



## Smart Transportation Emission Reductions

### *Identifying Truly Optimal Energy Conservation And Emission Reduction Strategies*

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## Summary

This report investigates methods for identifying the optimal (best overall, taking into account all benefits and costs) transportation emission reduction strategies. Current evaluation methods tend to undervalue *mobility management* (strategies that change travel behavior to increase transport system efficiency, also called *Transportation Demand Management* or *TDM*) due to various types of biases: (1) ignorance about these strategies; (2) failure to consider co-benefits; (3) failure to consider rebound effects of increased fuel economy; (4) a belief that mobility management impacts are difficult to predict; (5) a belief that mobility management programs are difficult to implement; and (6) a belief that any reduction in vehicle travel harms consumers and the economy. More comprehensive and objective analysis tends to rank mobility management strategies among the most cost-effective emission reduction options. This report describes ways to correct current planning bias so mobility management solutions can be implemented to the degree optimal.

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## Introduction

Imagine two neighbors with different transportation profiles. One is a sportswoman who owns an SUV or pickup truck that gets 15 mpg, but because she commutes by bus and runs errands by bicycle, she only drives 4,500 annual miles and so only consumes 300 gallons of fuel, producing about three tons of CO<sub>2</sub> each year. Another owns a small car which gets 50 mpg, but because he drives about 100 miles each day for commuting and errands, his vehicle is driven 30,000 annual miles and consumes 600 gallons of fuel, producing about six tons of CO<sub>2</sub>. Which transport pattern is best overall?

The lower mileage driver not only consumes less fuel and produces less pollution, she also imposes less traffic congestion and accident risk, reduces road and parking costs, and gets more exercise through walking and cycling. As a result, her transportation profile is best for society overall.

However, most current transportation emission reduction programs focus primarily on changing what motorists drive rather than how much they drive. These programs reward the purchase of fuel efficient and alternative fuel vehicles. They tend to ignore the additional benefits (besides energy conservation and emission reductions) of reducing mileage and the additional congestion and accident costs that result when increased fuel efficiency stimulates additional vehicle mileage. This is inefficient and unfair.

Mileage reduction strategies tend to be ignored because of an assumption that they are difficult to implement and would harm consumers. That is not necessarily true. Many high-mileage motorists would prefer to drive somewhat less and rely more on alternative modes, provided those alternatives are convenient, comfortable and affordable. Improving travel options and rewarding mileage reductions can benefit consumers directly, as well as reduce emissions and other transport problems.

This paper is concerned with identifying the *best* (i.e., overall optimal, taking into account all factors) way to reduce transportation energy consumption and pollution emissions. It complements related reports that describe cost-effective emission reduction strategies (Litman, 2007). This report focuses on the process used to evaluate emission reduction strategies. It identifies common biases that favor *efficient vehicle* solutions (which change what people drive) over *efficient transportation system* solutions (which change how much they drive).

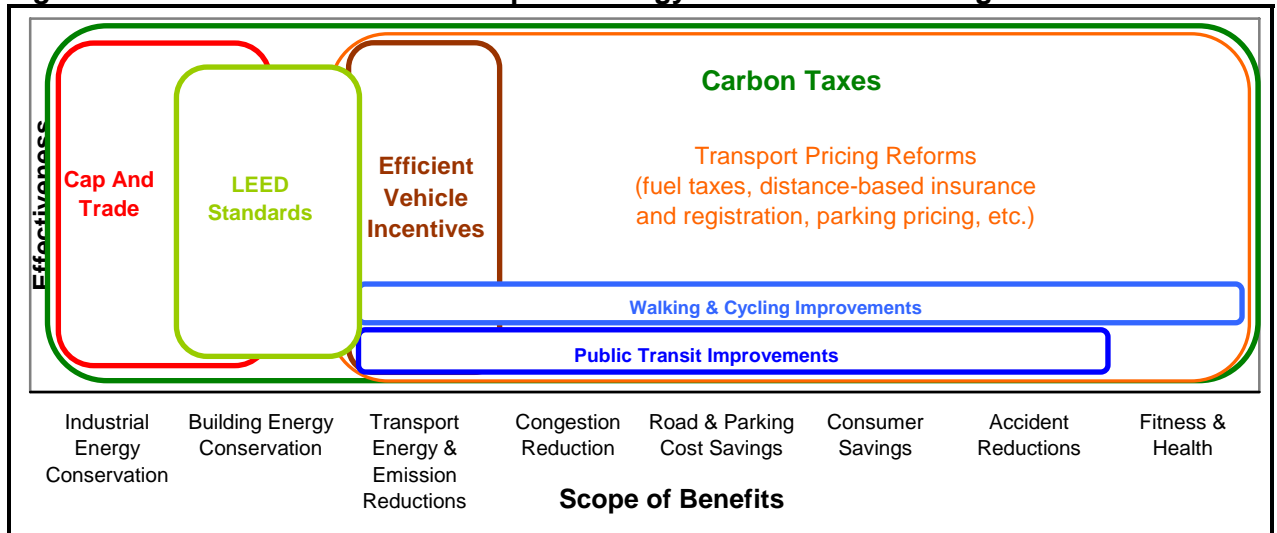
This has huge implications because transportation activity has many economic, social and environmental impacts. It is wrong to ignore any significant impacts when evaluating potential emission reduction options, yet, this is commonly done, resulting in the solutions to one problem (such as air pollution) that exacerbate other important problems (such as traffic congestion, accident risk or consumer costs), and undervaluing solutions that provide many modest benefits. This is good news, because it means that by applying more comprehensive analysis it is possible to identify truly optimal emission reduction strategies that maximize overall benefits to society.

## Effectiveness and Scope

There are many possible ways to conserve energy and reduce emissions. They differ widely in terms of their effectiveness (ability to reduce energy consumption and emissions), and their impacts (their total costs and benefits), as illustrated in Figure 1.

Cap-and-trade programs generally focus primarily on industrial emissions, and some building emissions, due to administrative convenience (it is easier to contract with a few large emitters than numerous small companies and households). Incentives to purchase fuel efficient vehicles, such as CAFE standards and feebates, can significantly reduce motor vehicle energy consumption but provide few other benefits, and by reducing per-mile vehicle operating costs they tend to increase total vehicle traffic which increases problems such as congestion, roadway costs, accidents and sprawl (Litman, 2005). Improving travel options, such as public transit and nonmotorized travel, individually provide relatively modest energy savings, but by reducing total vehicle traffic provide many additional benefits. Transportation pricing reforms (fuel taxes, distance-based insurance and registration fees, parking pricing, etc) reduce energy consumption and traffic impacts. By increasing vehicle efficiency *and* reducing traffic, carbon taxes provide maximum benefits.

**Figure 1 Effectiveness and Scope of Energy Conservation Strategies**



*Cap-and-trade programs support industrial and some building energy conservation programs, but have limited application to transportation energy conservation. LEED standards support building energy conservation. Efficient vehicle incentives can significantly reduce transport energy consumption but provide few other benefits, and by stimulating total vehicle travel increase traffic impacts. Improving travel options, such as public transit and walking, provides modest energy savings but many additional benefits. Transportation pricing reforms (fuel taxes, distance-based insurance and registration fees, parking pricing, etc) reduce energy consumption and traffic impacts. Carbon taxes effectively support virtually all forms of energy conservation, and provide many additional benefits.*

## Current Emission Reduction Evaluation Activities

Numerous current efforts implicitly or explicitly evaluate the cost effectiveness of potential emission reduction strategies:

- Catalogues provide information on the effectiveness, costs and benefits of various emission reduction strategies (CCAP, 2005; Dalkmann and Brannigan, 2007; VTPI, 2007; Gallagher, et al. 2007; *Mayors Climate Protection Center*).
- Studies provide an *emission reduction supply curve* (strategies ranked from lowest to increasing cost per ton of emissions reduced), so decision-makers can select the set of policies and programs that achieve emission reduction target at the lowest total cost (BTRE, 2002; Jansen and Denis, 1999; McKinsey, 2007; NAO, 2007).
- Legislation that implements emission reduction policies, regulations, taxes and trading programs (CAB, 2006; RFF, 2007).
- Emission markets allocate or auction emission rights that participants can buy or sell, to help implement the most cost-effective strategies (WRI, 2007).
- Carbon offset programs through which consumers and businesses finance emission reductions, which often emphasize cost effectiveness ([www.carbonfund.org](http://www.carbonfund.org)).

These efforts use various analysis methods to evaluate potential strategies. How options are analyzed affects results. A strategy that ranks high by one methodology may be ignored or undervalued by another. To identify truly optimal solutions, analyses should consider all potentially significant emission reduction options and their impacts.

Table 1 lists various transportation emission reduction strategies. These fall into two major categories: *efficient and alternative fuel vehicles*, which reduce emission rates per vehicle-mile, and *mobility management strategies*, which reduce total vehicle travel.

**Table 1 Transportation Emission Reduction Strategies** (CCAP, 2005; VTPI, 2007)

Efficient And Alternative Fuel Vehicles	Mobility Management		
	Improved Transport Options	Incentives To Choose Efficient Options	Land Use Management
Efficient vehicle technology development	Transit improvements	Congestion pricing	Smart growth policies
Fuel efficiency standards (such as CAFE).	Walking & cycling improvements	Distance-based fees	Transit oriented development
Alternative fuel requirements and incentives.	Rideshare programs	Commuter financial incentives	Location-efficient development
Feebates	HOV priority	Parking pricing	Parking management
Fuel tax increases.	Carsharing	Parking regulations	Carfree planning
	Telework & flextime	Fuel tax increases	Traffic calming
	Taxi service improvements	Transit encouragement	

*This table lists various emission reduction strategies. Efficient and alternative fuel vehicles reduce emission rates per vehicle-mile, while mobility management strategies reduce total vehicle travel.*

Most comprehensive studies indicate that both clean vehicle and mobility management will be needed to achieve significant energy conservation and emission reductions (Robèrt and Jonsson, 2006). However, most current emission reduction analysis is biased against mobility management because:

- *Mobility management is ignored or only a few strategies are considered.* Emission reduction planning sometimes ignores mobility management altogether, or only considers a limited number of potential strategies.
- *Co-benefits are ignored.* Current analysis gives little consideration to benefits such as congestion reduction, road and parking facility cost savings, consumer savings, reduced traffic accidents, and improved mobility for non-drivers, although these benefits are often larger in total value than emission reduction benefits.
- *Induced travel impacts are ignored.* Current analysis generally ignores the additional external costs that result when increased vehicle fuel efficiency and subsidized alternative fuels stimulates additional vehicle travel, called a *rebound effect*.
- *They consider mobility management emission reductions difficult to predict.* Although case studies and models are available for many of these strategies, this information is not widely applied to energy planning.
- *They consider mobility management programs difficult to implement.* Such programs often involve multiple stakeholders, such as regional and local governments, employers and developers, and various special interest groups. As a result, they tend to seem difficult and risky compared with other emission reduction strategies that only require changes to utility operations, fuel production or vehicle designs.
- *They assume that vehicle travel reductions harm consumers and the economy.* In fact, many mobility management strategies benefit consumers directly and increase economic productivity. There is plenty of evidence that, with improved travel options and efficient incentives, consumers would choose to drive less, rely more on alternative modes, and be better off overall as a result.

For these reasons, many current emission reduction planning efforts ignore mobility management altogether (Gallagher, et al., 2007) or only mention them incidentally (McKinsey, 2007). As a result, currently proposed emission reduction efforts will fail to implement mobility management as much as optimal and so will miss an opportunity to help address other planning objectives, such as congestion reduction, traffic safety, consumer savings and improved mobility for non-drivers. More comprehensive analysis is needed for mobility management strategies to receive the support they deserve.

The next section of this report examines these biases in more detail.

## **Biases Against Mobility Management**

*This section discusses in more detail various biases in current emission reduction evaluation.*

### ***Mobility Management Is Overlooked***

Many energy analysts are unfamiliar with mobility management, are only aware of a small portion of total potential strategies, or significantly underestimate mobility management's potential emission reductions. There is often confusion over what it is called and how it is defined; efforts to change travel behavior are sometimes referred to as *demand management* or *transportation demand management*, or describe as *driving disincentives*, *road pricing*, *commute reduction*, *transit improvements*, or *land use management*. As a result, mobility management is often ignored or only a limited set of potentially cost-effective strategies are considered in analysis.

Fortunately, this problem is relatively easy to correct. A variety of resources now exist which identify potential mobility management strategies and provide information on their costs, benefits and implementation requirements (CCAP, 2005; Dalkmann and Brannigan, 2007; VTPI, 2007; *European Program for Mobility Management*).

### ***Co-benefits Ignored***

Current analysis often gives little consideration to additional (besides emission reduction) benefits provided by mobility management, although they are significant in value ("TDM Evaluation," VTPI, 2007). These include congestion reductions, road and parking cost savings, consumer cost savings, increased traffic safety, improved mobility options for nondrivers, improved physical fitness and health, and support for strategic land use objectives (reduced sprawl). Not every mobility management strategy provides all of these benefits, but most provide many.

### ***Induced Travel Impacts Ignored***

Current analysis generally ignores the additional external costs that result when increased vehicle fuel efficiency or alternative fuel subsidies stimulate additional vehicle travel, called a *rebound effect* ("Rebound Effects," VTPI, 2007). Long-term rebound effects typically range from 15-30% (Small and Van Dender, 2005). For example, with a 20% rebound effect, a 50% increase in fuel economy will cause mileage to increase 10%, resulting in 40% net energy savings. Some recent analysis acknowledge that rebound effects will reduce net energy savings, but other induced travel impacts, such as increased congestion, accidents and facility costs are seldom considered or quantified (CBO, 2003).

Table 2 compares different types of transportation emission reduction strategies, taking into account co-benefits and rebound effects. More efficient or alternative fuel vehicles conserve energy, reduce air pollution, and may save consumers money (if fuel savings offset any additional vehicle costs), but because they tend to increase total annual mileage they tend to exacerbate other problems such as traffic congestion, road and parking facility costs, accidents and sprawl. By reducing total vehicle travel, mobility management strategies provide a wider range of benefits.

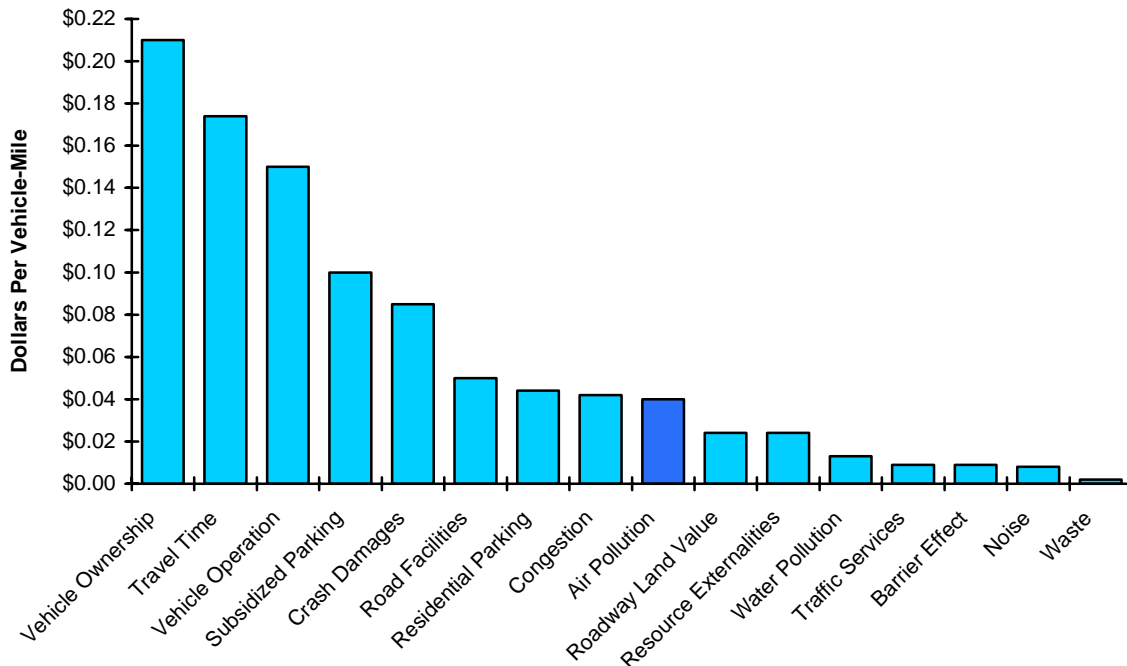
**Table 2** Comparing Benefits (Litman, 2007)

Benefits	Efficient And Alternative Fuel Vehicles	Mobility Management
Congestion reduction	✗	✓
Road and parking cost savings	✗	✓
Consumer cost savings	✓/✗	✓
Reduced traffic accidents	✗	✓
Improved mobility options for nondrivers		✓
Energy conservation	✓	✓
Pollution reduction	✓	✓
Improved physical fitness & health (exercise)		✓
Land use objectives (reduced sprawl)	✗	✓

*Efficient and alternative fuel vehicles only provide a few benefits, and by increasing total vehicle travel tend to exacerbate problems such as congestion, accidents and sprawl. Mobility management provides far more benefits. (✓ = achieves benefits; ✗ = reduces benefit)*

Figure 2 indicates estimates of various transportation costs, measured per vehicle-mile. The largest category is vehicle ownership (the fixed costs of owning a vehicle, including purchase costs, financing, depreciation and registration fees), totaling about \$2,700 per year or 21¢ per vehicle-mile, followed by other costs such as travel time, vehicle operation, crash damages, roadway costs, vehicle parking, congestion, air pollution, resource externalities (economic costs of importing petroleum), traffic services, water and noise pollution.

**Figure 2 Per-Mile Automobile Costs (Litman, 2006)**

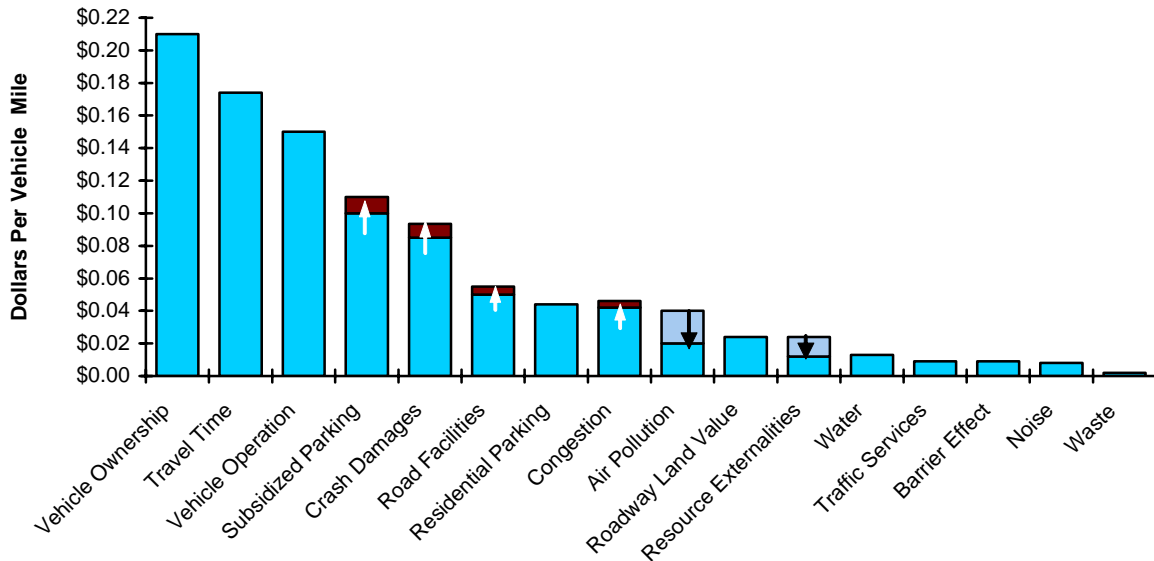


*This figure illustrates estimated automobile costs averaged per vehicle-mile.*

Air pollution is a moderate-size cost, typically estimated at 2-4¢ per vehicle-mile for an average automobile, with higher values for dirty vehicles in urban areas and lower values

for cleaner vehicles in rural areas (EDRG, 2007). Adding climate change emission costs does not significantly change air pollution’s ranking. For example, \$100 per metric tonne price of *carbon* equals about \$27 per ton of *carbon dioxide equivalent*, which equals about 25¢ per gallon of gasoline, or about 2.2¢ per average vehicle-mile. This represents the upper range of carbon price estimates. Although *damage costs* (the cost of damages caused per tonne of carbon emitted) could be higher, *control costs* (the marginal cost of reducing or sequestering a tonne of carbon) is likely to stay below this level, and a rational price reflects whichever is cheapest (Litman, 2006). Incorporating upper bound carbon values increases average automobile air pollution costs from 2-4¢ to 4-6¢ per vehicle-mile. This is not to ignore the value of vehicle emission reductions, but indicates the importance of also considering other impacts. An emission reduction strategy is worth much less if it increases these other costs and worth much more if it reduces other costs.

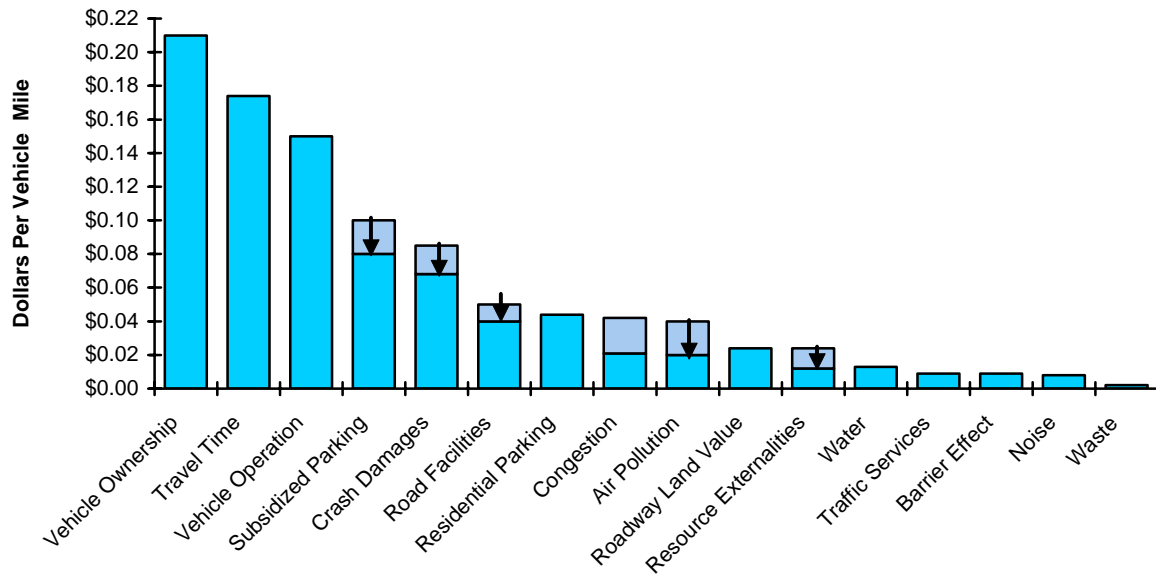
**Figure 3 Efficient Automobile Use** (Litman, 2006)



*This figure illustrates estimated impacts of reduced emissions per vehicle-mile. (Light blue indicates reduced costs, red indicates increased costs)*

For example, if pollution and resource externalities total 6¢ per vehicle-mile, a strategy that halves per-mile energy consumption and emissions by raising fuel economy from 20 to 30 mpg provides benefits worth 3¢ per vehicle-mile, or \$375 per year for a vehicle driven 12,500 annual miles. However, if motorists respond by driving 10% more miles (a typical rebound effect), energy and emission reduction benefits decline 10% to \$338, and mileage-related costs increase (Figure 3). A 10% increase in congestion, crash, road and parking externalities totals 2.7¢ per vehicle-mile or \$338 per year, offsetting the energy and emission reduction benefits. On the other hand, a mobility management strategy that reduces vehicle travel 20% provides energy conservation and emission reduction benefits worth 6¢ per vehicle-mile reduced, or \$150 annually, *plus* 20% reductions in mileage-related costs, totaling \$675, or \$825 in total annual benefits (Figure 4).

**Figure 4** Reduced Mileage Automobile Costs (Litman, 2006)



*This figure illustrates estimated impacts of reduced vehicle-mileage. (Light blue indicates reduced costs)*

### **Emission Reductions Considered Difficult to Predict**

Mobility management emission reduction effects are considered difficult to predict since they rely on behavior change, as opposed to technological changes. This perceived uncertainty makes it difficult for mobility management strategies to qualify for emission trading credits. These problems can be overcome (Donoso, Martinez and Zegras, 2006). Case studies and models can be used to predict mobility management travel impacts and emission reductions (Pratt, 2007; VTPI, 2007). Different types of mobility management strategies require different prediction methods.

- Conventional travel models can predict the effects of some mobility management strategies, such as transit service improvements, transit fare reductions, and increases in road or parking prices, and newer models can predict the impacts of other strategies such as transit service quality improvements (“Travel Model Improvements,” VTPI, 2007).
- Catalogues of mobility management strategies often include case studies that indicate their travel impacts and emission reductions (CCAP, 2005; VTPI, 2007)
- Specialized models are available to predict the effects of specific combinations of incentives in a particular trip reduction program (USF, 2006).
- Price elasticity models can be used to predict the effects of price changes on travel behavior (“Transportation Elasticities,” VTPI, 2007).
- Models and case studies can be used to predict the effects that land use changes have on travel behavior and per capita emissions (Ewing, et al., 2007; DKS Associates, 2007; “Land Use Impacts On Travel,” VTPI, 2007).

### ***Mobility Management Programs Considered Difficult To Implement***

Mobility management strategies often involve multiple stakeholders and new organization relationships, such as various levels of government, employers, developers, various special interest groups, and transportation management associations, and so often seem difficult and risky compared with changes to vehicle designs or fuel (Wright and Fulton, 2005). Energy analysts sometimes assume incorrectly that these strategies require new technologies, such as GPS-based pricing or high-speed rail (Lash, 2007). These perceived difficulties often make it difficult for mobility management strategies to qualify for emission trading credits.

However, there is now extensive experience with various mobility management strategies (CCAP, 2005; VTPI, 2006; Association for Commuter Transportation; European Program for Mobility Management). Mainstream transportation organizations now recognize the value of mobility management (often under the name of *transportation systems operations*) and increasingly implement it as a way to solve problems such as traffic congestion and inadequate mobility for non-drivers (CUTR, 2007; Poorman, 2005).

### ***Vehicle Travel Reductions Considered Harmful***

People often assume that reductions in mobility must be harmful to consumers and the economy and so should be avoided (CAB, 2006; “Evaluating Criticism of TDM,” VTPI, 2007). However, this assumption is not necessarily true. Many mobility management strategies directly benefit the people who reduce their vehicle travel by improving their travel options or providing optional, positive incentives. For example, if people shift from driving to alternative modes due to improvements in alternative modes or in response to positive incentives such as *parking cash out* (commuters who use alternative modes receive the cash equivalent of parking subsidies) they must be better off overall, since they would otherwise continue driving. Similarly, many consumers will choose more accessible, walkable communities, and drive fewer miles, if such communities have other attributes they value such as security, affordability and prestige. Even strategies that apply negative incentives, such as higher prices, can benefit consumers overall, if revenues are used to reduce other taxes or provide new services they value.

Several current trends are increasing the value of alternative modes, including an aging population, rising fuel prices and increasing traffic congestion. Although few motorists want to give up driving altogether, at the margin (compared with their current travel patterns) many people would prefer to drive less, and rely more on other forms of transport, provided that they are convenient, comfortable and affordable. As a result, mobility management strategies are increasingly justified to meet consumer demands.

Accurate mobility management evaluation requires *consumer surplus* analysis to measure the value consumers place on a change in the price or quality of their consumption (in this case, of vehicle travel). These methods are well established and widely used in economic evaluation (Small, 1999; “Evaluating TDM,” VTPI, 2007).

## Improving Emission Reduction Evaluation

This analysis indicates that, in various ways, current emission reduction planning tends to overlook and undervalue mobility management solutions. Fortunately, all of these biases can be corrected. Although this involves overcoming a variety of obstacles, the potential benefits are very large, making the effort worthwhile. More comprehensive analysis allows planners to identify the truly optimal emission reduction strategies, which provide far greater benefits than what would be selected by current, biased evaluations.

Table 3 summarizes the various types of biases against mobility management emission reduction strategies, and ways to correct them for more comprehensive and objective analysis.

**Table 3 Correcting Biases Against Mobility Management**

Type of Bias	Corrections
Mobility management ignored	Become more familiar with potential mobility management strategies and their impacts.
Co-benefits ignored	Become more familiar with the full benefits of vehicle travel reductions, including reduced congestion, road and parking facility costs, consumer costs, accidents, noise and water pollution, and sprawl, as well as improved mobility options for non-drivers, and improved public fitness and health. Develop methods to quantify these benefits for economic evaluation.
Induced travel impacts ignored	Become more familiar with rebound effects and develop methods to quantify these impacts for economic evaluation.
Mobility management impacts considered difficult to predict	Become more familiar with various models and case studies available for predicting the impacts of mobility management strategies. Improve these models so they are more flexible, accurate and easier to use.
Mobility management programs considered difficult to implement.	Become more familiar with case studies of mobility management implementation. Improve access to these resources.
Vehicle travel reductions considered harm consumers and the economy.	Become more familiar with methods used to evaluate the impacts of mobility management on consumer welfare. Develop better tools for applying this analysis for transport policy evaluation.

*This table indicates how existing biases can be corrected for more comprehensive and accurate analysis of optimal transportation emission reduction policies.*

## Optimal Emission Reduction Strategies

Although there are many possible ways to reduce energy consumption and pollution emissions, some are much better overall than others because they provide additional benefits and avoid exacerbating other problems.

One of the most appropriate emission reduction strategies is to gradually and predictably increase fuel taxes (“Fuel Tax Increases,” VTPI, 2006; Sterner, 2006). Fuel taxes should at least reflect all public expenditures on roadways and traffic services (Metschies, 2005). Many other mobility management strategies are probably cost-effective when all impacts are considered. These include (Leotta, 2007; Litman, 2007):

- *Pay-As-You-Drive Pricing* - Convert fixed vehicle charges into mileage-based fees.
- *Parking Cash-Out* - Offer commuters financial incentives for using alternative modes.
- *Parking Pricing* - Charge users directly for parking facility use, often with variable rates.
- *Road Pricing* - Charge users directly for road use, with rates that reflect costs imposed.
- *Transportation Demand Management Programs* - Programs that encourage use of alternative modes.
- *Transit and Rideshare Improvements* - Improve transit and rideshare services.
- *Walking and Cycling Improvements* - Create more walkable and bikeable communities.
- *Smart Growth Policies* - More accessible, multi-modal land use development patterns.
- *Freight Transport Management* - Encourage businesses to use more efficient transportation options.
- *Planning Reforms* - More comprehensive and neutral planning and investment practices.

Policies that encourage fuel efficient vehicle purchases are justified now to prepare for higher future fuel prices, and to reduce the relative disadvantage of driving efficient vehicles (if the entire fleet becomes more efficient there is less stigma and risk to smaller vehicle users). These include vehicle *fuel efficiency standards* (or carbon emission limits), *feebates* (surcharges on less efficient vehicles with revenues used to rebate efficient vehicle purchases), and *efficiency-based vehicle taxes and fees*. To minimize rebound effects and maximize total benefits it will be important to implement fuel tax increases and mobility management strategies in conjunction with efficient vehicle policies.

The main incentive for alternative fuels should be higher gasoline and diesel prices. Some alternative fuels may deserve public support, particularly for their basic development, but these should be evaluated critically to insure they are justified, taking into account all economic, social and environmental costs. Electric vehicle development should be encouraged but their production and use should not be subsidized since their overall benefits are modest; they reduce tailpipe emissions but increase electric generation emissions, and already receive about 2.5¢ per vehicle-mile subsidy because they pay no road use taxes. Propane and LPG also provide only modest benefits and so deserve only modest support.

## Conclusions

The universe of potential transportation energy conservation and emission reduction strategies is much larger than usually recognized. So are their impacts. Some approaches provide far more total benefits than others, because they offer significant co-benefits and avoid undesirable, unintended consequences.

In general, a gallon of fuel conserved, or a ton of air pollution emissions avoided, due to reduced vehicle travel is worth an order of magnitude more than the same energy savings and emission reductions provided by increased vehicle fuel efficiency or shifts to alternative fuels. This occurs because mileage reductions also reduce traffic congestion, road and parking facility costs, consumer costs, accidents, water and noise pollution, and sprawl, and often improve mobility options for non-drivers and increase public fitness and health. Many mobility management programs are justified for their economic benefits, and so provide essentially *free* environmental benefits. In contrast, increase vehicle fuel efficiency tends to stimulate more total vehicle travel, which exacerbates transportation problems.

Most analyses indicate that achieving climate change emission reduction targets will require a combination of strategies, including cleaner vehicles, alternative fuels and mobility management. The question is, how much of each?

A number of current trends are increasing the value of mobility management, including aging population, rising fuel prices, increased traffic congestion and changing consumer preferences. Mobility management implementation helps communities respond to future consumer demands and economic conditions.

Most current emission reduction evaluation tends to overlook and undervalue mobility management strategies. More comprehensive analysis is needed to allow mobility management strategies to be implemented to the degree justified. Mobility management is often excluded from emission trading altogether or bears an unreasonably high burden of proof. Better tools are needed for predicting mobility management emission reduction impacts and co-benefits, and protocols for implementing mobility management programs within emission markets.

This paper identifies specific biases in most current emission reduction analyses and provides recommendations for correcting these errors. The result can provide a framework for identifying truly optimal solutions.

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