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Quantifying the Benefits of Nonmotorized Transportation For Achieving Mobility Management Objectives

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Abstract

This paper investigates the ability of nonmotorized travel (walking, cycling, and their variants) to help achieve transportation planning objectives such as congestion reduction, road and parking facility cost savings, consumer cost savings, and various environmental and social benefits. It discusses methods for evaluating the benefits of improved walking and cycling conditions, increased nonmotorized travel, and shifts from motorized to nonmotorized modes. It finds that nonmotorized transportation tends to leverage proportionately larger reductions in vehicle travel. It describes various strategies for encouraging walking and cycling. This analysis indicates that nonmotorized travel provides significant benefits, and that these benefits can increase with cost effective incentives. Conventional transportation evaluation practices tend to overlook many of these benefits, and so undervalue nonmotorized transportation improvements and incentives.

This paper updates and expands on the article,
"Quantifying Bicycling Benefits for Achieving TDM Objectives,"
Transportation Research Record 1441, Transportation Research Board (www.trb.org), 1994, pp. 134-140.

Introduction

Mobility management (also called *transportation demand management*, or *TDM*) includes a variety of strategies that change travel behavior in order to increase transportation system efficiency (VTPI 2004). Mobility management is increasingly used to help achieve various planning objectives (ITE 1999; FHWA 2004).

Table 1 **Mobility Management Strategies That Encourage Nonmotorized Travel**

Improves Transport Options	Price Incentives	Land Use Management	Implementation Programs
Transit improvements Walking improvements Cycling improvements Bicycle parking facilities Bike/transit integration Guaranteed ride home	Congestion pricing Distance-based fees Parking cash out Parking pricing Pay-as-you-drive vehicle insurance Fuel tax increases	Smart growth Location-efficient development Parking management Transit oriented development Carfree planning Traffic calming	Commute trip reduction School and campus transport management Tourist transport management Transit marketing Nonmotorized encouragement

This table lists various mobility management strategies that tend to encourage nonmotorized travel.

Nonmotorized transport (*NMT*, also called *active transport* and *human powered transport*) includes walking, cycling, and variants such as skating, and use of wheelchairs and handcarts. Non-motorized transport plays an important role in mobility management. When vehicle is reduced, many trips shift to walking and cycling, either entirely or in conjunction with ridesharing and public transit use.

This paper examines the role that nonmotorized travel plays in an efficient transportation system. It provides guidelines for evaluating the various benefits that can result from improving nonmotorized travel conditions, increasing nonmotorized travel, and shifting travel from motorized to nonmotorized modes, as indicated in Table 2.

Table 2 **Nonmotorized Transportation (NMT) Benefits**

Improved NMT Conditions	Increased NMT	Shift from Automobile to NMT
Improved user convenience and comfort. Increased travel options. Improved basic mobility for non-drivers. More attractive and livable communities. Improved local property values	Improved public health and fitness. User enjoyment. Increased community cohesion (positive interactions among neighbors).	• Reduced traffic congestion. • Road and parking cost savings. • Consumer cost savings. • Reduced crash risk to others. • Air and noise pollution reductions. • Energy conservation. • Economic development benefits. • Supports strategic land use objectives.

Nonmotorized transport provides many benefits, particularly when it substitutes for driving.

The Role of Nonmotorized Transport

Nonmotorized travel (particularly walking) plays a unique and important role in an efficient transportation system. Walking is a fundamental human activity that provides basic mobility and serve many other functions. Walking provides connections among various modes, destinations and activities. Buildings, parking lots, train stations, transit terminals and airports are all pedestrian environments that depend on walking and cycling for circulation and connections. Most motorized trips involve nonmotorized links. Motorists walk from parked vehicles to destinations. Most transit trips involve nonmotorized links, so walking and cycling conditions determine the functional area of transit service. Air travelers walk from vehicles to airports and within terminals. People walk for circulation at destinations. As a result, improving nonmotorized conditions improves access by other modes.

Nonmotorized travel can provide many benefits. Walking and cycling are inexpensive for users and reduce costs such as congestion, parking subsidies, energy consumption and pollution emissions. Communities designed for walking and cycling are compact (so many destinations are within convenient distance of each other), connected (with streets that allow direct travel), designed at a human scale, have attractive sidewalks and paths. This improves accessibility, affordability and community livability.

Conventional planning tends to undercount and undervalue non-motorized travel (Litman, 2003). Many travel surveys indicate that only 2-5% of travel is by walking and cycling, implying that nonmotorized travel is unimportant. But such surveys often ignore short trips, non-work travel, travel by children, recreational travel, and nonmotorized links of motorized trips. For example, many travel surveys classify walk-drive-walk trips simply as automobile trips and bike-bus-walk trips as transit trips, even if the nonmotorized links take place on public sidewalks, paths and roads. Nonmotorized travel is typically three to six times greater than such surveys indicate (Rietveld 2000). Some experts conclude that increased walking and cycling can do little to solve transport problems because they only consider current commute trips that can shift completely to these modes (Comsis 1993; Apogee 1994), but other studies suggest that nonmotorized travel can play a more important role by substituting for errand trips, supporting other modes and helping increase land use accessibility (Mackett 2000; Socialdata 2000; Cairns et al. 2004).

Described differently, transportation systems can be evaluated in two different ways that have very different implications about the role of nonmotorized modes. Convetional planning tends to evaluate transportation system performance based on *mobility* (physical movement), and particularly *automobility* (motor vehicle movement) using indicators such as roadway level-of-service, average traffic speed and congestion delay indices. From this perspective, nonmotorized modes have a minor role to play in an efficient transport system since they are slow and represent a small portion of total mileage. When evaluated in this way, improving nonmotorized travel is only considered important to the degree that it improves automobile travel conditions.

But mobility is not usually an end in itself, the ultimate goal of most transport is *accessibility* (people's ability to reach desired goods, services and activities). Mobility is just one factor in accessibility; equally important are land use (the distribution of destinations and therefore the distance that must be traveled to reach activities), network connectivity (the quality of roads and paths), and the quality, affordability and integration of accessibility options (walking, cycling, public transit, taxi, delivery serices, electronic communication, etc.). Automobile-oriented improvements often turn out to provide less accessibility benefit, and nonmotorized improvements provide greater benefit, than conventional indicators suggest. For example, expanding congested roadways may do little to improve accessibility if it stimulates sprawl or creates barriers to nonmotorized travel, forcing people to drive for trips that would otherwise be made by walking and cycling. On the other hand, creating compact, mixed, walkable, "smart growth" communities can improve accessibility without increasing mobility. Mobility-oriented indicators such as roadway level-of-service ignore such impacts.

These are important issues because many planning decisions involve trade-offs between different types of access. For example, widening roadways and expanding parking facilities improves automobile access but tends to degrade nonmotorized travel conditions and stimulate sprawl, while smart growth land use policies tend to improve walking, cycling and public transit access but reduces automobile traffic speeds. Conventional transport planning tends to only recognize impacts on automobile access, which skews planning descisions toward automobile dependency and sprawl. More comprehensive analysis recognizes impacts on all modes and can therefore identify the most optimal solution to transportation problems.

For example, conventional planning tends to locate facilities such as schools along urban fringe arterials to provide convenient automobile access and abundant land for parking, although such locations provide poor nonmotorized access. More multi-modal planning tends to locate schools within residential areas and emphasize features such as sidewalks, paths, crosswalks and traffic calming. Many other planning decisions involve similar trade offs between different forms of accessibility, including expenditures (the portion of transport budgets to spend on sidewalks, paths, roads, parking facilities, and public transit services), roadway design (how much space to devote to sidewalks, bike lanes, parking lanes, and traffic lanes, and design speeds), development practices (whether to restrict or encourage compact, mixed development, and the amount of parking to require) and location decisions (where to locate facilities such as schools, offices and parks).

When transportation system performance is evaluated based on accessibility rather than mobility, it possible to recognize the full potential value of nonmotorized mode. To their credit, many planners give nonmotorized modes more consideration than justified by survey data or performance indicators. They realize that nonmotorized travel has critical functions in an efficient transport system, some of which are difficult to measure. However, this occurs in spite of, rather than supported by, conventional planning tools. More comprehensive analysis tends to further increase support for nonmotorized modes.

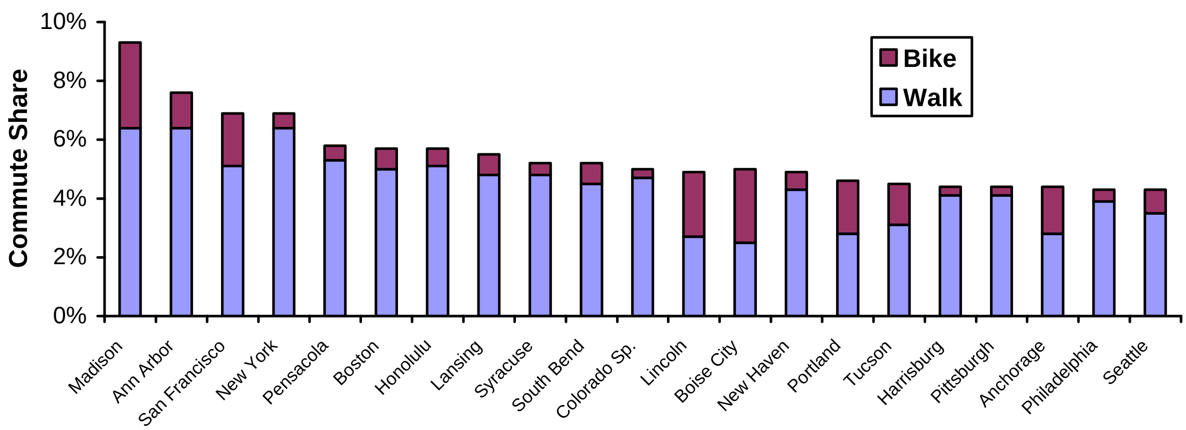
Travel Impacts

Mobility management program benefits depend on their travel impacts, such as the amount that nonmotorized travel increases and motorized travel decline. Shifts from automobile to nonmotorized modes are measured by *mode substitution rates*, that is, the ratio between increased nonmotorized person-miles and reduced motor vehicle-miles.

When walking and cycling improvements increase nonmotorized travel, typically, 20% to 50% of this substitutes for motorized travel. Similarly, when mobility management incentives reduce automobile travel a portion typically shifts to nonmotorized modes. Shorter trips tend to shift entirely to nonmotorized modes and longer trips shift to transit-plus-nonmotorized trips. For example, when UK residents were asked how they could reduce vehicle trips less than 8 kms, respondents indicated they could shift 31% to bus, 31% to walking, and 7% to bicycle (Mackett, 2001). When Canadian fuel prices increased about 15% in 2001, about a quarter of motorists shifted some automobile travel to other modes, of which 46% took transit, 36% walked, 24% cycled, and 20% shared car rides.

According to the *National Survey of Bicyclist and Pedestrian Attitudes and Behavior*, about 5% of walking and cycling trips are for commuting to work or school, and about half is for recreation and exercise (Gallup 2008). This suggests that for each nonmotorized commute trip there are about nine other utilitarian nonmotorized trips and about ten non-utilitarian (recreation and exercise) trips.

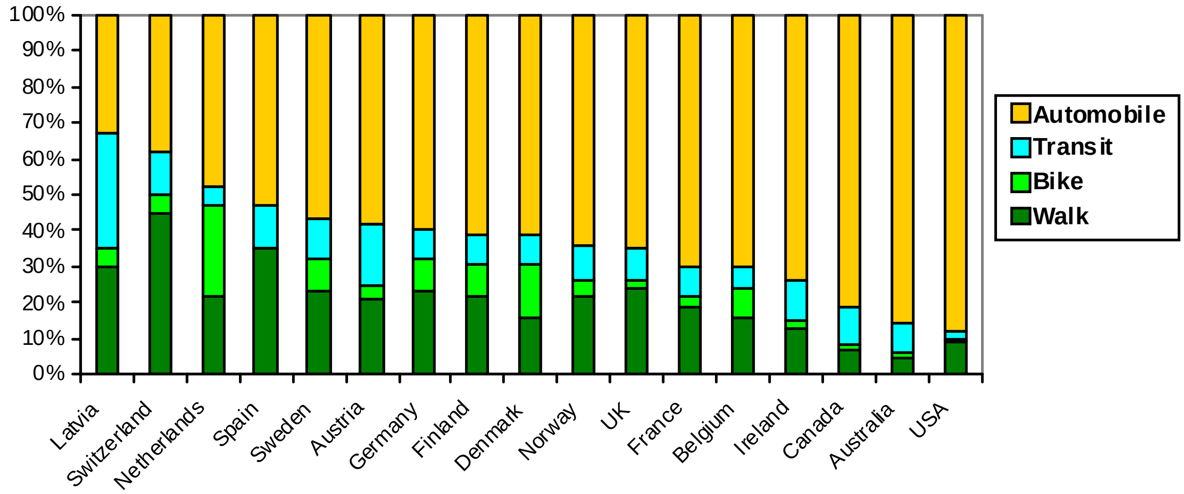
Figure 1 **Nonmotorized Commute Share** (U.S. Census 2007)



This figure shows U.S. cities with relatively high nonmotorized commute mode split.

Nonmotorized travel rates vary significantly from one community to another, depending on various factors, including land use patterns and the quality of nonmotorized facilities, as indicated in figures 1 and 2. Residents of walkable and bikeable communities tend to use these modes 100% to 500% more than in more automobile-dependent communities (Moudon, *et al*, 1996). Even some relatively cold and hilly cities, such as Madison, Ann Arbor, San Francisco and even Anchorage, and countries such as Sweden, Switzerland and Germany achieve high levels of nonmotorized travel.

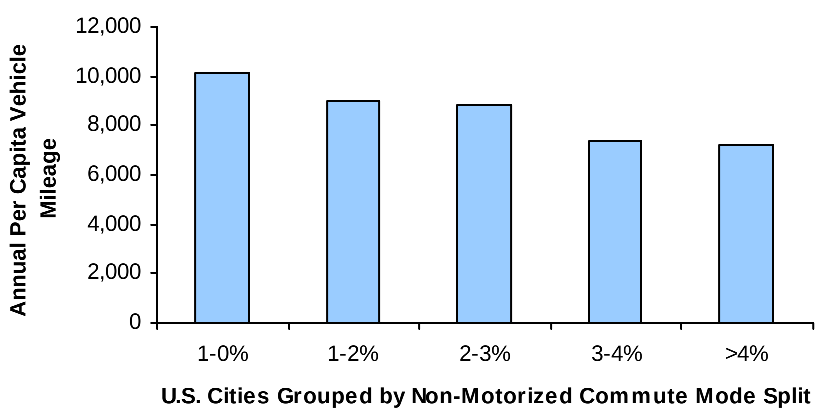
Figure 2 **Mode Split By Country** (Bassett, et al., 2008)



This figure shows the portion of total travel by different modes in various countries. Nonmotorized travel varies significantly between countries.

In addition to the direct impacts of shifts from motorized to nonmotorized travel, improved walking and cycling conditions and incentives to use nonmotorized modes often has indirect impacts that leverage additional vehicle travel reductions. A short walking or cycling trip often replaces a longer automobile trip; for example, people may choose between walking to a nearby store or driving to a more distant shopping center. Pedestrians and cyclists often use shortcuts unavailable to motorists. Nonmotorized transport supports *smart growth* (more compact, mixed, multi-modal development) that improves nonmotorized travel and reduces travel distances ("Smart Growth," VTPI, 2004). If improved walking and cycling conditions allows households to reduce their vehicle ownership, they tend to significantly reduce their total vehicle mileage.

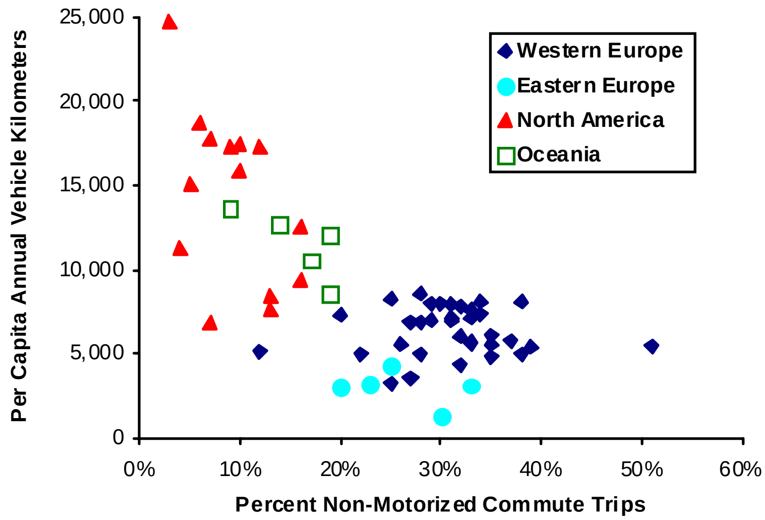
Figure 3 **Vehicle Mileage Vs. Nonmotorized Commuting** (Census and FHWA Data, 2000)



This graph compares average annual per capita vehicle mileage of U.S. cities categorized according to their nonmotorized commute mode split. As nonmotorized commuting increases, average annual mileage declines significantly.

Figure 3 that per capita annual vehicle mileage tends to decline as nonmotorized travel increases. Although nonmotorized mode split is small (less than 5% of trips and probably less than 1% of person-miles), the mileage differences are large. Each percentage point increase in nonmotorized transport is associated with about 700 fewer annual vehicle-miles, indicating that each nonmotorized mile is associated with a reduction of seven vehicle-miles. International data shows similar patterns, as indicated in Figure 4.

Figure 4 **Nonmotorized Vs. Motorized Transport** (Kenworthy and Laube, 2000)



International data show that vehicle travel tends to decline as nonmotorized travel increases.

Of course, not every walking or cycling trip causes seven miles of reduced driving. The lower vehicle mileage in cities with relatively high nonmotorized mode split reflects transportation and land use patterns, such as density, mix, street design, parking supply, and pricing which affect the relative attractiveness of motorized and nonmotorized travel. But programs that increase nonmotorized travel tend to support such patterns, that is, smart growth both supports is supported by improved nonmotorized travel conditions and increased nonmotorized travel activity. As a result, mobility management programs that increase nonmotorized transport can reduce motorized travel both directly and indirectly, causing proportionately larger reduction in vehicle-miles, although exactly how much depends on the situation.

Although some factors affecting nonmotorized travel reflect durable land use development patterns, others can be changed relatively quickly, including nonmotorized facility quality, traffic management practices, financial incentives (such as road and parking pricing) and public information. Many communities have experienced significant nonmotorized travel growth and reductions in nonmotorized travel due to policy changes and mobility management programs ("Success Stories," VTPI, 2004).

There appears to be significant latent demand for nonmotorized travel, that is, people would walk more frequently if they had suitable facilities and resources ("Latent Demand Score," FHWA 1999). One US survey found that 38% of respondents would like to walk to work, and 80% would like to walk more for exercise (STPP 2003). Similarly, there appears to be significant latent demand for housing in more walkable communities. A survey sponsored by the National Association of Realtors found that consumers value a shorter commute time and having sidewalks and places to walk in their neighborhood (Belden, Russonello & Stewart, 2004). Asked to choose between two communities, six in ten prospective homebuyers chose a neighborhood that offered a shorter commute, sidewalks and amenities like shops, restaurants, libraries, schools and public transportation within walking distance over a sprawling community with larger lots, limited walking opportunities, and longer commutes. Minorities are even more likely than other Americans to choose a walkable neighborhood that has a shorter commute, with 59% of women, 57% of Hispanics and 78% of African-Americans selecting more walkable communities. After hearing detailed descriptions of two communities, Americans favored the attributes of walkable, smart growth communities over sprawling communities with longer commutes 55% to 45%.

Various models can be used to predict nonmotorized travel demand and the travel impacts of walking and cycling facility improvements (Barnes and Krizek 2005; McDonald, et al. 2007). Loudon, Roberts and Kavage (2007) developed the *TDM Effectiveness Evaluation Model* (TEEM), a tool for evaluating the travel impacts and economic benefits of bicycle and pedestrian improvements. The tool is based on an index of bicycle and pedestrian accessibility reflecting the extent of physical infrastructure to accommodate these two modes. The results were used to estimate the change in walk and bicycle commute mode shares that would result from a specified percentage increase in the index values, and estimates of the costs of such improvements. The Australian TravelSmart program uses various incentives to encourage residents to use alternative travel modes (Socialdata Australia, 2000). Before-and-after surveys indicate that automobile trips typically decline 5% to 14%, about half of the reductions resulting from shifts to nonmotorized travel.

Comprehensive Evaluation Framework

Comprehensive transportation economic evaluation takes into account all significant impacts (benefits and costs), including those that are indirect and nonmarket (Litman 2007). Conventional evaluation tends to focus on a relatively limited set of impacts. For example, conventional transportation project investment models such as MicroBenCost generally only quantify facility costs, congestion costs, vehicle operating costs, crash rates and sometime pollution emission rates. Other impacts tend to excluded, including the effects of generated and induced travel (additional vehicle travel resulting from highway expansion that would not otherwise occur). This type of analysis tends exaggerate highway expansion benefits and undervalue improvements to alternative modes and mobility management strategies. Although nonmotorized transportation improvements do not usually rank as the most cost effective way to reduce a particular cost such as congestion, they tend to provide many diverse benefits, and so may be the most cost effective way to improve transportation overall, considering all impacts.

A comprehensive evaluation framework considers all impacts, including internal (to users) and external, direct and indirect. Table 3 identifies various impact categories. For example, a positive incentive such as a nonmotorized facility improvement or parking cash out rewards have direct costs to governments or businesses, provides direct benefits to existing users (the people who would be walking or cycling anyway), net benefits to new users, direct external benefits such as reduced traffic congeston, accident risk and pollution emissions, and indirect benefits if this helps create more accessible, multi-modal communities. A negative incentive, such as pricing currently free parking, provides revenues to governments or businesses, imposes costs on users who must either pay the fee or shift to another mode, and both direct and indirect external benefits.

Table 3 **Mobilty Management Impact Categories**

	Description	Examples
Government and businesses financial impacts	Additional costs or revenues to governments and businesses	• Project costs. • Additional future operating costs. • Additional toll, parking fee or fuel tax revenue.
User impacts	Changes in user convenience, comfort or financial costs or benefits, including benefits to existing and new users.	• Increased convenience and comfort from improted facilities. • Increased parking pricing or road toll paymens. • Financial benefits from parking cash out.
Direct external benefits	Direct benefits from reduced vehicle traffic.	• Reduced congestion. • Reduced crash risk. • Reduced pollution emissions.
Indirect external benefits	Indirect benefits from more efficient land use patterns.	• Long-term benefits from reduced vehicle ownership and sprawl.

Nonmotorized transport provides many benefits, particularly when it substitutes for driving.

If users shift mode in response to a positive incentive, they must be better off overall even if their new mode is slower or they would not make the shift. If users shift in response to a negative incentive, they are generally directly worse off, although their additional costs may be offset overall by external benefits.

To fully account for nonmotorized benefits an evaluation framework should include the following features.

- Account for all nonmotorized travel, including short trips, walking links that are part of motorized trips, travel by children, and recreational travel. This may involve special travel surveys, or extrapolating from conventional surveys by assuming that actual nonmotorized travel is three to six times greater than what is counted. Considering just commute trips or just utilitarian trips may significantly undervalue the benefits of walking and cycling improvements.

- Consider all benefits that result from improved nonmotorized conditions and increased nonmotorized travel:
    - Improved convenience, comfort and safety to nonmotorized travelers.
    - Transportation diversity value (improved mobility for non-drivers, improved emergency response and special event access).
    - Improved public health.
    - Some travelers' enjoyment of and preference for nonmotorized travel.
    - Increased livability if a community becomes more walkable and automobile traffic impacts are reduced.

- Consider all cost savings that result from reductions in motor vehicle travel, including:
    - Road and parking congestion reductions.
    - Congestion impacts on nonmotorized travel.
    - Road and parking facility cost savings.
    - Vehicle ownership and mileage-based depreciation costs.
    - Strategic land use impacts (reduced pavement area and sprawl).
    - Reduced per capita accident risk.
    - Energy conservation.
    - Air and noise pollution reductions.

Changes in direct user benefits can be quantified with *consumer surplus analysis*, which takes into account the net value of an activity from a consumer's perspective (Litman, 2001). Some factors to consider are discussed below.

- Strategies that improve walking and cycling conditions or offer new financial rewards for nonmotorized travel tend to benefit people who already walk or cycle.

- People who shift from motorized to nonmotorized modes in response to positive incentives (improved facilities, financial reward, etc), must benefit overall or they would not change, even if their travel time increases.

- Strategies that use driving disincentives, such as increased road and parking fees, impose direct costs on affected users, although can be offset by indirect benefits, such as reduced traffic congestion and reductions in other taxes and fees.

- Impacts vary depending on the individual person and trip. For example, travelers sometimes enjoy walking and cycling and so benefit directly from mode shifts, but at other times may dislike these activities, so a high cost value must be assigned if they are forced to shift. If travelers are allowed to choose and given positive incentives, they will use nonmotorized modes when appropriate, maximizing overall benefits.

Impact Evaluation Methods

This section describes various impacts to consider when evaluating mobility management strategies, and discusses how they can be quantified and monetized (measured in monetary units). It includes generic estimates of these values. Of course, actual benefits will vary depending on specific conditions, so these values should be adjusted as appropriate to reflect a particular situation and planning perspective. For more information see the *Bicyclepedia* (www.bicyclinginfo.org/bikecost), Alta Design (2005), and *Transportation Cost and Benefit Analysis* (Litman 2009).

Program Costs and Revenues

This includes all costs and revenues to the government or business that implements a mobility management program, including costs of building sidewalks, paths and bicycle parking, ongoing operations and maintenance costs, and costs for incentives such as parking cash out. Conversely, mobility management strategies such as increased road tolls, parking fees and fuel taxes provide additional revenues to governments and businesses. User fees and financial incentives are economic transfers, payments are essentially offset by revenues, the net costs are transaction costs such as equipment, labor and time needed to pay or collect the fees.

Direct User Impacts

This includes any changes in convenience, comfort or financial impacts to *existing users* (people who would walk and bicycle anyway) and *new users* (people who increase their walking and cycling in response to a mobility management strategy). Net user impacts can be monetized using the rule-of-half as described below.

Explanation of the "Rule of Half"

Economic theory suggests that the net change in consumer surplus from a price change that reduces vehicle travel equals half the monetary change (called the *rule of half*). This takes into account the trade-offs consumers make between factors such as money, time, convenience and mobility.

Assume a 10¢-per-vehicle-mile price change (such as increased road or parking pricing) causes you to drive 1,000 fewer annual miles. You would not give up highly valuable vehicle travel but there is probably some lower-value vehicle travel that you can reduce by shifting modes or destinations, or consolidating trips. The mileage foregone has incremental value to you, the consumer, between 0¢ and 10¢. If you consider the additional mile worth less than 0¢ (i.e., it has no value), you would not have taken it in the first place. If the additional mile is worth more than 10¢ per mile, a 10¢ per mile incentive is inadequate to convenience you to give it up – you'll keep driving. Only vehicle travel worth 1-9¢ per mile will you to give it up in response to a 10¢ per mile incentive – you'd rather save the money. Of the 1,000 miles foregone, we can assume the average user value (called *consumer surplus*) is the mid-point of this range, that is, 5¢ per vehicle mile. Thus, we can calculate that miles foregone by a 10¢ per mile financial incentive have average consumer surplus value of 5¢. If motorists drive 1,000 fewer vehicle miles due to higher fees the *net consumer cost* of $50, while a $100 financial reward that convinces motorists to drive 1,000 miles less provides a *net consumer benefit* of $50.

Congestion Reduction

Traffic congestion external costs consist of the incremental travel time, vehicle operating costs, stress and pollution emissions that each vehicle imposes on other road users. Various studies indicate that, in total, these costs average 10¢ to 35¢ per urban-peak vehicle mile, and more in some situations (Litman 2009; TTI 2007). To analyze bicycle congestion impacts, road conditions are divided into four classes:

1. *Uncongested roads and separated paths.*
   Bicycling on uncongested roads 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 4 summarizes congestion impacts of bicycling by road width, although traffic volume and intersection design are also factors.

Table 4 **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 when the rider can safely keep up with traffic (common on urban streets) probably contributes slightly less to congestion than an average car, due to a bicycle's smaller size.

4. *Narrow, congested roads with moderate to high speed traffic.*
   Bicycling on a narrow, congested road when the rider is unable to keep up with traffic can contribute to traffic congestion, depending on how easily faster vehicles can pass.

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, and bicycling is forbidden on urban freeways where congestion costs are usually highest. Similarly, walking generally imposes minimal congestion. Only at intersections or if roads lack sidewalks and traffic lanes are narrow does increased walking cause vehicle traffic delay, and these impacts are generally minimal. A large crowd of pedestrians or cyclists can delay vehicle traffic at intersections, but generally less than if the same trips were made by automobile. 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.

Estimated Benefits: Congestion reduction benefits per reduced automobile-mile are estimated to be worth an average of 25¢ per mile under urban peak conditions and 2¢ per mile under urban off-peak conditions. No congestion benefit is assumed for rural travel.

Barrier Effect

The *barrier effect* (also called *severance*) refers to delays, discomfort and lack of access that vehicle traffic imposes on nonmotorized modes (pedestrians and cyclists). The barrier effect is equivalent to traffic congestion costs (most traffic congestion cost estimates exclude impacts on nonmotorized travel). In addition to travel delays, vehicle traffic imposes crash risk and pollution on nonmotorized travelers. The barrier effect reflects a degradation of the nonmotorized travel environment. This imposes indirect costs by reducing non-drivers' accessibility, which tends to be inequitable, and forces people to shift from nonmotorized to motorized travel, which increases various external costs. Studies described earlier indicate that many people would like to walk and bicycle more but are constrained, in part, by heavy roadway traffic.

Swedish and the Danish roadway investment evaluation models incorporate methods for quantifying barrier effects on specific lengths of roadway (Litman 2009). Both involve two steps. First, a barrier factor is calculated based on traffic volumes, average speed, share of trucks, number of pedestrian crossings, and length of roadway under study. Second, demand for crossing is calculated (assuming no barrier existed) based on residential, commercial, recreation, and municipal destinations within walking and bicycling distance.

Estimated Benefits: Scandinavian and Canadian estimates indicate that the barrier effect averages 0.5¢ to 1.5¢ per vehicle mile under urban conditions.

Roadway Costs

Roadway construction and maintenance costs are a function of vehicle size, weight, speed, and, in some regions, studded tire use. These costs average about 4¢ per mile for automobiles, with higher costs for heavier vehicles (FHWA 1997; Litman 2009). Motorized transportation also requires various traffic services, such as policing, signals and emergency response. Walking and cycling impose minimal roadway wear, and their traffic service costs tend to be lower than for motor vehicle traffic since pedestrians and cyclists travel slower (reducing potential conflicts) and impose less risk on others. Sidewalks and paths are relatively inexpensive to build and maintain. Most cities have about similar miles of roads and sidewalks/paths, but devote 5 to 10 times as much money to motorized as nonmotorized facilities.

Although state highways are funded primarily by motor vehicle user fees such as fuel taxes, local roads (which pedestrians and bicyclists use most) are mostly funded by local taxes, which residents pay regardless of how they travel. As a result, these can be considered external costs, and shifts from motorized to nonmotorized travel reduces local government roadway costs.

Estimated Benefits: Shifts from driving to walking or bicycling are estimated to provide roadway facility and traffic service cost savings of 5¢ per mile for urban driving and 3¢ per mile for rural driving.

Parking Cost Savings

Typical urban parking facility cost estimates range from $50 to $100 per month, or about $2.50 to $5.00 per day, and higher in major urban centers (Litman, 2009). Bicycle parking costs much less. Up to 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).

In the short run, reduced automobile trips may simply result in unoccupied parking spaces, but over the long run most parking facilities have significant opportunity costs: reduced parking demand allows property owners to avoid expanding parking capacity or they can be rent, sell or convert parking facilities to other usese.

Estimated Benefits: Parking costs are not generally affected by trip length, so this cost is measured per trip rather than per mile. Shifting from automobile to nonmotorized travel is estimated to provide parking savings of $2.00 per urban-peak trip (a typical commute with $4.00 per day parking costs), $1.00 per urban off-peak trip, and $0.50 per rural trip.

Vehicle Cost Savings

Direct automobile operating costs (fuel and tire wear, tolls and parking fees) average about 10¢ per mile, plus another 10¢ per mile in mileage-based repair, depreciation, incremental insurance costs (Litman, 2009). Vehicle operating costs tend to be about 50% higher for short urban trips, due to cold starts (before the vehicle engine has warmed up), and congestion. Fixed vehicle costs (costs that vehicle owners pay regardless of how much a vehicle is driven) average about $5 per day.

A $50 pair of shoes typically lasts 1,000 miles of walking (about one year of normal use), or 5¢ per mile walked. A $750 bicycle ridden 3,500 annually requires about $100 annual maintenance and lasts 10 years, an average cost of 5¢ per mile cycled. These costs are subtracted from the vehicle costs to determine net vehicle savings. Walking and cycling use food for fuel, but this is generally small (a 150 pound person walking a mile burns an additional 80 calories, the energy in about one slice of bread, and cycling a mile burns half that), and most people enjoy eating and consume too many calories, and so this energy consumption is generally a benefit rather than a cost.

Transportation is the second largest category of expenditures in a typical household (after housing expenses), due to the high cost of owning motor vehicles. Increased use of nonmotorized modes can provide significant consumer savings, particularly for lower-income households. For example, improved walking and cycling conditions may allow a household to own one rather than two cars, or even give up car ownership altogether, providing thousands of dollars in annual savings.

Estimated Benefits: Shifts from driving to nonmotorized travel provide savings that are estimated to average 25¢ per mile under urban-peak conditions, 20¢ per mile under urban off-peak conditions, and 15¢ per mile under rural conditions. Greater savings are possible when nonmotorized travel improvements allow a household to own fewer cars.

Travel Time Costs

Time is a user cost (Litman 2009). Although bicycles compete favorably in door-to-door travel times with automobiles for some trips, nonmotorized travel is generally slower than driving. This implies increased time costs. However, actual costs vary significantly depending on conditions and individual preferences. Time costs are two to three times higher under undesirable conditions, but can be much lower, (time spent walking or cycling can be considered a benefit rather than a cost) under favorable conditions. If somebody who prefers to drive is forced to walk, their time costs may increase significantly, particularly if walking conditions are poor. On the other hand, additional travel time for walking and bicycling that results from positive incentives such as improved nonmotorized travel conditions or positive incentives is a user benefit rather than a cost since people only shift if they consider themselves better off overall.

Estimated Impacts: Various methods can be used to measure the value of changes in travel time, including consumer surplus analysis (Litman 2009). Travel time is generally valued a one-third to one-half of prevailing wages, with higher rates for walking in undesirable conditions, and lower or zero cost value under favorable conditions. When shifts from motorized to nonmotorized travel result from positive incentives, additional travel time can be considered to have no cost, or may be considered a benefit by users.

Accident Costs

Motor vehicles imposes significant crash costs. Traffic accidents are a the primary cause of deaths and disabilities among people in the prime of life Monetized crash costs are among the largest costs of motorized transportation ("Crash Costs," Litman 2009; Litman and Fitzroy 2006). Although walking and cycling have higher per-mile accident casualty rates than automobile travel, the incremental risk of a shift from driving to nonmotorized modes is much lower due to the following factors (During 2007; WHO 2008):

1. Nonmotorized travel imposes minimal risk to other road users.

2. High pedestrian and cyclists crash and casualty rates result, in part, because people with particular risk factors tend to use these modes, including children and people with disabilities. A responsible adult who shifts from driving to nonmotorized travel and takes basic precautions such as observing traffic rules and wearing a helmet tends to experience less than average risk.

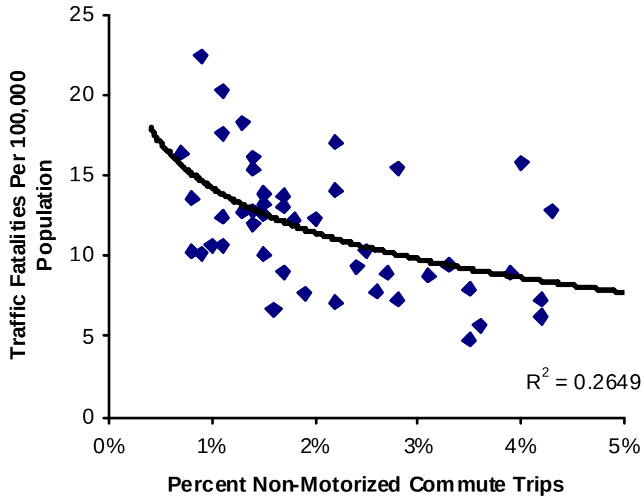
3. Road users tend to be more cautious where they expect to encounter walkers and cyclists.

4. Increased walking and cycling may spur communities to invest more resources in nonmotorized safety.

5. Nonmotorized trips tend to be shorter than motorized trips, so total per capita mileage declines. A local walking trip often substitutes for a longer automobile trip, and people who rely primarily on nonmotorized modes tend to travel significantly less than people who rely on automobile transportation, due to differences in their travel and location decisions.

6. Some walking and cycling promotion programs include education and facility improvements that reduce per-mile bicycle crash rates.

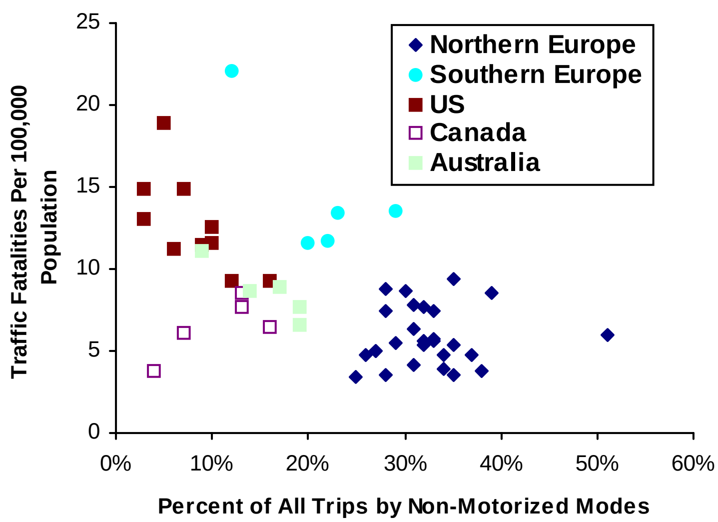
Figure 4 **Traffic Fatalities Vs. Non-Motorized Transport** (US Census 2000)



Per capita traffic fatality rates tend to decline nonmotorized travel increases.

Empirical evidence indicates that shifts from driving to nonmotorized modes tends to reduce total per capita crash casualty rates in an area, as indicated in figures 4 and 5. For example, walking and cycling travel rates are high in Germany and the Netherlands, yet the per capita traffic death rates are much lower than in automobile dependent countries (Pucher and Dijkstra, 2000; Fietsberaad, 2008). 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 5 **Traffic Fatalities Vs. Non-Motorized Transport** (Kenworthy and Laube 2000)



Per capita traffic fatalities tend to decline as the portion of nonmotorized urban travel increases.

Wardlaw (2001) and Jacobsen (2003) find that the per capita collisions between motor vehicles and nonmotorized travelers declines with increased nonmotorized travel. Jacobsen 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 being hit as a pedestrian 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%.

Several studies indicate that motor vehicle external accident costs average 2¢ to 12¢ per automobile mile, depending on vehicle type and driving conditions. Collision rates per vehicle mile tend to increase with traffic density, although fatality rates tend to decline as congestion reduces traffic speeds.

Estimated Benefits: Net benefits of a shift from driving to walking or cycling are estimated to average 5¢ per urban peak mile, 4¢ per urban off-peak mile, and 3¢ per rural mile. Although people who shift from motorized to nonmotorized modes may experience some increased accident risk, this can be minimized if mobility management programs include appropriate safety education and facility improvements, and can be offset overall by reductions in risk to others, and increased caution by drivers.

Energy Conservation
Consumption of natural resources, such as petroleum, can impose various external costs, include macroeconomic impacts and national security risks from dependence on imported petroleum, environmental damages, climate change impacts, and the loss of resources available for future generations. Put another way, resource conservation can provide various benefits to society. The external costs of petroleum consumption are estimated to be 1-4¢ per vehicle-mile for an average automobile (NRC, 2001). These impacts tend to be higher for short trips, due to cold starts, and under congested, urban travel conditions.

Estimated Benefits: Energy conservation benefits of a shift from driving to walking or cycling are estimated to average 5¢ per urban peak mile, 4¢ per urban off-peak mile, and 3¢ per rural mile.

Pollution Reduction
Walking and bicycling produce no air pollution. Per mile emission reductions are large because they usually replace short, cold-start trips for which internal combustion engines have high emission rates, so each 1% of automobile travel replaced by walking or cycling decreases motor vehicle emissions by 2% to 4% (Komanoff and Roelofs, 1993).

Estimated Benefits: Automobile air pollution costs are estimated to average 1¢ to 12¢ per automobile mile, with relatively high values under congested urban conditions (Small and Kazimi, 1995; McCubbin and Delucchi, 1996). Many monetized estimates include only a limited portion of total air pollution costs (for example, many ignore particulate pollution and air toxics), so a relatively high value is appropriate. A conservative estimate is 10¢ per mile for urban-peak driving, 5¢ for urban off-peak and 1¢ for rural driving.

SQW (2007) estimates that shifting from automobile to cycling provides air pollution emission reductions valued at 11.1British Pence per car kilometre in major cities and Pence in rural areas. 5.8 pence for petrol cars and and 32.2 pence for diesel cars in an urban area, and 2.1 pence for petrol cars and 2.0 pence per kilometer for diesel cars in rural areas. Table 5 summarizes these results.

Table 5 **Pollution Reduction Benefits** (SQW 2007)

	Urban	Rural
Petrol cars	5.8	2.1
Diesel cars	32.2	2.0
Weighted Average	11.1	2.1

Noise

Vehicle noise imposes disturbance and discomfort. Estimates of noise costs range from 0.2¢ to 5¢ per vehicle mile, depending on location and type of vehicle (Litman, 2009). Noise costs are greatest in dense urban areas where exposure is greatest (i.e. people are located close to roads).

Estimated Benefits: Noise reduction benefits from automobile travel shifted to nonmotorized modes are estimated to average 3¢ per mile for urban-peak driving, 2¢ for urban off-peak and 1¢ for rural driving.

Health and Fitness Benefits
Nonmotorized travel involves physical exercise which can provide substantial health benefits (AJHP 2004; "Health and Fitness," VTPI 2004). Inadequate physical exercise and excessive body weight are increasing problems that results in a variety of medical problems, including cardiovascular diseases, bone and joint injuries, and diabetes. About ten times as many people die from these medical problems than from traffic accidents. Although there are many ways to be physically active, increased walking and cycling are among the most practical and effective, particularly for inactive and overweight people (Sevick, et al. 2000). Recent studies indicate that residents of more walkable communities exercise more and are less likely to be overweight than residents of automobile-oriented communities (Ewing, Schieber and Zegeer 2003; Frank 2004).Some studies indicate that employes who bicycle commute are more productive, more punctual, and take less sick days (Shayler, et al, 1993; Queensland Transport 1999).

Some studies have monetized (measured in monetary values) the health benefits of improved walking and cycling ("Safety and Health," Litman 2009; Boarnet, Greenwald and McMillan 2008; SQW 2007). The UK Traffic Advisory Unit estimated that workplace cycling programs provide a $1.33 - $6.50 return for each $1 spent in cycle promotion due to increased productivity (Shayler, et al. 1993). A Scandinavian study estimates that a physically inactive person who shifts from automobile to bicycle commuting gives an economic benefit to the community of approximately 3,000-4,000 Euro per year (Sælensminde, 2002). Table 6 summarizes some of these study results.

Table 6 **Active Transportation Health Benefits** (SQW 2007)

	Annual Value Per Additional Cyclist	Notes
SQW calculations	£22 for 16 - 44 £235 for over 45	Inactive people achieving definition of active (30 minutes a day, 5 times a week) as a result of cycling
	£11.16 for 16 – 44 years £99.53 for 45 - 64 years £242.07 for 65 years and over £58.77 weighted average	Values calculated using National Heart Forum results. Assumes a "step" increase in physical activity associated with cycling e.g. sedentary people become lightly active, lightly active become moderately active etc. Shown by age and includes uplift to allow for stroke and colon cancer
DCMS Game Plan (2002)	Between £40.79 and £50.73 depending on scenario	Implied value from report results. Uses foregone earnings, not full welfare costs
Copenhagen Heart Study/Rutter	£498	Based on all cyclists (not just those becoming active) and all causes of mortality. Applied to UK mortality data and DfT value of life by Rutter
DfT/Sustrans model	£123	Uses number of deaths through inactivity and the National Heart Forum average values
TfL Business case (2006)	£88	As above but using London data
MACAW model	40 pence per kilometer	Assumed to be part of long term regular cycling

Land Transport NZ's Economic Evaluation Manual (EEM) outlines standards for the economic evaluation of both transportation infrastructure projects and transportation demand management (TDM) measures in New Zealand. It provides monetary values for the health benefits of active transportation resulting from both TDM measures and active transport infrastructure. It assumes that half of the benefit is internal to the people who increase their activity level by walking or cycling, and half are external benefits to society such as hospital cost savings.

Table 7 **Active Transportation Health Benefits** (LTNZ 2006)

	2005 $ NZ/km	2007 USD/km	2007 USD/mile
Cycling	0.16	0.12	0.19
Walking	0.40	0.30	0.48

Estimated Benefits: Walking and cycling can provide large health benefits, probably exceeding external accident reduction benefits. In other words, these benefits probably exceed 5¢ per mile of driving shifted to nonmotorized modes.

Improved Mobility for Non-Drivers

Walking and cycling help provide *basic mobility*, that is, they provide access to activities that society considers essential or important, such as medical services, education, employment, basic commercial and social activities ("Basic Access," VTPI, 2004). This provides benefits both to users and to society overall, by improving people's opportunities to participate in economic and social activities. People who are transportation disadvantaged depend significantly on nonmotorized modes. According to the 1990 National Personal Transportation Survey (NPTS), residents of households that do not own an automobile make 43% of trips by walking, 36% by car, and 16% by public transit (although transit probably provides about the same number of passenger-miles, since transit trips tend to be longer than walking trips). Even people who currently rely primarily on automobile travel may value having alternatives available in case they need them in the future, called *option value* ("Transportation Diversity," Litman, 2004).

Estimated Benefits: Although these benefits are large, they are difficult to quantify ("Evaluating Transportation System Diversity," VTPI, 2004; Litman, 2004c). One approach is to use transit subsidies as an indicator. Transit subsidies average about 60¢ transit passenger-mile, about half of which are justified to provide basic mobility for non-drivers (the other half are intended to attract motorists to transit in order to reduce traffic congestion, parking and pollution problems). This indicates that basic mobility is worth more than 30¢ per passenger-mile to society. To the degree that walking and cycling also provide basic mobility, their benefits should be comparable.

Strategic Land Use Development Objectives
Nonmotorized transportation can help achieve various strategic land use planning objectives by reducing the amount of land that must be paved for roads and parking facilities, and encouraging more compact development patterns (Litman, 1995; "Land Use Evaluation," VTPI, 2004). Nonmotorized transportation supports *smart growth* (also called New Urbanism) which refers to policies designed to create more resource efficient and accessible land use patterns. Table 8 lists potential smart growth benefits.

Table 8 **Smart Growth Benefits** (Burchell, et al, 1998; Litman 1995)

Economic	Social	Environmental
Reduced development and public service costs. Consumer transportation cost savings. Economies of agglomeration. More efficient transportation.	Improved transportation choice, particularly for nondrivers. Improved housing choices. Community cohesion.	Greenspace and wildlife habitat preservation. Reduced air pollution. Reduce resource consumption. Reduced water pollution. Reduced "heat island" effect.

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

Estimated Benefits: Shifting from sprawl to smart growth land use patterns can provide thousands of dollars in total annual per capita net benefits from public and consumer cost savings, increased economic productivity and improved environmental quality (Litman, 1995; Burchell, et al, 1998; Litman, 2009). To the degree that nonmotorized travel improvements affect land use patterns they can help provide these benefits.

Economic Development
Improved walking and cycling conditions and shifts from motorized to nonmotorized modes can increase economic productivity and development (Buis 2000; "TDM and Economic Development," VTPI 2004; NCDOT 2004; LAW 2009). As mentioned above, it helps create more economically efficient land use patterns. Nonmotorized facilities (trails and sidewalks) can increase nearby property values and help attract residents and industries that value environmental quality, physical fitness and outdoor recreation (NBPC, 1995; LGC, 2001). 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 home, and the following community amenities rated *important* or *very important*: jogging/bike trails (36%), sidewalks (28%), and shops within walking area (19%) (NAR & NAHB 2002).

Walking and cycling facility improvements and promotion programs can provide economic development benefits by increasing shopping opportunities (Transportation Alternatives & Schaller Consulting 2006; LAW 2009; Sztabinski 2009) and tourism activity (NBPC, 1995). One study estimates that rail trails in Australia provide an average of $51 in regional economic per cycle tourist per day (Beeton 2003).

Various studies indicate that well-planned nonmotorized transportation improvements can increase customer visits and business activity in an area (Hass-Klau, 1993; Lane, 2001). A German study showed that (European Commission 1999):

- Motorists are not better customers than cyclists, pedestrians, or users of public transport.
- Because they buy smaller quantities, cyclists go to shops more frequently (11 times a month on average, as opposed to 7 times a month for motorists).
- Approximately 75% of motorists purchase two or less bags of goods, and so could carry their purchases by walking or cycle.
- Most shopping trips involve distances that could be walked or cycled.
- The study concluded that a large number of motorists could shop by nonmotorized modes.

Reducing vehicle expenditures tends to increase regional employment and business activity because fuel and vehicles are generally imported from other areas (Litman and Laube, 1998; "TDM and Economic Development," VTPI, 2004). Shifting a million dollars in consumer expenditures for automobiles to a normal bundle of goods creates about 9 regional jobs and increases regional income about $250,000 (Miller, Robison and Lahr 1999).

Estimated Benefits: Nonmotorized travel improvements and shifts from driving to nonmotorized travel can provide a variety of benefits, each requiring separate analysis. Improved nonmotorized facilities can increase nearby property values. Because reduced automobile travel saves about 20¢ per mile in vehicle costs, each million miles reduced adds about two regional jobs and increases regional income by about $45,000.

User Enjoyment

Many people enjoy walking and cycling, as indicated by their popularity as recreational activities, and increased property values near public trails and parks. Walking and cycling are among the most popular form of physical recreational activity. Many transportation walking and cycling trips (that is, they have a practical function, such as commuting to work or running errands) also provide recreational enjoyment benefits. Mobility management programs that improve walking and cycling conditions (such as improved trails, sidewalks, streetscapes; security improvements; cycling skills development, encouragement programs, etc.) can provide user enjoyment benefits similar to those provided by public parks and trails.

Estimated Benefits: Typical communities spend more than a hundred dollars annually per capita on physical recreation facilities, such as parks and public recreational centers. This suggests that walking and cycling improvements that allow more people to engage in nonmotorized travel for both transportation and purely recreational purposes can provide benefits of significant value.

Community Livability and Social Benefits

Community Livability refers to the quality of an area perceived by residents, employees, customers and visitors (Litman, 1995; "Livability," VTPI, 2004). This includes safety and health (traffic safety, personal security, public health), local environmental conditions (cleanliness, noise, dust, air quality, water quality), social interactions (neighborliness, respect, community identity and pride), opportunities for recreation and entertainment, aesthetics, and existence of unique cultural and environmental resources (e.g., historic structures, mature trees, traditional architectural styles).

Automobile-oriented transport tends to result in community development patterns that are suboptimal for other community objectives (Forkenbrock and Weisbrod, 2001). Wide roads and heavy traffic tend to degrade the public realm (public spaces where people naturally interact) and in other ways reduce livability. Reduced vehicle traffic tends to increase neighborly interactions and community involvement (Appleyard, 1981). Untermann and Vernez Moudon (1989) comment,

> "A deeper issue than the functional problems caused by road widening and traffic buildup is the loss of sense of community in many districts. Sense of community traditionally evolves through easy foot access–people meet and talk on foot, which helps them develop contacts, friendships, trust, and commitment to their community. When everyone is in cars there can be no social contact between neighbors, and social contact is essential to developing commitment to neighborhood."

Improved walking and cycling conditions, increased nonmotorized travel and reductions in motorized travel tend to increase community livability. Walking and cycling provide a more intimate connection between people and their surroundings than can generally occur when people drive. To the degree that shifts to nonmotorized travel reduce motor vehicle traffic volumes and parking demand, it increases design flexibility that helps preserve cultural features (e.g., preserving historic sites), improve community services (provide more space for sidewalks, parks and landscaping), and support other community development objectives (such as urban redevelopment and reduced sprawl).;

Estimated Benefits: Although these impacts are often significant, as reflected in higher property values, more tourism and increased retail activity in areas considered more livable, it is difficult to quantify the value provided by a particular travel shift.

Additional Environmental Benefits

Automobile travel and highway facilities contribute to several additional environmental problems, including water pollution, wildlife deaths, habitat fragmentation and increased impervious surface (FHWA 1993; FHWA 2008; Litman 2009). Shifts from automobile to nonmotorized travel reduces these costs.

Estimated Benefits: These benefits are highly variable, depending on conditions, and difficult to measure, but in many situation they are significant (Litman, 2004).

Benefit Summary

Improved walking and cycling conditions, increased nonmotorized travel, and shifts from motorized to nonmotorized modes provide various benefits. Table 9 lists the benefit categories described in this paper, identifies travel the changes to which they apply, and provides monetized estimates if available. Additional health, land use, economic, user livability and environmental benefits are not monetized, but probably significant.

Table 9 **Estimated Benefits of Nonmotorized Transport**

Benefits	Applies	Urban Peak	Urban Off-Peak	Rural
Congestion Reduction	C	$0.20	$0.02	$0.00
Roadway Cost Savings	C	$0.05	$0.05	$0.03
Vehicle Cost Savings	C	$0.25	$0.20	$0.15
Parking Costs (per trip)	C	$2.00	$1.00	$0.50
Air Pollution Reduction	C	$0.10	$0.05	$0.01
Noise Pollution Reduction	C	$0.03	$0.02	$0.01
Energy Conservation	C	$0.05	$0.04	$0.03
Traffic Safety Benefits	C	$0.05	$0.04	$0.03
Health and Fitness Benefits	B & C	NA	NA	NA
Improved Mobility For Non-Drivers	A, B & C	NA	NA	NA
Strategic Land Use Objectives	A, B & C	NA	NA	NA
Economic Development	A & C	NA	NA	NA
User Enjoyment	A & B	NA	NA	NA
Community Livability	A, B & C	NA	NA	NA
Additional Environmental Benefits	C	NA	NA	NA
Total Per Mile		*> $2.73*	*> $1.42*	*> $0.76*
Average Walking Trip (0.6 miles)		*> $1.67*	*> $0.85*	*> $0.46*
Average Cycling Trip (2.0 miles)		*> $5.56*	*> $2.84*	*> $1.52*

(*Applies*: A = Improved nonmotorized conditions; B = Increased nonmotorized travel; C = Reduced automobile mileage. NA = Not available.).

This table lists various benefits of nonmotorized transport, and provides monetized estimates where possible. Many benefits not monetized, so the value of shifts from motorized to nonmotorized travel is likely to be greater than indicated by these estimated totals.

Analysis of mode shift benefits should be based on the automobile mileage reduced, not the increased nonmotorized travel. As described earlier, shifts to nonmotorized modes often leverage additional motorized travel reductions. This analysis indicates that typical trips shifted from automobile to walking or cycling provide benefits worth at lease $0.46 to $5.50, and probably much more considering all benefits, including those unsuited for monetization, and leveraged vehicle mileage reductions. If seven motor vehicle-miles are reduced for each increased mile of nonmotorized travel through broader changes in transportation and land use patterns, as the data suggest, then benefits exceed $3.29 per walking trip and $38.50 per cycling trip. Of course, actual benefits vary depending on the type of trip and travel conditions.

Some of these benefits are *internal* (enjoyed by the user), and others are *external* (enjoyed by others). That some benefits are internal should not diminish their importance. Society supports many projects and services to benefit users, including road and parking facilities to benefit motorists, transit to provide mobility, and parks to provide recreation.

Strategies to Increase Nonmotorized Travel

Various mobility management strategies that improve nonmotorized conditions and encourage nonmotorized travel are described below. For more information see the *Online TDM Encyclopedia* (VTPI, 2004), and various other information sources (ADONIS, 1999; ITE, 1999; FHWA, 2004).

Nonmotorized Planning and Facilities

Better planning can improve the quantity and quality of pedestrian facilities, such as paths, sidewalks and crosswalks ("Pedestrian and Bicycle Planning," VTPI, 2004). High-quality multi-use paths can increase nonmotorized travel on a corridor. Such trails are often highly valued by communities and can increase nearby property values (NBPC, 1995). Special paths are particularly helpful if they connect common destinations (homes, worksites, schools, campuses, commercial areas, recreation centers, etc.) and provide shortcuts.

Nearly all communities with high levels of bicycle transportation have extensive path and bike lane networks. One study found that each mile of bikeway per 100,000 residents increases bicycle commuting 0.075 percent (Nelson and Allen, 1997). However, a poorly designed or maintained bicycle facility can be more dangerous than none at all.

Developing urban bicycle lanes often involves a tradeoff with on-street parking. There are three justifications for choosing bicycle lanes over automobile parking in such situations:

1. *Equity*. Local roads are funded through local taxes that residents pay regardless of their travel patterns. It is only fair that bicyclists receive a share of road space and funds.
2. *Priority*. Mobility is the primary function of public roads, and is the justification for devoting public land and financial resources to them. Vehicle storage (i.e., on-street parking) can be considered a less important function than traffic movement, since offstreet parking can be supplied by private firms. Since bicycle lanes can improve traffic flow for both bicyclists and motor vehicles, such facilities deserve higher priority than on-street parking.
3. *Parking efficiency*. Reduced automobile parking capacity that results when on-street parking spaces are converted to bike lanes can be offset if the bike lanes result in reduced automobile trips. For example, if 80 automobile parking spaces are converted to bike lanes which results in an average daily shift of 100 commute trips from automobile to bicycle, there would be a net *gain* of 20 parking spaces.

Roadway Improvements

Some relatively inexpensive roadway improvements can improve cycling conditions (Litman, et al, 2002. These include pothole filling, paving road shoulders, installing curb cuts and smoothing railroad crossings. Some communities establish "spot improvement" programs. Some arterials lanes can be converted to bicycle lanes with no reduction in traffic capacity. Many highway agencies and local governments now specify that all highways and arterials without curbs have a smooth shoulder of 1-3 metres wherever possible, in part to more safely accommodate cyclists.

Bicycle Parking and Changing Facilities
Long-term parking must keep bicycles and accessories safe from theft and protected from weather ("Bicycle Parking," VTPI, 2004). Racks must be well designed and located for convenience and security. Bicycle commuters may need showers and lockers. In some situations, 5-20% of trips to a destination can be by bicycle, particularly schools and campuses, worksites and commercial areas in communities that encourage cycling.

Traffic Calming
Traffic calming includes a number of strategies that control vehicle traffic volumes and speeds, and improve road conditions for pedestrians and cyclists ("Traffic Calming," VTPI, 2004). This tends to improve walking and cycling conditions, increase nonmotorized travel, and reduce automobile travel.

Nonmotorized Encouragement and Safety Programs
Employers, bicycle clubs, and other organizations can promote pedestrian and bicycle transportation, sponsor promotional events and contests, distribute safety information and support safety campaigns. A map that highlights preferred bicycle routes can encourage bicycle transportation, especially beginning riders.

Bicycle-Transit Integration
Bicycling and transit are complementary modes ("Bike/Transit Integration," VTPI, 2004). Bicycling is ideal for making short trips in low traffic areas, while transit is most efficient on longer trips on congested corridors. Bicycles are widely used to access transit stations in many parts of the world. Such intermodal bicycle trips can be encouraged by providing secure bicycle storage at transit stations and park-and-ride lots, by allowing bicycles to be carried on buses and trains, and by promoting bicycling along with other efficient modes.

Transit Improvements
Virtually every transit trip includes walking or cycling links. As a result, efforts to improve transit service and increase transit ridership often involve walking and cycling improvements, including better sidewalks, bike paths and bicycle parking around stations, and more accessible land use patterns that create pedestrian-oriented urban villages along transit lines.

Commute Trip Reduction (CTR) Programs.
Commute Trip Reduction (CTR) programs provide commuters with resources and incentives to reduce their automobile trips ("Commute Trip Reduction," VTPI, 2004). These can be effective at worksites and campuses in both urban and suburban locations. Automobile trip reductions of 10-30% are common among affected commuters, and a significant portion of trips often shift to nonmotorized modes, either alone or in conjunction with transit and ridesharing. Nonmotorized travel conditions around worksites and campuses are also important because commuters are more likely to use alternative modes if they can walk to nearby services for errands during breaks.

Transportation Price Reforms

Various transportation price reforms are justified on economic efficiency and equity grounds, including road pricing, parking pricing, Pay-As-You-Drive vehicle insurance and registration fees, and increased fuel taxes (VTPI, 2004). These change travel patterns in various ways, including shifts to nonmotorized modes, either alone or in conjunction with transit and ridesharing.

Land Use Policies

Smart growth, *new urbanism* and *transit oriented development* refer to land use development polities that create more compact, mixed, multi-modal, walkable communities ("Smart Growth," VTPI, 2004). These can be implemented in various ways and at various scales. Residents and employees in communities that reflect these design principles often drive 20-35% less and use nonmotorized modes two to four times more than residents of more conventional, automobile-oriented communities ("Land Use Impacts on Transportation," VTPI, 2004). These improved nonmotorized accessibility is particularly important for non-drivers.

Summary

Table 10 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 nonmotorized travel conditions, increasing nonmotorized travel, and shifting 10-30% of motorized travel to nonmotorized modes.

Table 10 **Travel Impacts of Strategies to Encourage NonMotorized Travel**

Strategy	Improves Nonmotorized Conditions	Increases NMT Travel	Reduces Automobile Travel
Pedestrian & Bicycle Facilities	Significant	Significant	Moderate
Roadway Improvements	Moderate	Moderate	Small
Bicycle Parking & Showers	Significant	Moderate	Small
Traffic Calming	Significant	Moderate	Small
Encouragement & Safety Programs	Moderate	Moderate	Small
Bicycle-Transit Integration	Moderate	Small	Small
Transit Improvements	Small	Moderate	Significant
Commute Trip Reduction	Moderate	Moderate	Significant
Transportation Price Reforms	Small	Moderate	Significant
Land Use Policy Reform	Significant	Significant	Significant

("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 nonmotorized conditions, increase nonmotorized travel and reduce automobile travel.

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 nonmotorized transport (also see Nelson 1995; Ker 2001; Litman 2001; Sælensminde 2004). The following formula can be used to determine the maximum investment justified for policies or programs that shift travel from automobile to walking or cycling.

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

Example 1: Pedestrian Facility

Table 11 shows the estimated monetized benefits to society of 10,000 miles shifted from driving to nonmotorized 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. Because many significant benefits are not monetized in this analysis (health and enjoyment benefits to users, improved community livability and social cohesion), total benefits are probably much greater, so a larger investment could be justified. This analysis assumes a 1:1 mode substitution rate, that is, each nonmotorized mile substitutes for one motor vehicle mile.

Table 11 **Benefits of 1,000 Miles Shifted To Nonmotorized 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 nonmotorized 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 paper (each nonmotorized 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 nonmotorized 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 nonmotorized travel encouragement programs.

Example 2: Cycling Program

Table 12 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 nonmotorized 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 12 **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 (Table 5)	$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: Nonmotorized Component of Commute Trip Reduction Program

Table 13 shows the monetized benefits from a commute trip reduction program that convinces 100 employees who would otherwise drive to walk or bicycle, 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 nonmotorized travel leverages additional reductions in motorized travel, for example, if some households reduce their automobile ownership.

Table 13 **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 nonmotorized modes at a typical urban worksite.

Conclusions

Improving nonmotorized conditions, increased nonmotorized travel, and shifting travel from automobile to nonmotorized modes can provide many benefits, including internal benefits to the people who use these modes and external benefits to others. Nonmotorized transport plays a unique and important role in the transportation system. It provides health and fitness, enjoyment, basic mobility, connections between and access to other modes, opportunities for people to interact with their communities and the environment, and a cost effective alternative to motorized travel. Improved and increased nonmotorized transportation can help achieve a variety of transportation planning objectives, both alone and in conjunction with other modes. Improved and increased nonmotorized travel tends to leverage additional motor vehicle travel reductions. Analysis in this study suggests that each mile of increased nonmotorized transport reduces about seven motor vehicle miles.

Conventional planning and evaluation practices tends to overlook or undervalue many nonmotorized transportation benefits. More comprehensive evaluation methods are needed to identify the full benefits of policies and investments that improve nonmotorized travel and encourage shifts from motorized to nonmotorized modes.

Some nonmotorized benefits are suitable for monetization using methods commonly used by transportation agencies to evaluate policies and investments. These include congestion reductions, road and parking facility cost savings, consumer cost savings, energy conservation and emission reductions, and reduced accident risk to other road users. Other benefits are more difficult to monetize, although they are probably significant compared with commonly monetized impacts. These include health and fitness benefits, improved mobility for non-drivers, support for strategic land use objectives, economic development, user enjoyment, community livability, and additional environmental benefits. Table 14 shows the monetized benefits of shifts from automobile to nonmotorized travel under three travel conditions. Total benefits are probably far greater, taking into account additional, unmonetized benefits and leverage effects.

Table 14 **Automobile to Nonmotorized Travel Monetized Benefits**

	Urban Peak	Urban Off-Peak	Rural
Total Per Mile	*> $2.75*	*> $1.43*	*> $0.76*
Average Walking Trip (0.6 miles)	*> $1.68*	*> $0.86*	*> $0.46*
Average Cycling Trip (2.0 miles)	*> $5.60*	*> $2.86*	*> $1.52*

This table indicates the monetized benefits of shifts from automobile to nonmotorized modes. Additional benefits are not monetized, so total benefits are likely to be much greater.

There are many ways to improve and encourage nonmotorized 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, they are seldom considered the most effective way of solving a particular problem. However, they provide multiple and synergistic benefits. When all benefits are considered, much greater support is often justified for walking and cycling.

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