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Smart Transportation Emission Reduction Strategies

Identifying Truly Optimal Ways To Conserve Energy And Reduce Emissions

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Summary

This report investigates the optimal (best overall, taking into account all benefits and costs) transportation emission reduction strategies. Current evaluation methods tend to undervalue *mobility management* (also called *Transportation Demand Management* or *TDM*) strategies that increase transport system efficiency by changing travel behavior, due to biases that include (1) ignorance about these strategies; (2) failure to consider co-benefits; (3) failure to consider rebound effects of increased fuel economy; (4) belief that mobility management impacts are difficult to predict; (5) belief that mobility management programs are difficult to implement; and (6) belief that vehicle travel reductions harm 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 walks, bikes and rides public transit for most local travel, but drives a fuel inefficient sport utility vehicle 4,500 annual miles for out-of-town trips, consuming 300 gallons of fuel and producing three tons of CO_2. Another drives a fuel efficient hybrid 100 daily miles, consuming 600 gallons of fuel and producing six tons of CO_2 annually. Which travel 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 transport pattern is best for society overall.

However, most current transportation emission reduction programs focus on changing vehicle and fuel type rather than the amount people drive. Such programs generally ignore the additional external costs that result when increased fuel efficiency stimulates additional vehicle travel, and the additional benefits (besides energy conservation and emission reductions) resulting from travel reductions. This is inefficient and unfair.

Mileage reduction strategies tend to be ignored because people often assume they are difficult to implement and harm consumers. That is not necessarily true. Many 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.

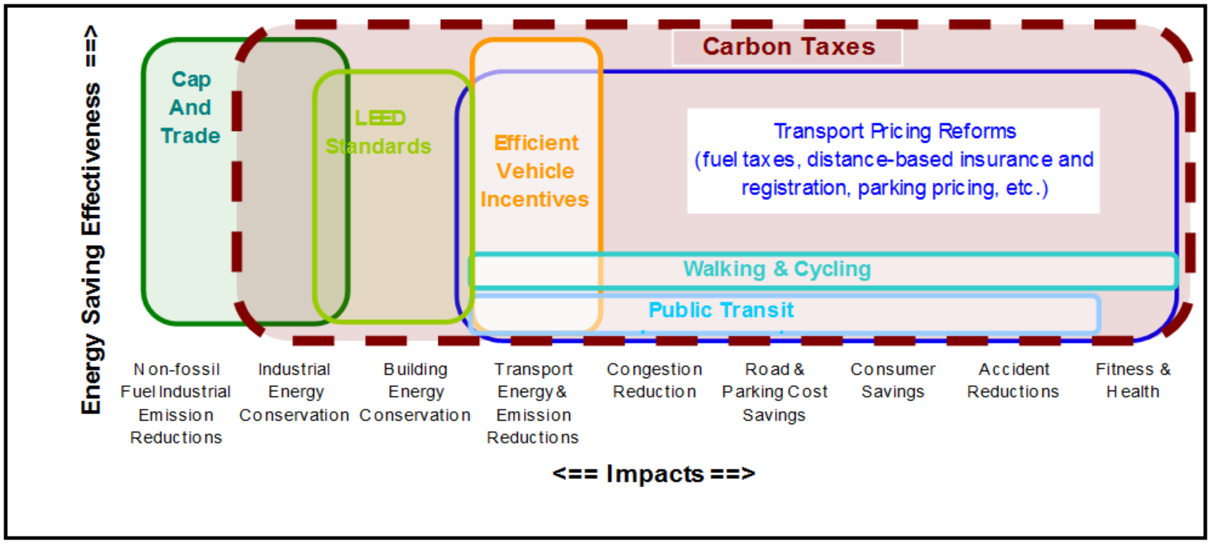
This report identifies *optimal* (i.e., overall best, taking into account all factors) ways to reduce transport energy consumption and pollution emissions. It explores the process used to evaluate emission reduction strategies and identifies common biases that favor *efficient vehicle* solutions (which change what people drive) over *efficient transport systems* solutions (which change how much people drive). It complements related reports that describe cost-effective emission reduction strategies (Litman 2007).

This has important implications because transportation activity has many economic, social and environmental impacts. It is a mistake to ignore any significant impacts when evaluating potential emission reduction options, yet this is commonly done, resulting in 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 multiple benefits. This is good news overall, 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 (amount of energy consumption and emissions reduced) and impacts (total costs and benefits), as illustrated in Figure 1.

Figure 1 **Effectiveness and Scope of Emission Reduction Strategies**



Cap-and-trade programs generally only support industrial emission reductions. LEED standards support building energy conservation. Efficient vehicle incentives reduce transport energy consumption but provide few other benefits, and by stimulating more driving can exacerbate traffic problems. Transportation pricing reforms (fuel taxes, distance-based insurance and registration fees, parking pricing, etc), and carbon taxes, reduce energy consumption and traffic impacts. Public transit and nonmotorized improvements provide modest energy savings but many additional benefits.

Cap-and-trade programs generally focus 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 reduce motor vehicle energy consumption per vehicle-mile but provide few other benefits, and by reducing per-mile vehicle operating costs they tend to increase total vehicle traffic (a *rebound effect*) which increases problems such as congestion, roadway costs and accidents (Litman 2005; Morrow, et al. 2010). Transport pricing reforms (fuel taxes, distance-based insurance and registration fees, parking pricing, etc) reduce energy consumption and traffic impacts. Carbon taxes encourage energy conservation in all sectors. Improving travel options, such as walking, cycling and public transit, individually provide relatively modest energy savings but by reducing vehicle traffic provide many additional benefits. Strategies that help achieve multiple planning objectives (congestion reductions, road and parking cost savings, traffic safety, improved mobility for non-drivers, improved public fitness and health, etc.), rather than just energy savings and emission reductions, represent true sustainable transportation policies (Grant, et al. 2014; Litman and Burwell 2006).

Current Emission Reduction Evaluation Activities

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

- Various studies and 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; Bomberg, et al. 2008; *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 targets at the lowest total cost (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).

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: *cleaner vehicles* (more efficient and alternative fuel vehicles which reduce per-mile emission rates), and *mobility management* (strategies that reduce total vehicle travel).

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

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

This table lists various emission reduction strategies. Cleaner vehicle strategies reduce emission rates per vehicle-mile, while mobility management strategies reduce total vehicle travel.

Most comprehensive studies indicate that both cleaner vehicles and mobility management strategies are needed to achieve energy conservation and emission reduction targets (Robèrt and Jonsson 2006; Burbank 2008; Leather 2009), but many emission reduction analyses are biased against mobility management because they:

- *Ignore mobility management or only considers a few strategies.* Emission reduction planning sometimes ignores mobility management altogether, or only considers a limited number of potential strategies.

- *Ignore co-benefits.* 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.
- *Ignore induced travel impacts.* 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*.
- *Considers mobility management emission reductions difficult to predict.* Although case studies and models exist for many of these strategies, this information is not widely applied to energy planning.
- *Considers 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.
- *Assumes 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), only mention them incidentally (McKinsey 2007), or undervalue their total benefits. 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 will give mobility management strategies 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 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 reduce vehicle travel are sometimes referred to as *demand management* or *transportation demand management*, or described as *driving disincentives*, *road pricing*, *commute reduction*, *transit improvements*, or *land use management*. As a result, analyses often consider only a limited set of mobility management strategies.

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

Conventional analysis often gives little consideration to additional (besides emission reduction) benefits provided by mobility management, such as congestion reductions, road and parking cost savings, consumer cost savings, increased traffic safety, improved mobility options for nondrivers, and improved physical fitness and health, although they are often significant in value. Economists increasingly recognize the value of comprehensive analysis that considers these impacts (Castillo, et al. 2007; Creutzig, et al. 2009; Kendra, et al. 2007; Litman 2007; Leather 2009). Decker, et al. (2017) found that Smart Growth development provides significant economic as well as environmental benefits.

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 2007; UKERC 2007). 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.

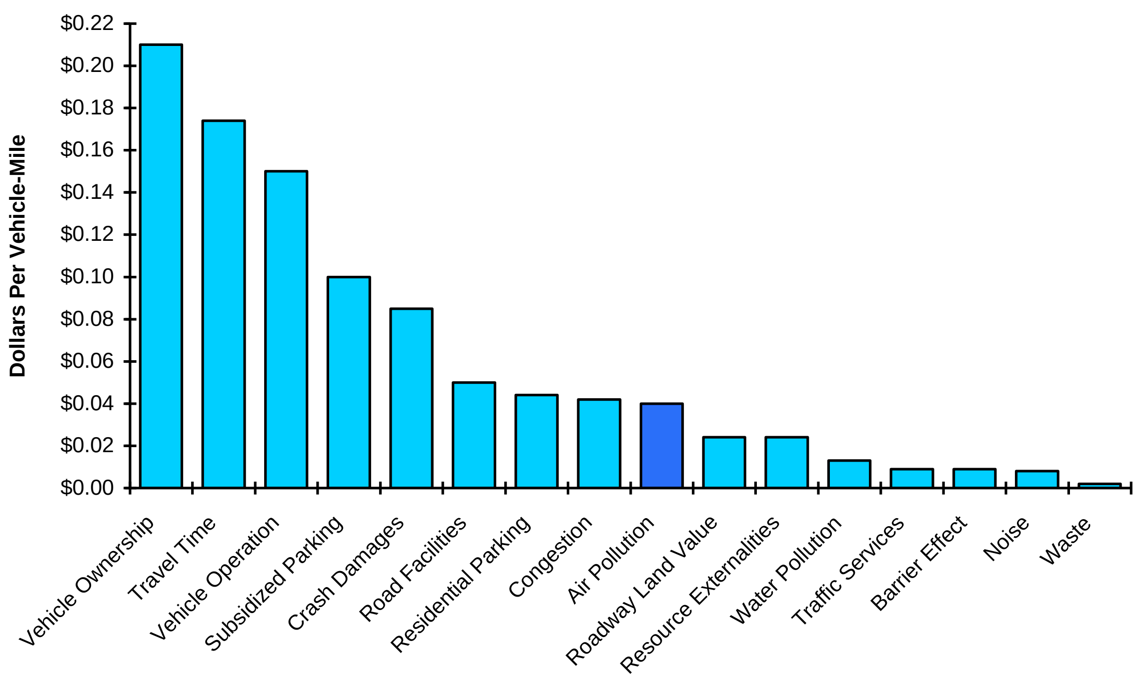
Table 2 **Comparing Benefits** (Litman 2007)

Benefits	Efficient And Alternative Fuel Vehicles	Mobility Management
Vehicle Travel Impacts	*Increased*	*Reduced*
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 benefits)

Figure 2 indicates estimates of various transportation costs, measured per vehicle-mile. The largest category is vehicle ownership (fixed costs, including vehicle purchase, 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.

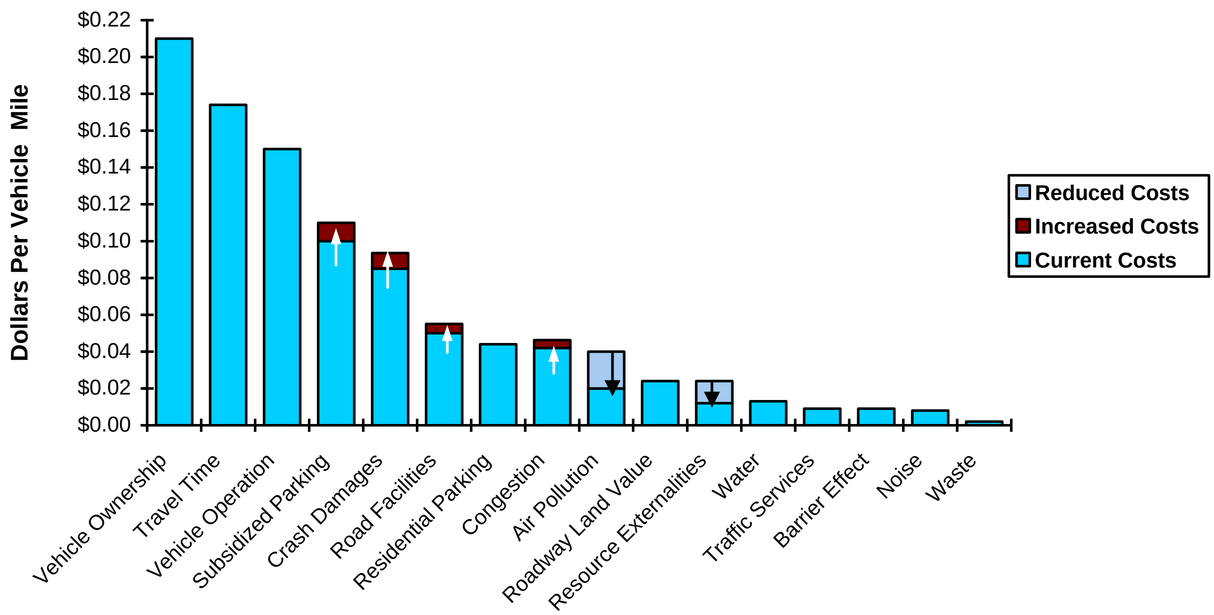
Figure 2 **Per-Mile Automobile Costs** (Litman 2006a)



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 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* may be higher, *control costs* (the marginal cost of reducing or sequestering a tonne of carbon) is likely to stay below this level and rational prices reflect whichever is cheapest (Litman 2006a). 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 vehicle emission costs, but indicates the importance of considering other impacts too. An emission reduction strategy is worth much less if it increases other costs and worth much more if it reduces other costs.

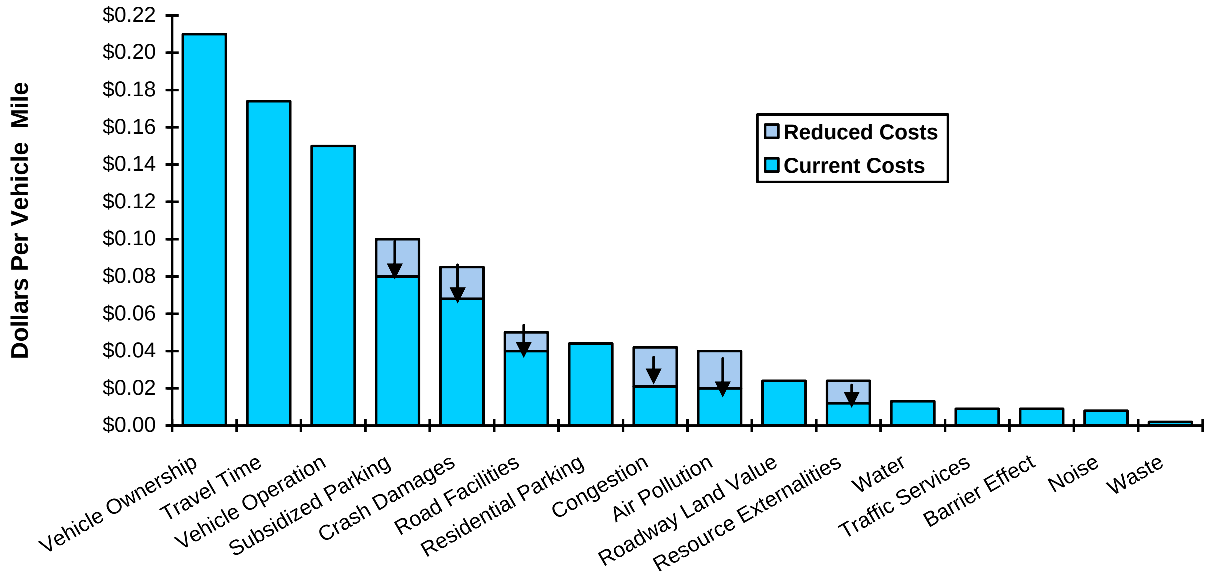
Figure 3 **Efficient Automobile Use** (Litman 2006a)



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 40 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 2006a)



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; CCAP 2008). 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 predict the effects of specific combinations of incentives in a particular trip reduction program (USF 2006).
- Price elasticity models predict the effects of price changes on travel behavior ("Transportation Elasticities," VTPI 2007).
- Models and case studies 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; Glaeser and Kahn 2008).

Overlooking Indirect and Long-term Impacts

Comprehensive evaluation applies *lifecycle cost analysis*, which considers indirect and long-term impacts, in addition to direct and immediate impacts. For example, when comparing investments in different modes or land use development policies, lifecycle analysis consider, in addition to direct fuel consumption, lifecycle analysis considers vehicle and facility embodied energy, and impacts on residents total motor vehicle travel (Kimball, et al. 2013; Nichols and Kockelman 2015).

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 credits. However, there is now extensive experience with mobility management (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 mobility reductions harm consumers and the economy, and so should be avoided (CAB 2006). However, this assumption is not necessarily true (Litman 2009a). Many mobility management strategies directly benefit consumers by improving their travel options or providing positive incentives. For example, if people drive less 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 could otherwise continue driving. Similarly, many consumers will choose more accessible, walkable communities, and drive fewer miles, if such communities have attributes such as security, affordability and prestige. Even negative incentives, such as higher prices, can benefit consumers overall if communities use revenues to reduce other taxes or improve services they value.

Several current trends increase the value of alternative modes, including aging population, rising fuel prices and increasing traffic congestion (Litman 2006b). 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).

Regulations: Necessary and Effective

Advocates often claim that fuel efficiency regulations are necessary to overcome market resistance to more efficient and alternative fuel vehicles and are the most efficient way to achieve energy savings. Their arguments have some merit.

Consumers tend to require very short paybacks on energy saving investments. Vehicles are durable goods and the vehicles purchased now by higher-income motorists will be driven by lower-income motorists many years in the future. To the degree that future consumers will prefer more fuel efficient vehicles than what is currently being purchased, regulations may be justified to achieve equity as well as environmental objectives.

Advocates of regulation argue that fuel is inelastic: large price changes have relatively little impact on fuel consumption. They often cite analysis by Small and Van Dender (2007) which indicated that gasoline price elasticities were -0.09 in the short run and -0.40% in the long run during the 1997 to 2001 period, about half the values observed from 1966 to 1996. They implied that these trends will continue, resulting in ever declining price sensitivity. However, those results likely reflect unique factors during those years, including declining real fuel prices, demographics (peak Baby Boom driving years), and sprawl-encouraging development policies. Recent studies suggest that fuel price elasticities increased after 2006 (CERA 2006). Komanoff (2008) estimates that the short-run U.S. fuel price elasticity reached a low of -0.04 in 2004, but this increased to -0.08 in 2005, -0.12 in 2006 and -0.16 in 2007.

This suggests that regulations may be justified to help shift the vehicle market toward more efficient and alternative fuel vehicles to reduce emissions and anticipate future consumer demands, but these should be implemented in conjunction with complementary policies such as consumer education about fossil fuel external costs and future price increases, gradual and predictable fuel tax increases, and mobility management strategies to avoid unintended consequences from increased vehicle travel rebound effects.

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 various 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	Learn about 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	Study the rebound effects and develop methods to quantify these impacts for economic evaluation.
Mobility management impacts considered difficult to predict	Review 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.	Read case studies of mobility management implementation. Improve access to these resources.
Vehicle travel reductions considered harm consumers and the economy.	Explore methods used to evaluate the impacts of mobility management on consumer welfare. Develop better tools for applying this analysis for transport policy evaluation.
Regulations necessary and effective	Implement regulations in conjunction with complementary policies to maximize benefits and avoid unintended consequences from increased vehicle travel rebound effects.

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 (Cambridge Systematics 2009; Leotta 2007). Table 4 summarizes examples of these "win-win" strategies.

Table 4 **Win-Win Transportation Solutions** (Litman 2007)

Name	Description	Transport Impacts
Planning Reforms	More comprehensive and neutral planning and investment practices.	Increases support for alternative modes and mobility management, improving options.
Transportation Demand Management Programs	Local and regional programs that support and encourage use of alternative modes.	Increased use of alternative modes.
Road Pricing	Charges users directly for road use, with rates that reflect costs imposed.	Reduces vehicle mileage, particularly under congested conditions.
Parking Pricing	Charges users directly for parking facility use, often with variable rates.	Reduces parking demand and facility costs, and encourages use of alternative modes.
Parking Cash-Out	Offers commuters financial incentives for using alternative modes.	Encourages use of alternative commute modes.
Pay-As-You-Drive Pricing	Converts fixed vehicle charges into mileage-based fees.	Reduces vehicle mileage.
Fuel Taxes- Tax Shifting	Increases fuel taxes and other vehicle taxes.	Reduces vehicle fuel consumption and mileage.
Transit and Rideshare Improvements	Improves transit and rideshare services.	Increases transit use, vanpooling and carpooling.
Walking and Cycling Improvements	Improves walking and cycling conditions.	Encourages use of nonmotorized modes, and supports transit and smart growth.
Carsharing	Vehicle rental services that substitute for private automobile ownership.	Reduced automobile ownership and use.
Smart Growth Policies	More accessible, multi-modal land use development patterns.	Reduces automobile use and trip distances, and increases use of alternative modes.
Freight Transport Management	Encourage businesses to use more efficient transportation options.	Reduced truck transport.

This table summarizes various Win-Win strategies that encourage more efficient transportation.

Frank, et al. (2010) and found that *smart growth* features (transit accessibility, residential density, and street connectivity) tend to increase per capita walking and reduce per capita motor vehicle fuel consumption, providing both health and environmental benefits.

One of the most appropriate emission reduction strategies is to eliminate current fuel subsidies (Koplow 2010; Metschies, Thielmann and Wagner 2007), and gradually and predictably increase fuel taxes, at least to reflect all public expenditures on roadways and traffic services, or to apply a carbon tax on all fossil fuels ("Fuel Tax Increases," VTPI 2006; Sterner 2007; Metschies 2005; *Carbon Tax Center*; Litman 2009c).

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.

Alternative fuels should be encouraged primarily by higher gasoline and diesel prices, particularly with carbon taxes (Toman, Griffin and Lempert 2008). Some alternative fuels may deserve public support for 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

There are many potential energy conservation and emission reduction strategies. Which are best? Which deserve the greatest support? Some provide significant co-benefits and avoid undesirable, unintended consequences and so provide greater total benefits. In general, a gallon of fuel conserved by reducing vehicle travel provides an order of magnitude more benefit than the same energy savings provided by shifts to more efficient or alternative fuel vehicles. This occurs because mileage reductions provide other economic, social and environmental benefits, such as reduced traffic congestion, facility costs, accidents and sprawl. Many mobility management programs are justified for their economic benefits and so provide essentially *free* environmental benefits. In contrast, increased vehicle fuel efficiency tends to stimulate more total vehicle travel, which exacerbates other transportation problems: emissions decline but congestion, parking costs, accidents and sprawl increase.

Mobility management helps communities prepare for future demands. Current demographic and economic trends (aging population, rising fuel prices, increased traffic congestion and changing consumer preferences) are increasing the value of alternative modes and smart growth development.

This is not to suggest that energy conservation is unimportant or that efforts to improve vehicle fuel efficiency or develop alternative fuels is harmful. On the contrary, petroleum consumption and pollution emissions are urgent problems to solve. However, emission reduction efforts should consider all options and impacts in order to implement those that are overall most beneficial. Although some regulations may be justified to overcome market impediments to more efficient and alternative fueled vehicles, these should be implemented in conjunction with complementary policies such as consumer education about fossil fuel external costs and future price increases, gradual and predictable fuel tax increases, and mobility management strategies to avoid unintended consequences from increased vehicle travel rebound effects.

Most current evaluation tends to overlook and undervalue mobility management benefits. More comprehensive analysis allows 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. We need better tools to predict mobility management emission reduction impacts and co-benefits, and protocols to implement 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.

The strategies recommended in this paper are “win-win” solutions that provide multiple benefits. They are justified on economic efficiency grounds and so can provide essentially free emission reductions.

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