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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," published in *Transportation Research Record*, No. 1441 ("Nonmotorized Transportation Around the World"), 1994, pp. 134-140.

Introduction

There are two general ways to improve transportation system performance. One is to increase motor vehicle capacity, for example, by expanding roads and parking facilities. The other, called *mobility management* (also called *transportation demand management*, or *TDM*), is to use existing vehicle facilities more efficiently (VTPI, 2004). Mobility management is increasingly accepted by transportation professionals and applied in many situations (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	Congestion pricing	Smart growth	Commute trip reduction programs
Walking improvements	Distance-based fees	New urbanism	School and campus transport management
Cycling improvements	Employee transportation benefits	Location-efficient development	Tourist transport management
Bicycle parking facilities	Parking cash out	Parking management	Transit marketing
Bike/transit integration	Parking pricing	Transit oriented development	Nonmotorized encouragement
Guaranteed ride home	Pay-as-you-drive vehicle insurance	Carfree planning	
	Fuel tax increases	Traffic calming	

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

Nonmotorized transport (*NMT*, also called *active transport* and *human powered transport*; which includes walking, cycling, and their variants such as wheelchair travel, skating and handcarts) plays an important role in mobility management. When motorists reduce their vehicle use in response to mobility management programs, a significant portion of trips often shift to walking and cycling, either entirely or in conjunction with other alternative modes such as transit and ridesharing (as discussed in more detail later).

Improving nonmotorized travel conditions, increasing nonmotorized travel, and shifts from motorized to nonmotorized transport can provide various benefits, such as those listed below.

Box 1 **Benefits From Motorized to Nonmotorized Travel Shifts**

- Reduced traffic congestion.
- Reduced parking problems.
- Road and parking facility cost savings.
- Consumer cost savings.
- Reduced crash risk to other road users.
- Increased health and fitness.
- Air and noise pollution reductions.
- Supports strategic development objectives.
- Energy conservation.
- Increased local employment due to reducing expenditures on petroleum and vehicles.
- Creates more livable communities.
- Improved public realm (public spaces where people interact) and increasing social cohesion (interactions between people in a community).
- Improved mobility options for non-drivers.

Shifts from motorized to nonmotorized travel can provide many benefits, some of which are often overlooked.

The Role of Nonmotorized Transport

Nonmotorized travel (particularly walking) plays a unique and critical role in the transportation system. Walking is a fundamental human activity which provides physical fitness, enjoyment and essential mobility. Nonmotorized travel facilitates many other activities, including thinking, conversing, social interactions and exploring. It serves young and old, rich and poor, transportation and recreation activities, and many other functions. Walking provides connections between activities and modes. Buildings, parking lots, train stations, transit terminals and airports are all pedestrian environments that depend on walking for circulations and connections. Even space travel is often described as allowing humans to *walk* on the moon or other planets.

Most motorized trips involve nonmotorized links. For example, motorists must walk from parking facilities to their destination, and often walk between nearby destinations. Air travelers must walk from their vehicles to airports and for circulation within terminals. Most transit trips involve nonmotorized links, so walking and cycling conditions determine the functional area of transit service. Commuter are more likely to use transit and rideshare if they can easily walk from their worksite to transit stops, and to nearby restaurants and shops for personal errands. As a result, walking and cycling improvements are often an effective way to improve other modes.

Nonmotorized travel provides many indirect benefits. A community designed for walking and cycling must be compact (so many destinations are within convenient distance of each other), connected (with streets that allow direct travel), designed at a human scale, have functional and attractive sidewalks and paths, have effective strategies to control traffic speeds, and feel safe to vulnerable users. Increased nonmotorized travel tends to improve community cohesion (the quality of neighborly interactions), security and aesthetics. These features provide many benefits besides just mobility.

However, nonmotorized travel is often overlooked and undervalued. Conventional travel surveys find that only about 2% of total travel is by nonmotorized modes, which implies that it is unimportant, and improving nonmotorized conditions can do little to solve transport problems. But conventional surveys undercount nonmotorized travel because they ignore short trips, non-work travel, travel by children, recreational travel, and nonmotorized links. Actual nonmotorized travel is usually three to six times greater than these surveys indicate (Litman, 2004b). Nonmotorized travel tends to be stigmatized. Some people consider walking and cycling outdated, unsophisticated and unexciting compared with motorized modes, or even as symbols of poverty and failure.

To their credit, many transportation professionals give nonmotorized transportation more consideration than justified by their travel survey data. They realize that nonmotorized travel has critical functions in an efficient and balanced transportation system, some of which are difficult to measure. However, this occurs in spite of, rather than supported by, conventional transportation planning analysis. There is much that can be done to improve evaluation of nonmotorized transportation.

Travel Impacts

The benefits of a nonmotorized program are affected by their travel impacts, including increases in nonmotorized travel and reductions in motorized vehicle travel. 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.

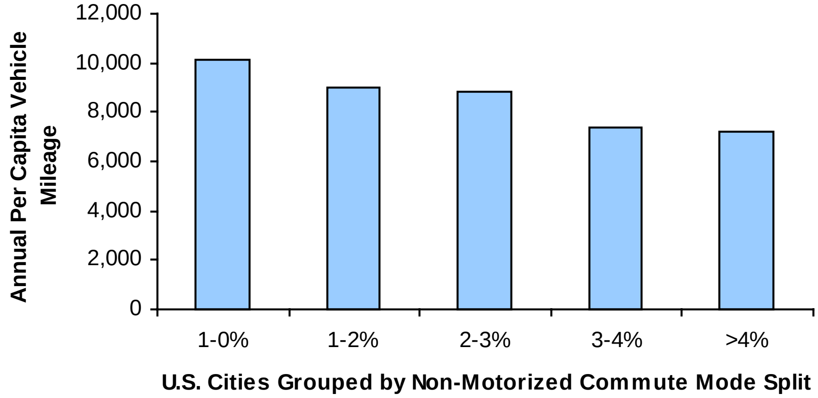
When nonmotorized travel increases due to improved conditions, not all new walking and cycling trips substitute for automobile trips, some reflect increased total travel (including recreational trips) or shifts from transit or ridesharing. Typically, 20% to 50% of increased nonmotorized travel substitutes for motorized travel, depending on conditions.

When pricing incentives and vehicle restrictions reduce automobile travel, a significant portion often shift to nonmotorized modes ("Transport Elasticities," VTPI, 2004). Shorter trips (less than three miles) tend to shift entirely to nonmotorized modes, and longer trips shift to combined transit and nonmotorized trips. For example, when UK residents were asked how they could reduce vehicle tirps 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, a federal Competition Bureau survey found that 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. Shoup (1997) found that parking cash out (allowing commuters to exchange a free parking space for cash) caused a 13-point reduction in automobile trips, a 9-point increase in carpooling, a 9-point increase in transit use, and a 1-point increase in nonmotorized commute trips.

In addition to person-miles shifted from motorized to nonmotorized travel, increased nonmotorized transportation tends to 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. When people shift to nonmotorized travel for a particular trip, or when households reduce their vehicle ownership due to improved nonmotorized conditions, they tend to reduce their total vehicle mileage. Nonmotorized transport supports *smart growth* land use patterns (more compact, mixed, multi-modal development) that reduce travel distances and total motorized travel ("Smart Growth," VTPI, 2004).

Figure 1 shows average per capita annual vehicle mileage in U.S. cities categorized by nonmotorized commute mode split. As nonmotorized travel increases, average vehicle mileage declines. Although nonmotorized mode split is small (representing less than 5% of trips and probably less than 1% of person-miles, since nonmotorized trips tend to be shorter than motorized trips), the mileage differences are large. Each percentage point increase in nonmotorized transport is associated with about 700 fewer annual vehicle-miles. Assuming commute mode split is representative of total personal travel, urban residents average 10,000 annual person-miles, and nonmotorized trips average one mile in length, each nonmotorized mile is associated with seven reduced vehicle-miles.

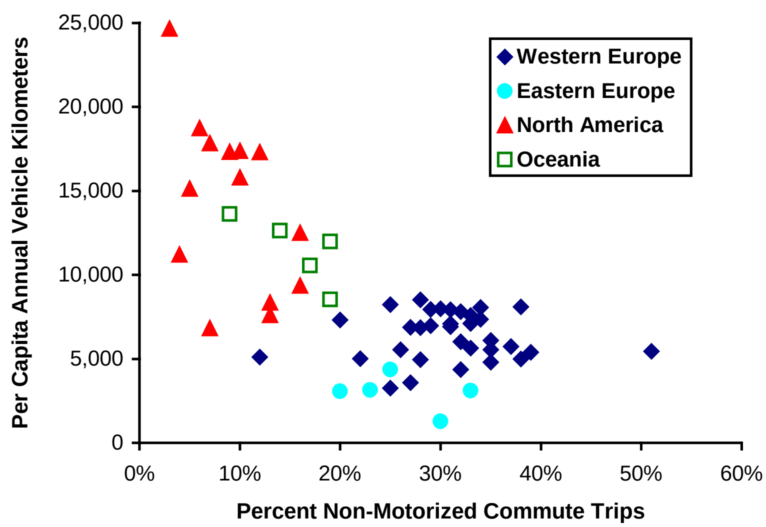
Figure 1 **Vehicle Mileage Vs. Nonmotorized Commuting** (Census and FHWA Data, 2000)



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.

International data also indicate that increased nonmotorized travel is associated with reduced driving, as indicated in Figure 2. Of course, association does not prove causation. 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 land use and transport system factors, 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 create such communities, which is to say that smart growth supports nonmotorized travel and nonmotorized travel supports smart growth. As a result, mobility management programs that increase nonmotorized transport usually leverage reduced motorized travel, causing proportionately larger reduction in vehicle-miles, although exactly how much depends on the situation.

Figure 2 **Nonmotorized Vs. Motorized Transport** (Kenworthy and Laube, 2000)

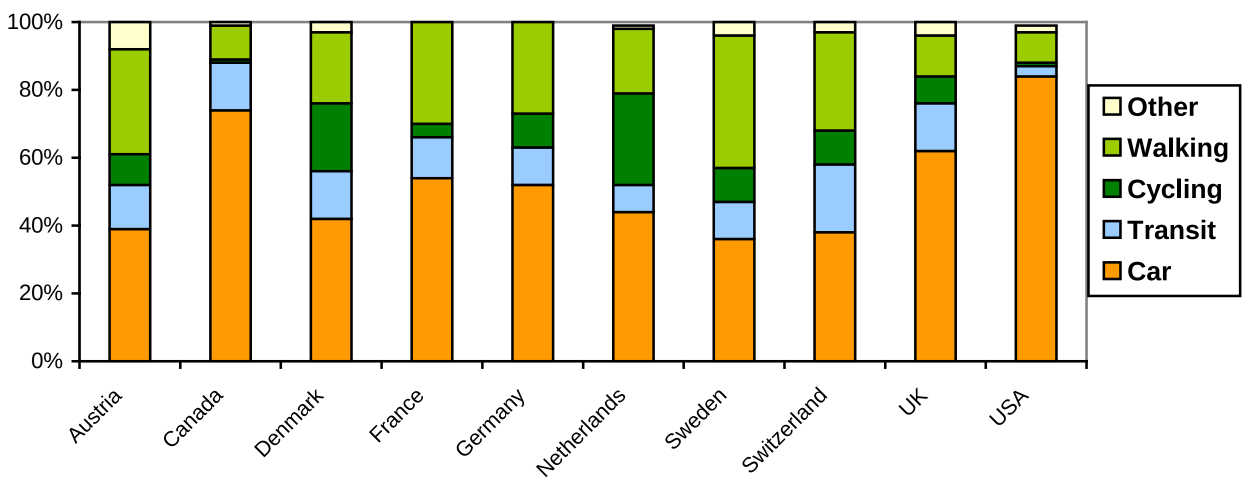


International data show that vehicle travel tends to decline as nonmotorized travel increases.

These leverage effects probably apply only to nonmotorized travel used for transportation purposes, not to recreation walking and cycling. For mobility management evaluation an important question is the degree that factors that can be changed through public policies can increase nonmotorized travel and leverage reductions in motorized travel in the short or medium term. If higher nonmotorized transport and lower motor vehicle mileage in different geographic areas completely reflect the legacy of patterns established decades earlier, it may be futile to try to change them. However, at least some of factors can be changed by public policies in medium-term, including nonmotorized facility quality, traffic management practices, financial incentives (such as road and parking pricing) and public information and attitudes can be changed in the short term, and other factors, such as the location of public facilities, the design of new buildings, and community redevelopment practices. Many communities have experienced significant nonmotorized travel growth and reductions in nonmotorized travel over a few years due to policy changes and mobility management programs ("Success Stories," VTPI, 2004).

Some experts conclude that walking and cycling can do little to solve transportation problems because they only consider current commute trips that can shift completely to nonmotorized modes (Comsis, 1993; Apogee, 1994). But other studies give more positive assessments of potential travel impacts. According to some studies, 5-10% of urban automobile trips can reasonably be shifted to nonmotorized transport (ADONIS, 1999; Mackett, 2000; Socialdata Australia, 2000; Cairns et al, 2004).

Figure 3 **Urban Mode Split** (Pucher and Lefevre, 1996)



This figure shows the portion of urban travel by different modes in various countries. Nonmotorized travel varies significantly from one country to another.

For example, the Australian TravelSmart program uses various incentives to encourage residents to use alternative travel modes (Socialdata Australia, 2000). Before-and-after surveys find that automobile trips decline by 5% to 14%, and that about half of these reductions result from shifts to nonmotorized travel. Rates of nonmotorized travel vary significantly from one community to another, depending on land use patterns, transportation system design factors, and community attitudes, as indicated in Figure 3. Even relatively cold and hilly countries, such as Sweden, Switzerland and Germany achieve high levels of nonmotorized travel. Similarly, North American cities, such as Eugene, Oregon and Missoula, Montana have much higher rates of nonmotorized travel due to supportive public policies.

One study found that residents in a pedestrian friendly community walked, bicycled, or rode transit for 49% of work trips and 15% of their non-work trips, 18- and 11-percentage points more than residents of a comparable automobile oriented community (Cervero and Radisch, 1995). Another study found that walking is three times more common in a community with pedestrian friendly streets than in otherwise comparable communities that are less conducive to foot travel (Moudon, *et al*, 1996). Handy (1996) found that a more pedestrian-friendly residential and commercial environment in Austin, Texas neighborhoods increases walking and reduces automobile travel for errands such as local shopping. About two-thirds of walking trips to stores replaced automobile trips.

Most communities appear to have significant latent demand for pedestrian travel, that is, people would walk more frequently if they had suitable facilities and resources. 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). The table below summarizes a Canadian public survey indicating high levels of interest in cycling and walking.

Table 2 **Active Transportation Survey Findings** (Environics, 1998)

	Cycle	**Walk**
Currently use this mode for leisure and recreation.	48%	85%
Currently use this mode for transportation.	24%	58%
Would like to use this mode more frequently.	66%	80%
Would cycle to work if there "were a dedicated bike lane which would take me to my workplace in less than 30 minutes at a comfortable pace."	70%	NA
Support for additional government spending on bicycling facilities.	82%	NA

This survey indicates a high level of interest in cycling and walking.

Comprehensive Evaluation

Comprehensive evaluation takes into account all significant impacts (benefits and costs) from transportation services and activities (Litman, 2001; "Comprehensive Transport Planning" VTPI, 2004). Conventional planning tends to be *reductionist*, that is, it focuses primarily on a particular problem or goal. For example, transportation agencies focus on congestion reduction, environmental agencies focus on pollution reduction, and social agency focus on improving mobility for disadvantaged people. Impacts outside their mandate are generally given little consideration. As a result, conventional planning tends to undervalue strategies that provide modest but multiple benefits, such as increased nonmotorized travel. Programs to improve and encourage nonmotorized transport are not usually considered the most cost effective way of reducing congestion, improving environmental quality or increasing mobility for non-drivers, although it helps achieve all of these objectives and several more. Comprehensive evaluation therefore requires changing planning practices so strategies that provide many modest benefits receive the recognition they deserve ("Sustainable Transport and TDM," VTPI, 2004).

A nonmotorized transportation evaluation framework should account for the following three types of travel changes and their incremental impacts:

1. Improved nonmotorized travel conditions to existing users (people who would walk or bicycle regardless of changes).
2. Increased nonmotorized travel.
3. Reduced motorized travel.

For example, sidewalk improvements increase comfort and safety for people who currently walk that route, provide health and enjoyment benefits if walking increases, and provide additional benefits when walking substitutes for driving. Some of these benefits accrue to users (the people who walk), and some to non-users, such motorists who face less congestion, and residents who experience less air and noise pollution.

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.
- 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 community livability and social cohesion as more walk in neighborhoods.

- 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.

- Understand the potential demand for nonmotorized travel, if it is given adequate support, and if integrated with other mobility management strategies such as improved transit service and more accessible land use development.

Mobility management 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.

The next section of this guide describes individual impacts and discusses how they can be quantified and monetized (measured in monetary units) for evaluation purposes. It includes generic estimates of benefits under urban-peak, urban off-peak and rural travel conditions. 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 Pendakur, Badami and Lin (1995), FHWA, 1997 and 2000; and the *Transportation Cost and Benefit Analysis Guidebook* (Litman, 2004a). Also see *Evaluating Public Transit Benefits and Costs* (Litman, 2004c), which includes similar analysis applied to public transit.

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, including impacts on motorists and nonmotorized (called *the barrier effect*). Various studies indicate that, in total, these costs average 10¢ to 35¢ per urban-peak vehicle mile, and more in some situations (Litman, 2004a; "Congestion Reduction," VTPI, 2004).

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 3 summarizes congestion impacts of bicycling by road width, although traffic volume and intersection design are also factors.

Table 3 **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 mileage because most bicyclists avoid riding under such conditions, and bicycling is forbidden on urban freeways where congestion costs are usually highest (Forester, 1982). 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. Of course, a large crowd of pedestrians and cyclists can delay motor vehicle traffic at intersections, but much less delay than if the same trips were made by automobile.

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.

Roadway Costs

The cost of building and maintaining roads is 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, 2004a). Walking and cycling impose minimal roadway wear. Sidewalks and paths are relatively inexpensive to build and maintain. Most cities have about equal linear miles of roads and sidewalks/paths, but devote 5 to 10 times as much money to motorized as nonmotorized facilities, and walking and cycling cause little wear to such facilities.

In addition to roadway facility costs, motorized transportation also requires various traffic services, such as policing, signals and emergency response. These costs average 1-2¢ per vehicle-mile. While nonmotorized modes use many of these services, their costs tend to be much lower than for motor vehicle traffic, since pedestrians and cyclists tend to travel slower (reducing potential conflicts) and impose less risk on others.

Although many people assume that roadway facilities and services are fully funded through 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, 2004a). 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).

Parking cost savings depend on marginal impacts. In the short run, reduced automobile trips may simply result in unoccupied parking spaces, but many destinations have parking problems that decline if parking demand is reduced, and over the long run reduced parking demand allows property owners to avoid expanding parking capacity, or existing parking supply can be rented, leased or converted to other uses.

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, 2004a). 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 amount), and most people enjoy eating and consume too many calories, and so this energy consumption is generally a benefit rather than a cost.

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, 2004a). 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, this cost varies 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) if consumers choose it 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 can be considered a benefit rather than a cost, since people only make this 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, 2001; Litman, 2004a; Litman, 2004c). 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.

Air Pollution
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.

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, 2004a). 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.

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.

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, and monetized crash costs are among the largest costs of motorized transportation ("Crash Costs," Litman, 2004a; Litman, 2004d). Although walking and cycling have higher per-mile accident casualty rates than automobile travel, the overall incremental risk of a shift from driving to nonmotorized modes is much lower due to the following factors:

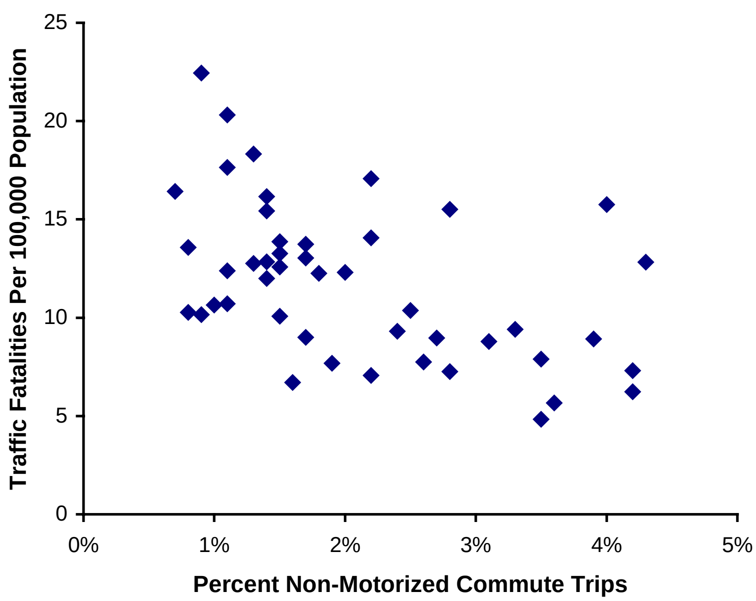
1. Nonmotorized travel imposes minimal risk to other road users.

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

3. 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.

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

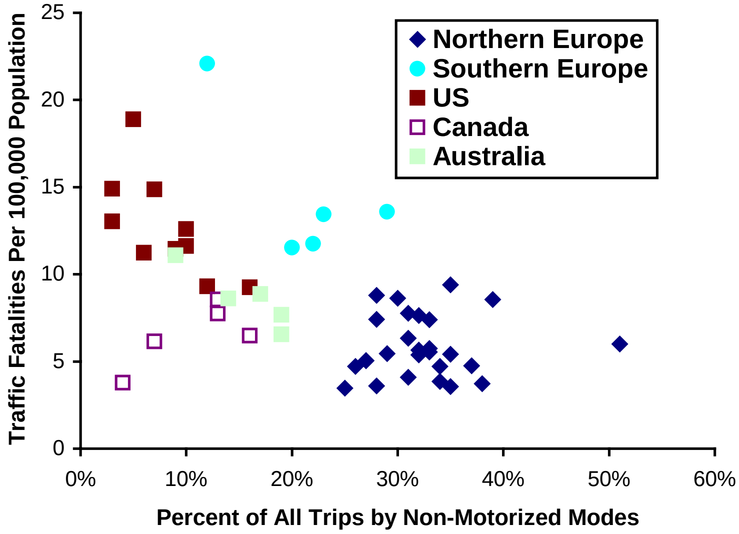
Figure 4 **Traffic Fatalities Vs. Non-Motorized Transport** (US Census, 2000)



Per capita traffic fatality rates tend to decline in U.S. metropolitan regions as the portion of nonmotorized urban 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). 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.

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.

Additional, Unmonetization Benefits

Increased nonmotorized travel and shifts from motorized to nonmotorized modes can provide several additional benefits unsuited to monetization. These are discussed below.

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. 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).

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 4 lists potential smart growth benefits.

Table 4 **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, 2004a). 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). 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). Reducing automobile expenditures tend to increase regional employment and business activity because fuel, vehicles and parts are generally imported from other areas (Litman and Laube, 1998; "TDM and Economic Development," VTPI, 2004). Each million dollars in automobile expenditures shifted to a normal bundle of consumer goods creates about 9 regional jobs and increases regional income by 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 as 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, 1999; Litman, 2004a). 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 5 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 5 **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 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 nonmotorized travel conditions, increasing nonmotorized travel, and shifting 10-30% of motorized travel to nonmotorized modes.

Table 6 **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 investments. This section shows examples of evaluation applied to nonmotorized transport (also see Nelson, 1995; Ker, 2001; Litman, 2001). The following formula can be used to determine the maximum investment justified for mobility management programs that achieve a shift from automobile to walking or bicycling.

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

Example 1: Pedestrian Facility

Table 7 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 7 **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 much 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 8 shows the funding level justified for a cycling program for each 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 8 **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 9 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 9 **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 10 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 10 **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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