient. However, this is not necessarily true.

Non-motorized travel can be time competitive with driving for short trips: for walking up to a half-mile, which represents about 14% of total personal trips in the U.S.; for cycling up to three miles, which represents about half of total trips (Dill and Gliebe 2008; Litman 2010). Transport planning that improves pedestrian and cycling connectivity, and land use planning that creates more compact, mixed development increases the portion of trips by which non-motorized travel is time competitive.

Travel time unit costs (cents per minute or dollars per hours) vary significantly depending on conditions and preferences (Mackie, et al. 2003). Where walking and cycling conditions are unfavorable, travel time costs are high, but under favorable conditions costs are low or even negative: time spent walking or cycling is considered a benefit rather than a cost ("Travel Time Costs," Litman 2009). Many people value walking or cycling for enjoyment and exercise (it can reduce the need to spend special time exercising), and so will choose these modes even if they take longer than driving. Because walking and cycling are inexpensive travel modes, their *effective speed* (travel time plus time spent earning money to pay for transport) is often faster than driving (Tranter 2004). These factors are highly variable. A person may one day prefer walking and another day prefer driving. If people have high quality walk and cycling conditions they can choose the mode they consider best overall, taking into account all benefits and costs.

Evaluating Impacts: Various methods can be used to measure the value user place on their travel time (Litman 2009). Travel time is generally valued at 30-50% of prevailing wages, with lower values under favorable conditions and higher values under unfavorable conditions. If people choose non-motorized modes in response to positive incentives (improved walking and cycling conditions, or financial rewards) they must be better off overall (increased consumer surplus), even if their speeds decline.

Accident and Health Risk

Walking and cycling tend to have relatively high per kilometer crash casualty rates, which implies that policies and programs that increase active transport will increase crash costs. However, as described earlier, total per capita traffic crash and health risks tend to decline as non-motorized travel increases because:

- Average crash rates do not necessarily apply to a particular individual. A responsible pedestrian or cyclist who takes basic precautions, such as observing appropriate traffic rules, using lighting at night, and wearing a helmet can have much lower crash injury rates than overall average.
- Risk to other road users declines, particularly if higher-risk drivers (such as young males) shift to non-motorized modes.
- Per-kilometer pedestrian and cyclist crash injury rates tend to decline with increased use of these modes, called *safety in numbers* (Jacobsen 2003).
- More use of these modes justifies facility improvements and programs that increase safety.
- Walking and cycling provide fitness and health benefits that can more than offset incremental crash risk.

Evaluating Impacts: Comprehensive analysis described earlier in this report can be used to evaluate the incremental accident and health risks of specific walking and cycling programs, taking into account changes in risk to pedestrians and cyclists and to other road users.

Benefit and Cost Summary

Table 16 summarizes the various benefits and costs that can be considered when evaluating non-motorized transport impacts.

Table 16 **Summary of Non-Motorized Transport Benefits and Costs**

Impact Category	Description
Improve NMT Conditions	*Benefits from improved walking and cycling conditions.*
User benefits	Increased user convenience, comfort, safety, accessibility and enjoyment
Option value	Benefits of having mobility options available in case they are ever needed
Equity objectives	Benefits to economically, socially or physically disadvantaged people
Increase NMT Activity	*Benefits from increased walking and cycling activity*
Fitness and health	Increased physical fitness and health
Reduced Vehicle Travel	*Benefits from reduced motor vehicle ownership and use*
Vehicle cost savings	Consumer savings from reduced vehicle ownership and use
Avoided chauffeuring	Reduced chauffeuring responsibilities due to improved travel options
Congestion reduction	Reduced traffic congestion from automobile travel on congested roadways
Reduced barrier effect	Improved non-motorized travel conditions due to reduced traffic speeds and volumes
Roadway cost savings	Reduced roadway construction, maintenance and operating costs.
Parking cost savings	Reduced parking problems and facility cost savings.
Energy conservation	Economic and environmental benefits from reduced energy consumption.
Pollution reductions	Economic and environmental benefits from reduced air, noise and water pollution.
Land Use Impacts	*Benefits from support for strategic land use objectives*
Pavement area	Can reduce road and parking facility land requirements
Development patterns	Helps create more accessible, compact, mixed, infill development (smart growth)
Economic Development	*Benefits from increased productivity and employment*
Increased productivity	Increased economic productivity by improving accessibility and reducing costs
Labor productivity	Improved access to education and employment, particularly by disadvantaged workers.
Shifts spending	Shifts spending from vehicles and fuel to goods with more regional economic value
Support specific industries	Support specific industries such as retail and tourism
Costs	*Costs of improving non-motorized conditions*
Facilities and programs	Costs of building non-motorized facilities and operating special programs
Vehicle traffic impacts	Incremental delays to motor vehicle traffic or parking
Equipment	Incremental costs to users of shoes and bicycles
Travel time	Incremental increases in travel time costs due to slower modes
Accident risk	Incremental increases in accident risk

This table summarizes potential non-motorized transport benefits and costs.

There are many types of non-motorized policies and projects, which can have various travel impacts, resulting in various benefits and costs. Not every NMT improvement achieves every benefit, but most provide several. Table 17 summarizes factors to consider when evaluating non-motorized transport polices and projects. It indicates, for example, that improving recreational walking and cycling provides user benefits and health benefits. Improving mobility and accessibility for disadvantaged people tends to achieve equity benefits. Reducing automobile travel reduces various external costs. Of course, many NMT projects have all these travel impacts, and therefore help achieve all of these benefits.

Table 17 **Non-Motorized Transportation Evaluation Factors**

Category	Factors To Consider	Implications
User benefits	Does the project improve walking or cycling conditions? How much? How many current and additional users will benefit?	Improving NMT conditions benefits existing and new users. The greater the benefits and the more users, the greater the total user benefits.
Equity benefits	Does improve basic access (users ability to access essential services and activities)? Does it benefit physically, economically or socially disadvantaged people? How many and under what conditions?	The more it benefits disadvantaged people, the greater the social equity benefits.
Fitness and health benefits	Does it increase physical fitness? Will it cause a significant number of people to exercise more than they otherwise would?	More physical activity by otherwise sedentary people provides benefits.
Motor vehicle reduction benefits	Does it reduce automobile travel, directly or indirectly? What type and how much motor vehicle travel is reduced? Will it help reduce vehicle ownership?	The greater the reduction in motor vehicle travel, the greater the benefits. Benefits tend to be larger for urban-peak travel reductions. Reductions in automobile ownership tend to leverage additional savings and benefits.
Community development objectives	How will it affect land use and economic development patterns? Does it support strategic community development objectives, such as efforts to encourage use of alternative modes, smart growth development, or expand tourism?	The greater the impacts, and the greater the consistency with strategic planning objectives, the greater the total benefits.

This table summarizes factors to consider when evaluating a particular policy or project.

This type of analysis can also be applied in reverse. For example, if a new highway creates a barrier to non-motorized travel in an area, the same framework can be used to calculate the various costs, such as degraded walking and cycling conditions, reduced walking and cycling activity, shifts from non-motorized to motorized travel, and sprawled land use.

Various factors can affect the magnitude of these impacts:

- The amount of demand for walking and cycling activity, including latent demand (additional walking and cycling trips that people would make with improved NMT conditions).
- The magnitude of change, such as the degree that walking and cycling conditions improve. For example, adding sidewalks along a busy roadway, or providing an important shortcut for pedestrians and cyclists, can significantly improve walking and cycling on that corridor.
- The degree that a particular project is integrated with other complementary strategies. For example, non-motorized transport improvements tend to be particularly beneficial if implemented with public transit improvements (such as better walking and cycling access to transit stations), efficient pricing (such as more efficient road, parking, insurance and fuel pricing), and smart growth land use policies (such as zoning codes that allow more compact and mixed development, and efforts to increase affordable housing in walkable areas).
- The number and type of people affected. The more people affected, and the more they need or value walking and cycling, the greater the potential benefits.
- Any equity impacts caused by benefits or costs to disadvantaged people (e.g., improved access for people with disabilities, cost savings or other benefits to low income people).
- Increased physical fitness and health, particularly by otherwise sedentary people.
- Shifts in motor vehicle travel, and therefore impacts on congestion, road and parking facility costs, consumer costs, accidents, energy consumption, and pollution emissions. These impacts tend to be particularly large if urban-peak or drunk driving is reduced.
- Land use impacts can provide various benefits such as more compact and mixed land use, neighborhood redevelopment, habitat preservation. Their value depends on the magnitude and type of impacts, and how that aligns with community development objectives.

Table 18 illustrates a matrix that can be used to summarize the impacts and benefits of a particular NMT policy or project. For example, to evaluate sidewalk improvements, indicate how much it improves walking and cycling conditions and who benefits; how much it will increase NMT activity; how much it reduces automobile travel; and how much it will change land use patterns.

Table 18 **Non-Motorized Transportation Evaluation Framework**

	NMT Conditions	NMT Activity	Automobile Travel	Land Use
	Is walking and cycling easier or safer?	*Does walking or cycling activity increase?*	*Does automobile travel decline?*	*Does it strategic planning objectives?*
Describe impact				
How much				
Who is affected				

This table can help summarize the impacts and benefits provided by a particular policy or project.

The following tables indicate various types of impacts (benefits and costs) that can result from non-motorized transport improvements, and provides default values for many of these impacts, measured in mils per passenger-mile (one-thousandth of a dollar, measured $0.000). These are based on values described in this report, and from *Transportation Cost and Benefit Analysis* (Litman 2009). Where possible, these default values should be adjusted to reflect specific conditions.

Improved Non-Motorized Travel Conditions

Table 19 summarizes direct benefits that result from walking and cycling improvements. These values are multiplied times the number of person-miles of travel on the improved facility. These are measured in "mils" (a thousandth of a dollar) per passenger-mile.

Table 19 **Improving Walking and Cycling Conditions** (Per Person-Mile)

Impact Category	Urban Peak	Urban Off-Peak	Rural	Overall Average	Comments
User benefits	$0.250	$0.250	$0.250	$0.250	The greater the improvement, the greater this value.
Option value	$.035	$.035	$.035	$.035	Half of *diversity value*.
Equity objectives	$.035	$.035	$.035	$.035	Half of *diversity value*. Higher if a project significantly benefits disadvantaged people.

This table summarizes the estimated value of improved walking and cycling conditions.

Increased Non-Motorized Travel Activity

Table 20 summarizes typical benefit values, measured in cents per mile of travel of increased walking and cycling activity. Higher values may be justified if an unusually large number of users would otherwise be sedentary.

Table 20 **Increased Walking and Cycling Activity** (Per Passenger Mile)

Impact Category	Urban Peak	Urban Off-Peak	Rural	Overall Average	Comments
Fitness and health – walking	$0.500	$0.500	$0.500	$0.500	Benefits are larger if pedestrian facilities attract at-risk users.
Fitness and health – cycling	$0.200	$0.200	$0.200	$0.200	Benefits are larger if cycling facilities attract at-risk users.

This table summarizes the estimated fitness and health value of increased walking and cycling activity. Impacts are measured in "mils" (a thousandth of a dollar) per passenger-mile.

Reduced Automobile Travel

Table 21 summarizes typical benefit values, in cents per reduced motor vehicle-mile, including automobile travel shifted to non-motorized modes, and any additional vehicle travel reductions that result if improved walking and cycling conditions helps create more compact and mixed land use development.

Table 21 **Typical Values – Reduced Motor Vehicle Travel**

Impact Category	Urban Peak	Urban Off-Peak	Rural	Overall Average	Comments
Vehicle cost savings	$0.250	$0.225	$0.20	$0.225	This reflects vehicle operating cost savings. Larger savings result if some households can reduce vehicle ownership costs.
Avoided chauffeuring driver's time	$0.700	$0.600	$0.500	$0.580	Based on $9.00 per hour driver's time value.
Congestion reduction	$0.200	$0.050	$0.010	$0.060	
Reduced barrier effect	$0.010	$0.010	$0.010	$0.010	
Roadway cost savings	$0.050	$0.050	$0.030	$0.042	
Parking cost savings	$0.600	$0.400	$0.200	$0.360	Parking costs are particularly high for commuting and lower for errands which require less parking per trip.
Energy conservation	$0.030	$0.030	$0.030	$0.030	
Pollution reductions	$0.100	$0.050	$0.010	$0.044	

This table summarizes the estimated benefits of reduced motor vehicle travel.

Land Use Impacts

Table 22 summarizes various benefits to communities if increased walking and cycling, and associated reductions in automobile ownership and motor vehicle traffic, help create more compact, mixed land use development, which reduces sprawl-related costs.

Table 22 **More Walkable and Bikeable Community**

Impact Category	Urban Peak	Urban Off-Peak	Rural	Total	Comments
Reduced pavement	$0.010	$0.005	$0.001	$0.002	Specific studies should be used when possible.
Increased accessibility	$0.080	$0.060	$0.030	$0.051	Specific studies should be used when possible.

This table summarizes various benefits if walking and cycling improvements reduce impervious surface area and encourage more compact, mixed land use development patterns.

Economic Development Impacts

Table 23 lists various ways that non-motorized transport improvements can help support economic development (increased employment, productivity, property values, tax revenues, etc.). Because these are so variable, specific analysis is needed to quantify these impacts, so no specific default values are provided. Even if these impacts cannot be quantified, they can be described.

Table 23 **Economic Development Benefits**

Impact Category	Urban Peak	Urban Off-Peak	Rural	Total	Comments
Increased productivity					From transport cost savings to commuters, businesses and governments.
Labor productivity					From expanded labor pools, reduced commuting costs and improved employee fitness and health.
Spending shifts					From reduced consumer expenditures on vehicles and fuel.
Support specific industries					If NMT improvements support retail, tourism, or other local industries.

This table summarizes various economic development benefits from non-motorized transport improvements.

Non-Motorized Transport Costs

Table 24 summarizes typical costs of improving non-motorized conditions and increasing non-motorized travel.

Table 24 **Typical Values – Walking and Cycling Costs**

Impact Category	Urban Peak	Urban Off-Peak	Rural	Total	Comments
Facilities and programs					Highly variable.
Vehicle traffic impacts					Highly variable.
Equipment	$0.080	$0.070	$0.060		Depends on assumption, such as whether food consumption is a benefit or cost.
Travel time					Highly variable depending on conditions and user preferences.
Accident risk					

This table summarizes potential non-motorized transport benefits and costs.

Evaluating Specific Non-Motorized Improvements

This section describes examples of NMT evaluation.

Pedestrian Facility Improvements (Sidewalks, Paths and Crosswalks)

Pedestrian improvements tend to benefit existing and new users, increase walking activity, and reduce driving. Pedestrians may comfortably share roadspace with motor vehicles where traffic speeds and volumes are very low (less than 12 miles per hour and fewer than 30 vehicles during peak hour, sometimes called *naked streets*), elsewhere, sidewalks, paths and crosswalks are important, particularly for vulnerable pedestrians such as children and people with disabilities. Increased walking tends to improve public fitness and health. Since physically and economically disadvantaged people often depend on walking, pedestrian improvements tend to provide option and equity value.

Pedestrian facilities tend to have network effects so benefits increase as the network expands. A short, isolated length of sidewalk may provide minimal benefit, while a link that connects two otherwise isolated sidewalk networks, or provides a shortcut (such as connecting two cul de sacs) can provide large benefits. Pedestrian improvements can have leverage effects: increases in walking cause proportionately larger reductions in vehicle travel. For example, Guo and Gandavarapu (2010) estimate that completing the sidewalk network in a typical U.S. town would increase 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), or about 10 miles of reduced VMT for each mile of increased walking.

Sidewalks usually increase adjacent property values by improving access (Peffer 2009; PBIC 2009), but this reflects only a portion of total benefits since non-residents also benefit from improved access and reduced driving, so total benefits are likely to be much greater than property value changes indicate (Clark and Davies 2009).

Factors affecting pedestrian facility improvement benefits

Magnitude of improvement
- Whether it significantly improves pedestrian conditions where walking is otherwise difficult.

Demand
- Number of potential users, including youths, people with disabilities or low incomes, seniors, dog owners, and people who want to walk for exercise.
- Connects important destinations such as schools, businesses, public transit stops, and parks.

Supports special planning objectives
- If located in a commercial or resort area where walkability supports economic development.
- Whether it includes universal design to improve mobility for people with disabilities.
- If it increases physical activity by otherwise sedentary people.

Network and synergetic effects
- Whether it connects to a large pedestrian network (other sidewalks and paths).
- Whether part of an integrated program to improve alternative modes and support smart growth.

Bicycle Facility Improvement (Paths, Bike Lanes and Parking Facilities)

Bicycle improvements are similar to pedestrian improvements, although with a more limited range of users. Such enhancements benefit existing and new users, can increase cycling activity, and reduce driving. Although many cyclists can comfortably share road space with motor vehicles, particularly if traffic speeds and volumes are moderate and traffic lanes are sufficiently wide and smooth, many people are reluctant to cycle without special facilities. Increased bicycling tends to improve public fitness and health. Since some physically and economically disadvantaged people depend on cycling, bicycle facility improvements can provide option and equity value.

Bicycle facilities tend to have network effects so benefits increase as the network expands. A short, isolated length of bikepath may provide minimal benefit, while a link that connects two otherwise isolated cycling networks, or provides a shortcut (such as connecting two cul de sacs) can provide large benefits.

Factors affecting bicycle network benefits

Magnitude of improvement
- Whether located on or parallel to a busy roadway where cycling is otherwise difficult.
- If a missing link that connects sections of the cycling network.

Demand
- Number of potential users, including children and young adults, people with lower incomes, and people who want to bicycle for exercise.
- Connects important destinations such as schools, shops, public transit stops and parks.

Supports special planning objectives
- If in a commercial or resort area where access and recreation support economic development.
- If many residents are sedentary and would benefit from increased physical activity.

Network and synergetic effects
- Connects to a large cycling network.
- Is part of an integrated program of to improve alternative modes and support smart growth.

Non-motorized Transport Education and Encouragement Programs

Education and encouragement programs help overcome barriers to walking and cycling (ignorance, social stigma, a habit of driving), increase use of these modes, and reduce motor vehicle travel. Such programs tend to have synergistic effects with facility improvements. On the other hand, education and encouragement programs can fail or increase risk if walking and cycling conditions are poor.

Factors affecting education and encouragement program benefits

Magnitude of improvement

- Program quality. Whether it responds to local conditions and preferences, and so helps overcome barriers such as ignorance, social stigma, and a habit of driving.
- Whether it addresses specific problems, such as high rates of cycling traffic violations.
- Community support. Whether it attracts support from sports and recreation, school, public health, transportation, business, neighborhood and environmental organizations.

Demand

- Number of people who are likely to increase their walking and cycling activity.
- The degree that participants reduce their driving.

Supports special planning objectives

- Whether located in an area, such as a city or resort community, where reductions in automobile travel can provide large benefits (such as reduced traffic congestion and parking problems).
- The program targets people who are sedentary and overweight, and so benefit significantly from more active transport.

Network and synergetic effects

- Whether part of an integrated program to improve and encourage non-motorized transport.
- Whether it helps build broad community support for active transportation.

Public Bike Systems

Public Bike Systems (PBS, also called *Bike Sharing* and *Community Bike Programs*) provide convenient rental bicycles intended for short (less than 5 kilometer), utilitarian urban trips. A typical Public Bike System consists of a fleet of bicycles, a network of automated stations where bikes are stored, and bike redistribution and maintenance programs. Bikes may be rented at one station and returned to another. Use is free or inexpensive for short periods (typically first 30 minutes). This allows urban residents and visitors to bicycle without needing to purchase, store and maintain a bike.

Public bikes tend to benefit users directly, by providing convenient and affordable transport and recreation. They can provide additional benefits by increasing cycling activity and substitute for automobile travel (either alone or in conjunction with public transit).

Factors affecting Public Bike System benefits

Magnitude of improvement
- The convenience of the service, including the number and location of stations, the ease of use, and the quality of bikes.

Demand
- Number of people who are likely to use the services.
- The degree that Public Bike users increase their cycling and reduce their driving.

Supports special planning objectives
- Whether located in an area, such as a city or resort community, where reductions in automobile travel can provide large benefits.

Network and synergetic effects
- Whether the system is integrated with public transit services.
- Whether part of an integrated program to improve and encourage non-motorized transport.

Calculating Optimum Investments

Transportation economic analysis compares the incremental benefits and costs of different policies and programs. This section shows examples of evaluation applied to non-motorized transport (also see Nelson 1995; Ker 2001; Litman 2001; Sælensminde 2004; MacMillen, Givoni and Banister 2010). The following formula can be used to determine the maximum investment justified for policies or programs that shift travel from automobile to non-motorized modes.

Optimal Investment/Year = (Benefits/Trip x Modal Shift)/Year

Example 1: Pedestrian Facility

Table 25 shows the estimated monetized benefits to society of 10,000 miles shifted from driving to non-motorized travel under urban off-peak conditions, based on benefit values in Table 5. A new public path might cause such an annual shift (e.g., 46 trips shifted daily). Using a 7% discount rate over 20 years, this represents a present value of about $100,000. This indicates the capital investment that could be justified for such a facility. Total benefits are probably much greater than estimated because some potentially large impacts are not monetized in this analysis (health and enjoyment, community livability and cohesion, etc.), so greater investments may be justified. This analysis assumes a 1:1 mode substitution rate, that is, each non-motorized mile substitutes for one motor vehicle mile.

Table 25 **Benefits of 1,000 Miles Shifted To Non-motorized Transport**

Benefits	Per Mile	Total
Congestion Reduction	$0.02	$200
Roadway Cost Savings	$0.05	$500
Vehicle Cost Savings	$0.20	$2,000
Parking Costs (assuming 1-mile average trip length)	$1.00	$10,000
Air Pollution Reduction	$0.05	$500
Noise Pollution Reduction	$0.03	$300
Energy Conservation	$0.04	$400
Traffic Safety Benefits	$0.04	$400
Total	*$1.43*	*$14,300*

This table indicates monetized benefits of 1,000 miles shifted from motorized to non-motorized travel under urban off-peak conditions. Since many benefits are not monetized, total benefits are probably larger.

A higher substitution rate would provide greater benefits. Applying the 1:7 substitution rate indicated earlier in this report (each non-motorized mile substitutes for seven motor vehicle miles), would mean that benefits average about $10 per trip and $100,000 per year. These larger benefits are likely to occur if a non-motorized facility is part of an overall program to create a more walkable community, which might also include changing development practices (e.g., locating more shops and schools within walking distance of homes and employment sites), roadway design, traffic management and parking management, as well as non-motorized travel encouragement programs.

Example 2: Cycling Program

Table 26 shows the funding level justified for a cycling program per percentage point shift it causes from driving to cycling in an urban community with 20,000 commute trips and 35,000 non-commute trips each day. In this case up to $280,000 could be spent for each percent of commute trips, and $365,365 for each percentage point of non-commute trips shifted from driving to non-motorized travel. Annual investments of up to $3.2 million could be justified for a bicycle improvement and encouragement program that causes a 5-point shift from driving to cycling, and more taking into account additional, unmonetized benefits. Applying the 1:7 substitution rate would mean that benefits exceed $39 per commute trip and $20 per non-commute trip. These larger benefits are likely to occur if the cycling program is part of a comprehensive mobility management program that improves travel options and encourages reduced automobile travel.

Table 26 **Maximum Funding Per 1-Point Shift from Driving to Cycling**

	Commute Trips	Non-Commute Trips	Totals
Trips per day	20,000	35,000	55,000
Days per year	250	365	
Travel Condition	Urban-Peak	Urban Off-Peak	
Benefits per trip	$5.60	$2.86	
Calculation	20,000 x 250 x $5.60 x .01	35,000 x 365 x $2.86 x .01	
Totals	*$280,000*	*$365,365*	*$645,365*

This table shows the estimated annual benefits from each one-point shift from automobile to bicycle travel, considering only monetized benefits. Total benefits are probably much higher.

Example 3: Non-motorized Component of Commute Trip Reduction Program

Table 27 shows the monetized benefits from a commute trip reduction program that convinces 100 employees to shift from driving to non-motorized commuting, if they have average daily round-trip travel distances of 5 miles, $5.00 per day parking costs, and 240 annual work days. This program provides $210,000 in monetized benefits, plus additional benefits from improved health and enjoyment, and other unmonetized benefits. This indicates the level of program funding that could be justified. As described above, benefits are larger if the increased non-motorized travel leverages additional reductions in motorized travel, for example, if some households reduce their automobile ownership.

Table 27 **Commute Trip Reduction Program Benefits**

Benefits	Per Mile	Per Commuter	Total Daily
Congestion Reduction	$0.20	$1.00	$100
Roadway Cost Savings	$0.05	$0.25	$25
Vehicle Cost Savings	$0.25	$1.25	$125
Parking Costs		$5.00	$500
Air Pollution Reduction	$0.10	$0.50	$50
Noise Pollution Reduction	$0.05	$0.25	$25
Energy Conservation	$0.05	$0.25	$25
Traffic Safety Benefits	$0.05	$0.25	$25
Total		*$8.75*	*$875*

This table illustrates the value of shifting 100 employees from driving to non-motorized modes at a typical urban worksite.

Examples

Several non-motorized transportation improvement economic evaluations are described in the report, "Making the Case for Investment in the Walking Environment: A Review Of The Evidence" (Living Streets 2011).

Active Transport Evaluation (MacMillen, Givoni and Banister 2010)

In a study titled, *The Role Of Walking And Cycling In Advancing Healthy And Sustainable Urban Areas*, MacMillen, Givoni and Banister (2010) estimate the costs and benefits of pedestrianizing a commercial street in Oxford, England. They estimate that this project would reduce area vehicle trips 27%, as shoppers and commuters who currently drive shift modes. Estimated costs included the project's capital and incremental operating expenses, increased traffic crashes, and loss of 25 car parking spaces. Estimated benefits included improved public fitness, reduced traffic congestion, increased journey ambience (more enjoyable travel experience) and greenhouse gas reductions. They conclude that current project evaluation practices overlook or undervalue many active transport benefits, resulting in an underinvestment in walking and cycling improvements.

New Zealand Active Transport Monetization Program

The New Zealand Transport Agency *Economic Evaluation Manual* includes specific procedures for evaluating walking and pedestrian improvements. It applies a benefit factor of $2.70/km to new or safer pedestrian trips, and $1.45/km for new or safer cycling trips (NZTA 2010, Vol. 2, p. 8-11). Additional before-and-after research measures how specific types of non-motorized improvements tend to increase non-motorized travel activity (Turner, et al. 2011).

Cycling Improvement Economic Evaluation

Foltýnová and Kohlová (2007), analyzed impacts of improved cycling infrastructure on cycling activity using a stated preferences survey to determine willingness to bicycle in response to various cycling improvements in the city of Pilsen, in the Czech Republic. Considering just direct health and air pollution reduction benefits, the cycling facility improvements are not considered cost effective.

Bicycle Improvement Benefit/Cost Analysis (Gotschi 2011)

This study assessed how costs of Portland's past and planned investments in bicycling relate to health and other benefits. Bicycle facility costs are compared with 2 types of monetized health benefits: health care cost savings and value of statistical life savings. Levels of bicycling are estimated using past trends, future mode share goals, and a traffic demand model. This analysis indicates that by 2040, investments in the range of $138 to $605 million will result in health care cost savings of $388 to $594 million, fuel savings of $143 to $218 million, and savings in value of statistical lives of $7 to $12 billion. The benefit-cost ratios for health care and fuel savings are between 3.8:1 and 1.2:1, and an order of magnitude larger when value of statistical lives is used. This indicates that such efforts are cost-effective, even when only a limited selection of benefits is considered.

Valuing Bicycling in Wisconsin (Grabow, Hahn and Whited 2010)

The study, *Valuing Bicycling's Economic and Health Impacts in Wisconsin* estimated the economic value of bicycling in the state of Wisconsin, including economic activity from bicycle manufacturing and sales ($593 million), tourism and recreational value ($924 million), health benefits of increased physical activity ($320 million) and pollution emission reductions ($90 million). Total estimated benefits average about $360 per resident. The study also investigated factors that affect cycling demand.

Neighborhood Design and Health

The study project, *Neighbourhood Design, Travel, and Health* (Frank, et al. 2010), describes various factors that affect walkability, methods for measuring those factors, and the impacts of neighborhood walkability on per capita automobile travel, physical activity and fitness in the Vancouver, BC metropolitan region. The results indicate that:

- Adults living in the 25% most walkable neighborhoods walk, bike and take transit 2-3 times more, and drive approximately 58% less than those in more auto-oriented areas.
- Residents in the most walkable areas, with good street connectivity and land use mix, were half as likely to be overweight than those in the least walkable neighborhoods.
- Living in a neighbourhood with at least one grocery store was associated with nearly 1.5 times likelihood of getting sufficient physical activity, compared to areas without grocery stores. Each additional grocery store within a 1-kilometer distance from an individual's residence was associated with an 11% reduction in the likelihood of being overweight.
- The most walkable neighborhoods have the least ozone pollution, but the most nitric oxide pollution. Some neighborhoods have relatively high walkability and low pollution.

Recommendations for Comprehensive Evaluation

As this report discusses, in various ways conventional economic evaluation tends to undervalue non-motorized transport. Most communities that invested significantly in non-motorized travel, such as Davis, California and Eugene, Oregon, did so without formal benefit/cost analysis. These programs resulted from public officials and community members who realized intuitively that non-motorized transport can provide much greater benefits than recognized in conventional planning (Buehler and Handy 2008). Now that these networks are mature, residents of these cities enjoy substantial benefits, including consumer cost savings, parking cost savings, accident reductions, improved public health, reduced pollution, and stronger local economies. More comprehensive economic evaluation may help other communities recognize these benefits and therefore overcome the political and institutional barriers to improving non-motorized transport.

Below are guidelines for comprehensive non-motorized transport evaluation.

- Recognize the many roles that walking and cycling can play in an efficient transport system, including basic and affordable mobility, access to motorized travel, exercise, enjoyment and tourism.
- Use comprehensive travel surveys that count all non-motorized travel, including non-commute trips, non-motorized links of automobile and public transit trips, and recreational walking and cycling activity.
- Consider total non-motorized travel demand, including the increased walking and cycling activity that would result from improved walking and cycling conditions, and factors that are likely to increase future demands such as aging population, rising fuel prices, increased urbanization, and rising health and environmental concerns.
- Consider network and synergistic effects. Evaluate non-motorized improvements as an integrated program that includes facility improvements, traffic calming, encouragement programs and demand management strategies, rather than evaluating each project or program individually.
- Consider all categories of benefits from improved and increased non-motorized transport, including improved mobility for non-drivers, consumer savings, user enjoyment, health benefits, congestion reduction, road and parking cost savings, energy conservation, emission reductions, increased economic development, and support for efficient land use development. Do not limit analysis to just the benefits traditionally considered in motorized transport project evaluation.
- Consider non-motorized transport’s leverage effects on automobile travel – each additional mile of walking and cycling tends to reduce 5-10 miles of automobile travel. This significantly increases estimated benefits.
- Consider all funding sources. Walking and cycling programs should receive substantial funding from both transportation and recreational funding sources because non-motorized transport provides both transport and recreational benefits.

Criticisms

The following criticisms are sometimes raised against claims of non-motorized benefit analysis.

Inferior Good – Declining Demand

People sometimes argue that non-motorized transportation is an *inferior good*, that is, as people become wealthier they shift from non-motorized to motorized transport, so investments in non-motorized facilities is wasteful and efforts to encourage non-motorized travel is either futile or harmful to consumers. Although it is true that as people shift from poverty to a mid-level income they tend to shift from non-motorized to motorized travel, further increases in wealth do not necessarily reduce walking and cycling. Many higher-income cities and countries have relatively high walking and cycling mode share. Activities such as bicycle commuting and neighborhood walking appear to be popular among higher-income people, provided that conditions are favorable (good cycling facilities, walkable neighborhoods, etc.). If this is true then non-motorized transport is not an inferior good in areas with good walking and cycling conditions, so improving such conditions is efficient and responsive to consumer demands.

Slow and Inefficient

Critics sometimes argue that, since non-motorized modes are slower, they are inefficient, as discussed in the *Costs* section of this report. While it is true that walking and cycling are often slower than automobile travel, they have an important role to play in an efficient transport system. Improving walking and cycling conditions can contribute to time and money savings that increase efficiency. Walking and cycling are the most efficient modes for shorter trips, which often support motorized travel, for example, by allowing motorists to walk from vehicles to destinations, or to walk rather than drive among various destinations located close together, such as various shops in a commercial center. Improvements, such as pedestrian shortcuts and better roadway crossings improve non-motorized travel speeds. From some perspectives, such as when evaluated based on *effective speed* (total time spent in travel, including time devoted to working to pay for vehicles and fares) non-motorized travel is often more time-efficient than motorized travel overall. Improving non-motorized travel can save drivers' time by reducing traffic congestion and the need to chauffeur non-drivers. The most efficient transport system is one in which travelers have viable options, including good walking and cycling conditions, so they can choose the most efficient mode for each trip, considering all benefits and costs.

Excessive Costs and Subsidies

Some pedestrian and cycling projects and programs may have relatively high subsidy costs per mile of travel, and so seem cost-inefficient. For example, a special pedestrian signal or pedestrian bridge may costs tens or hundreds of thousands of dollars, and depending on use and how costs are allocated, the costs may average many dollars per user, which seems high compared with roadway costs per automobile passenger. However, such analysis often underestimates true automobile travel costs and subsidies (ignoring, for example, parking subsidies and total accident costs). A pedestrian signal or bridge may allow walking or cycling to replace automobile trips that impose many dollars in total costs.

Unfair To Motorists

Motorist organizations sometimes argue that motor vehicle user revenue (fuel taxes and registration fees) expenditures on pedestrian and cycling facilities is an unfair *diversion* of money that should be dedicated to roadway facilities. This reflects a horizontal equity principle that consumers should generally "get what they pay for and pay for what they get." However, such arguments only reflect half of the equation (get what they pay for) and ignore the other (pay for what you get), which would require that virtually all roadway costs be financed by user fees, which would require 50-100% increase in such fees. In addition, special walking and cycling facilities are largely needed because of the risk and pollution that motorized traffic imposes on pedestrians and cyclists, and to reduce conflicts so motorists can drive faster than would otherwise be required. To the degree that this is true, motorists have a responsibility to help finance non-motorized facilities.

Inefficient and Wasteful

There is sometimes criticism that demand for non-motorized travel is exaggerated by wishful thinking, and that a particular facility or program will fail to attract users and achieve benefits as claimed. This certainly could occur, but it may reflect other problems with program design rather than an overall lack of demand. For example, a sidewalk or crosswalk improvement may attract few users if it is located in an automobile-dependent location, and a walk-to-school encouragement program may fail if walking conditions are inferior. However, where an appropriate combination of physical improvements and support are implemented, impacts are often significant, and many non-motorized projects and programs have exceeded expectations.

Conclusions

Non-motorized transport plays an important and unique role in an efficient transport system. It provides basic mobility, affordable transport, access to motorized modes, physical fitness and enjoyment. Improving non-motorized conditions benefits users directly, and benefits society overall, including motorists who experience less traffic congestion, accident risk and chauffeuring burdens. By helping to create more accessible, multi-modal communities, non-motorized improvements can leverage additional motor vehicle travel reductions, so a mile of increased non-motorized transport reduces several motor-vehicle miles.

Conventional transport project evaluation methods tend to overlook and undervalue non-motorized transport. Conventional travel statistics imply that only a small portion of total travel is by non-motorized modes (typically about 5%), but this results, in part, from travel survey practices which overlook many short and non-motorized trips. NMT represents a relatively large portion of total trips and travel time (typically 10-20% in urban areas), and many of the trips it serves are high value, and would be costly to perform by motorized modes. More comprehensive evaluation considers additional non-motorized transport benefits, including indirect reductions in vehicle travel, and additional benefit categories.

Some benefits are relatively easy to measure. Transport economists have developed methods for monetizing (measuring in monetary units) traffic congestion, road and parking facility costs, vehicle expenses, crash risk, and pollution emissions. Some non-motorized benefits can be estimated by adapting these values, for example, by applying the same methods used to measure reductions in vehicle congestion delays to calculating the value of reduced barrier effect delay and pedestrian shortcuts. Values used to evaluate traffic deaths and injuries can be used to value the fitness and health benefits of active transport. Affordability can be quantified by indicating cost savings to lower income users. Other impacts may be more difficult to monetize, but should at least be described. These include user enjoyment, option value, support for equity objectives, more compact and accessible land use development (smart growth), economic development, improved community livability, and additional environmental benefits such as habitat preservation.

There are many ways to improve and encourage non-motorized travel. Although most communities are implementing some of these strategies, few are implementing all that are justified. Most of these strategies only affect a portion of total travel, so their impacts appear modest, so they are seldom considered the most effective way of solving a particular problem. However, they provide multiple and synergistic benefits. When all impacts are considered, many communities can justify much more support for walking and cycling.

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