Win-Win Transportation Emission Reduction Strategies

Smart Transportation Strategies Can Reduce Pollution and Provide Other Important Economic, Social and Environmental Benefits

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The Earth’s surface is covered by a thin and precious atmosphere. There are many ways to protect it, some of which provide significant co-benefits. (Photo, NASA)

Summary
There are many possible ways to reduce pollution emissions, but some provide more total benefits than others. Win-Win transportation strategies are cost-effective policy reforms that solve transportation problems by improving resource-efficient mobility options and removing market distortions that cause excessive motor vehicle travel. They provide many economic, social and environmental co-benefits, in addition to reducing emissions. If implemented to the degree that is economically justified, Win-Win solutions can reduce transport emissions 30-60% while helping to achieve other community goals. A useful rule of thumb is that at least half of transportation emission reduction targets should be achieved with Win-Win strategies. This report discusses the Win-Win concept, describes Win-Win strategies, and provides guidance for their optimal implementation.
Introduction to Win-Win Strategies
There are many possible ways to reduce transportation pollution emissions. Which are best? That depends on how they are analyzed. Some strategies only reduce emissions, while others provide other economic, social and environmental benefits. Good planning accounts for all significant impacts when selecting emission reduction strategies.

Win-Win solutions are Transportation Demand Management (TDM) strategies that improve and encourage resource-efficient travel options (walking, bicycling, ridesharing and public transit), and Smart Growth development policies that create more compact, multimodal neighborhoods where residents tend to own fewer vehicles, drive less, rely more on resource-efficient modes, and spend less money on transportation. These changes provide many benefits including congestion reductions, road and parking facility cost savings, consumer savings and affordability (savings to lower-income households), social equity benefits such as independent mobility for non-drivers, improved public health and safety, and reduced sprawl-related costs, to name a few.

An integrated set of cost-effective Win-Win strategies can typically reduce affected vehicle travel and emissions by 30-60% compared with what would otherwise occur, while providing substantial co-benefits.

These are, admittedly, big claims. To understand why such large benefits are possible it is useful to consider some basic economic principles. Efficient markets have certain requirements, including consumer sovereignty (consumers have options that respond to their demands), efficient pricing (prices reflect production costs), and neutrality (public policies do not arbitrarily favor one good or group over others). Many current transport policies violate these principles in ways that reduce efficiency and exacerbate problems. Although few motorists want to give up automobile travel altogether, surveys indicate that many would prefer to drive less, rely more on efficient modes, and live in more walkable neighborhoods, provided they are convenient, comfortable and affordable. Win-Win solutions respond to these demands.

This is timely issue. There is growing agreement on the need to reduce emissions but disagreement concerning how. When evaluating options it is important to apply comprehensive analysis that considers all impacts including rebound effects, co-benefits and social equity goals. More comprehensive evaluation tends to support Win-Win solutions, alone and in conjunction with “clean vehicle” strategies such as fuel switching, to maximize their benefits.

This report examines these issues. It describes basic economic principles required for an efficient and equitable transportation system, identifies current policy distortions that violate these principles, describes various Win-Win transportation emission reduction strategies, and evaluates their benefits. This should be of interest to anybody involved in transportation or emission reduction planning.
Types of Emission Reduction Strategies

There are two general approaches to reducing transportation emissions: cleaner vehicles strategies that reduce per mile emission rates, and vehicle travel reduction strategies that reduce total vehicle mileage. Table 1 lists examples of these approaches.

<table>
<thead>
<tr>
<th>Cleaner Vehicles</th>
<th>Motor Vehicle Travel Reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technologies and policies that reduce emission rates per vehicle-mile</td>
<td>TDM and Smart Growth policies that reduce total vehicle travel</td>
</tr>
<tr>
<td>• Shifts to more efficient and alternative fuel vehicles (e.g., hybrid, electric and hydrogen).</td>
<td>• Multimodal planning (improve walking, bicycling, public transit, ridesharing, etc.)</td>
</tr>
<tr>
<td>• High emitting vehicle scrapage programs.</td>
<td>• Smart Growth policies that create more compact and multimodal communities.</td>
</tr>
<tr>
<td>• Efficient driving and anti-idling campaigns.</td>
<td>• Transportation Demand Management programs (commute trip reduction, freight transport management, etc.)</td>
</tr>
<tr>
<td>• Switching to lower carbon and cleaner fuels.</td>
<td>• More efficient road, parking and vehicle pricing.</td>
</tr>
<tr>
<td>• Inspection and maintenance programs.</td>
<td>• Vehicle parking policy reforms.</td>
</tr>
<tr>
<td>• Resurface highways.</td>
<td></td>
</tr>
<tr>
<td>• Roadside “high emitter” identification</td>
<td></td>
</tr>
<tr>
<td>• Increase fuel prices by reducing subsidies and increasing taxes (encourages both types of strategies)</td>
<td></td>
</tr>
</tbody>
</table>

“Cleaner vehicles” reduce emission rates. Vehicle travel reductions reduce total motor vehicle mileage.

These can also be categorized using the avoid-shift-improve framework (Creutzig, et al. 2018; TUMI 2019): **Avoid** reduces travel distances; **shift** changes travel from resource-intensive to resource-efficient modes; and **improve** reduces vehicle emission rates.

All of these strategies reduce emissions but they vary in other effects. Because cleaner vehicles generally have lower operating costs than conventional vehicles, they tend to increase total vehicle travel and associated costs. For example, electric vehicles operating costs are about half those of fossil fuel vehicles, which typically increases annual vehicle-miles by 10-30%. This is called a rebound effect, and the additional vehicle-miles are called induced vehicle travel (Byun, Park and Jang 2017; Moshiri and Aliyev 2017). Although there are still net emission reductions – a 10-30% rebound effect still leaves 70-90% net energy savings – the induced vehicle travel increases congestion, crash risk, non-tailpipe vehicle emissions, and sprawl-related costs such as habitat loss. The additional vehicle travel provides user benefits, otherwise they would not drive the additional miles, but these tend to be modest since the additional vehicle travel consists of marginal-value miles that users are most willing to forego if their costs increase.

Conversely, vehicle travel reduction strategies usually provide co-benefits in addition to emission reductions (Fang and Volker 2017; IGES 2011; ITF 2021). These are often numerous and significant in value, so vehicle travel reduction strategies often provide much larger total benefits than clean vehicle strategies, as discussed later in this report.
In recognition of these co-benefits, many experts recommend that vehicle travel reduction strategies receive at least as much consideration as clean vehicle programs (Milovanoff, Posen and MacLean 2020; Small 2019; Vaughan 2019). Many jurisdictions have vehicle travel reduction and mode shift targets (ACEEE 2019; Klein 2019; Thorwaldson 2020). For example, California state law requires reducing per capita vehicle travel 15% by 2050 (GOPR 2018). Washington State requires 30% reductions by 2035 and 50% by 2050 (WSL 2008). The United Kingdom has a goal that half of urban journeys will be by bicycle or walking by 2030 (DfT 2020). These targets are intended to help achieve various community goals including congestion reduction, infrastructure savings, affordability, public health and traffic safety, and social equity. They can also be justified as a way to correct past policies that resulted in automobile dependency, and respond to changing travel demands (Boarnet 2013; STTI 2018). Guides and tools are available for designing vehicle travel reduction plans (Byars, Wei and Handy 2017).

Table 2 illustrates a basic framework for comparing the goals achieved by various strategies. Although all reduce emissions, cleaner vehicles tend to increase total vehicle travel and encourage sprawl development, which reduces their net benefits and increases their external costs. Conversely, vehicle travel reduction strategies help achieve numerous economic, social and environmental goals.

### Table 2 Comparing Emission Reduction Strategies

<table>
<thead>
<tr>
<th>Community Goals</th>
<th>Cleaner Vehicles</th>
<th>Vehicle Travel Reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increased</td>
<td>Reduced</td>
</tr>
<tr>
<td>Congestion reduction</td>
<td>Worse</td>
<td>Better</td>
</tr>
<tr>
<td>Roadway cost savings</td>
<td>Worse</td>
<td>Better</td>
</tr>
<tr>
<td>Parking cost savings</td>
<td>Worse</td>
<td>Better</td>
</tr>
<tr>
<td>Consumer savings and affordability</td>
<td>Mixed</td>
<td>Better</td>
</tr>
<tr>
<td>Traffic safety</td>
<td>Worse</td>
<td>Better</td>
</tr>
<tr>
<td>Mobility options for non-drivers</td>
<td>Worse</td>
<td>Better</td>
</tr>
<tr>
<td>Energy conservation</td>
<td>Better</td>
<td>Better</td>
</tr>
<tr>
<td>Pollution reduction</td>
<td>Better</td>
<td>Better</td>
</tr>
<tr>
<td>Physical fitness and health</td>
<td>Worse</td>
<td>Better</td>
</tr>
<tr>
<td>More compact development</td>
<td>Worse</td>
<td>Better</td>
</tr>
</tbody>
</table>

By reducing vehicle operating costs, Cleaner Vehicle strategies increase total vehicle travel, sprawl, and associated costs. Vehicle travel reduction strategies help achieve many multiple goals.

This is not to suggest that clean vehicle strategies are bad and should never be implemented, but it demonstrates the importance of applying comprehensive analysis when evaluating emission reduction options. It asks, for example, to achieve a 30% emission reduction target, would you prefer to subsidize electric cars for 40% of your neighbors, or instead to convince your neighbors to reduce their vehicle travel by 30%?
A Dozen Excellent Win-Win Strategies

This section describes twelve Win-Win strategies. For more information see Dutzik 2016; ICAT 2020; ITF 2020; PPMC 2016; SUM4All 2020; TFA and SGA 2020; TUMI 2020; and VTPI 2020.

Transportation Planning Reforms

Conventional transportation planning practices tend to favor faster modes over slower but more affordable and resource-efficient modes (STTI 2018; Grant, et al. 2013), which creates automobile-dependent transportation systems and sprawled development patterns (Shill 2018). More comprehensive and multimodal planning, sometimes called least-cost planning, tends to create more diverse and efficient transportation systems, and justify more vehicle travel reduction strategies (Lindquist and Wendt 2012). Transport model improvements provide better information on the impacts and benefits of vehicle travel reductions (GOPR 2018; Schneider, Handy and Shafizadeh 2014). When fully implemented such reforms typically reduce vehicle travel 10-30% compared with conventional, automobile-oriented planning (TransForm 2009).

Public Transit Improvements and Transit-Oriented Development

There are many ways to improve public transit including increasing service, giving transit vehicles priority in traffic, improving vehicle and station comfort, and more convenient user information and payment systems. Transit Oriented Development (TOD) uses transit stations as a catalyst to create compact, walkable neighborhoods where residents tend to own fewer cars, drive less and rely more on non-auto modes (World Bank 2018). High quality transit can attract 5-15% of urban trips, and TOD residents typically drive 20-50% less than in automobile-oriented areas (Salon 2014).

Active Travel Improvements

Active modes include walking, bicycling, and variants such as wheelchairs and scooters. They provide many benefits including independent mobility, affordability, improved physical and mental health, community livability and enjoyment. Approximately 12% of U.S. personal trips are made by active modes, and their potential is much greater (Kuzmyak and Dill 2012). A quarter of current vehicle trips are less than one mile, a distance suitable for walking; half are less than three miles, a distance suitable for bicycling; and most are less than five miles, a distance suitable for e-biking (Bhattacharya, Mills, and Mulally 2019). Active mode improvements can also increase transit travel.

There are many ways to increase active travel including better facilities (sidewalks, crosswalks, paths and bike parking), traffic calming, and more compact development (AARP and CNU 2021; Agnellio 2020). These typically reduce automobile travel 5-15% (CARB 2010-2015). Frank, et al. (2011) found that increasing the portion of street with sidewalks from 30% to 70% reduces local vehicle travel by 3.4% and emissions 4.9%. A major academic study, A Global High Shift Cycling Scenario, estimated that improving bicycling conditions could increase urban bicycle and e-bike mode shares from the current 6% up to 17-22% (Mason, Fulton and McDonald 2015).
Electric Micro Modes
Electric micro modes include e-bikes, e-scooters and variants. They can travel faster, farther, in more conditions and with heavier loads than human powered equivalents (ITDP 2019). One study, which accounted for various climatic and geographic constraints, estimated that in typical urban areas they could achieve 10-15% mode shares and 12% vehicle emission reductions (McQueen, MacArthur and Cherry 2020).

Vehicle Sharing
Vehicle sharing refers to scooter, bike and car rental services designed to provide a convenient alternative to private vehicle travel. This allows households to own fewer vehicles and rely more on alternative modes. Motorists who shift from car ownership to carsharing typically reduce their vehicle travel 30-60%, and scooter- and bike-sharing can substitute for automobile trips (CARB 2010-2015; Clewlow 2015).

Efficient Parking Pricing
Efficient parking pricing means that motorists pay cost-recovery prices for the parking facilities they use, with higher rates under congested conditions (ICAT 2020). It can also include parking cash out, which means that non-drivers receive the cash equivalent of parking subsidies offered to motorists, and parking unbundling, which means that parking is rented separately from building space, so occupants are no longer required to pay for costly parking spaces they don’t need. Including land, construction and operating expenses, a typical urban parking space has $500-1,500 annual costs, so efficient prices are typically $2-8 per day, and more during peak periods (Litman 2019). Efficient parking pricing is facilitated by using new automated pricing methods. Efficient parking pricing typically reduces affected vehicle travel 10-30% (CARB 2010-2015).

Efficient Road Pricing
Road Pricing means that motorists pay directly for driving on a particular roadway or in a particular area. Decongestion Pricing (also called Value Pricing) refers to road pricing with higher fees during peak periods to reduce congestion. Economists have long advocated road pricing as an efficient and equitable way to fund transport facilities and reduce traffic congestion. Efficient road pricing typically reduces affected vehicle traffic 10-30%, with larger reductions if implemented with improvements to alternative modes such as public transit (CARB 2010-2015).

Pay-As-You-Drive (PAYD) Pricing
Pay-As-You-Drive (also called Distance-Based and Mileage-Based) pricing means that vehicle insurance, registration, taxes and lease fees are based directly on the vehicle’s annual mileage (Bordoff and Noel 2008). For example, a $400 annual insurance premium becomes 3¢ per mile and a $1,200 annual premium becomes 10¢ per mile. A typical U.S. motorist would pay about 7¢ per mile for insurance, plus 3¢ for registration fees and taxes. This is more equitable and affordable, and typically reduces affected vehicles’ annual mileage by 5-15%, depending on design (Greenberg and Evans 2017).
Reduce Fuel Subsidies and Increase Fuel Taxes

Motor vehicle fuel is subsidized in various ways (IMF 2015). Eliminating subsidies and increasing fuel taxes are efficient ways to reduce energy consumption and pollution emissions, finance roadways, and internalize petroleum production and distribution costs such as environmental damages and explosion risks (ExternE 2015; NAS 2009). Eliminating fuel subsidies is predicted to reduce global GHG emissions 11-18% (IMF 2015; Merrill, et al. 2015). Carbon taxes reflect a fuel’s carbon content. Fuel taxes would need to approximately double to cover all roadway costs (in 2018 U.S. governments collected $121 billion in vehicle fuel taxes and road tolls, about half of the $225 billion spent on roads [FHWA 2018]), and more to internalize other costs. A $50 per metric ton carbon tax would be 44₵ per gallon of gasoline, increasing current retail prices about 25%. The price elasticity of vehicle fuel is typically about -0.3 in the short run and -0.7 in the long run, so a 25% price increase would reduce consumption about 7% within two years and 18% within ten years (CARB 2014; Litman 2015).

Transportation Demand Management (TDM) Programs

TDM programs encourage use of resource-efficient modes (SANDAG 2015; WSDOT 2017). Commute Trip Reduction programs target employee travel. School and Campus Trip Management programs target students and school staff. Transportation Management Associations target a particular area, such as a commercial or industrial center. Although most TDM strategies individually only affect a small portion of total travel, an integrated program can typically reduce affected vehicle travel 5-15% if it only provides information and encouragement, and 10-30% if it has financial incentives such as efficient road or parking pricing (CARB 2010-2015). Cities such as Portland, Seattle and Vancouver demonstrate TDM program effectiveness, as illustrated below.

Figure 1  Examples of Successful Vehicle Travel Reduction Programs
**Smart Growth Development Policies**

*Smart Growth* refers to development practices that result in more compact, multimodal communities where travel distances are shorter and people have more travel options. This is sometimes called a *15-minute neighborhood*, where common services are accessible within a 15 minute or bike ride (AARP and CNU 2021; TfA and SGA 2020). Surveys indicate that many families want to live in such neighborhoods, but cannot due to inadequate supply; Smart Growth policies respond to these demands by allowing more infill development (NAR 2017). Smart Growth policies typically reduce per capita vehicle travel and emissions 10-30%, and more if implemented with complementary strategies such as efficient road and parking pricing (Kimball, et al. 2013).

The report, *Quantifying the Effect of Local Government Actions on VMT* (Salon 2014), used sophisticated analysis to measure how local transportation and land use policies affect work and non-work travel. It found that households located in automobile-dependent, urban fringe areas drive about three times more miles and produce about three times the carbon emissions as otherwise comparable households located in compact, multimodal neighborhoods (Figure 2). Smart Growth policies would allow most households and businesses to locate in compact, multimodal neighborhoods.

**Figure 2**  Household VMT by Neighborhood Type (Salon 2014)

*Households in central, multimodal neighborhoods drive less and generate less pollution than they would in sprawled, automobile-dependent areas.*

**Freight Transport Management**

*Freight Transport Management* includes various strategies to increase the efficiency of freight and commercial transport (CIVITAS 2015). This includes improving distribution practices to reduce vehicle trips, shifting freight to more resource efficient modes (such as from air and truck to rail and marine), improving efficient modes such as marine and rail, and better siting of industrial locations to improve distribution efficiency. Freight vehicle represent less than 10% of total vehicle travel but about 30% of vehicle emissions. More efficient management typically reduces freight vehicle travel 5-20% (Goetz and Alexander 2019).
**Win-Win Solutions Summary**

Table 2 summarizes these Win-Win strategies.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Transport Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning Reforms</td>
<td>More comprehensive and neutral planning and investment practices.</td>
<td>Increases support for alternative modes and mobility management, improving options.</td>
</tr>
<tr>
<td>Transit and Transit-Oriented Development</td>
<td>Improves transit and rideshare services.</td>
<td>Increases transit use, vanpooling and carpooling.</td>
</tr>
<tr>
<td>Active Travel Improvements</td>
<td>Improves walking and cycling conditions.</td>
<td>Encourages use of nonmotorized modes, and supports transit and smart growth.</td>
</tr>
<tr>
<td>Electric Micromobility</td>
<td>Encourage e-scooters and e-bikes</td>
<td>Increases micromodes, reduces auto travel.</td>
</tr>
<tr>
<td>Carsharing</td>
<td>Convenient vehicle rental services.</td>
<td>Reduced automobile ownership and use.</td>
</tr>
<tr>
<td>Parking Pricing</td>
<td>Charges users directly for parking facility use, often with variable rates.</td>
<td>Reduces parking demand and facility costs, and encourages use of alternative modes.</td>
</tr>
<tr>
<td>Road Pricing</td>
<td>Charges users directly for road use, with rates that reflect costs imposed.</td>
<td>Reduces vehicle mileage, particularly under congested conditions.</td>
</tr>
<tr>
<td>Pay-As-You-Drive Pricing</td>
<td>Converts fixed vehicle charges into mileage-based fees.</td>
<td>Reduces vehicle mileage.</td>
</tr>
<tr>
<td>Higher Fuel Taxes - Tax Shifting</td>
<td>Increases fuel taxes and other vehicle taxes.</td>
<td>Reduces vehicle fuel consumption and mileage.</td>
</tr>
<tr>
<td>Transportation Demand Management Programs</td>
<td>Local and regional programs that support and encourage use of alternative modes.</td>
<td>Increased use of alternative modes.</td>
</tr>
<tr>
<td>Smart Growth Policies</td>
<td>More accessible, multi-modal land use development patterns.</td>
<td>Reduces automobile use and trip distances, and increases use of alternative modes.</td>
</tr>
<tr>
<td>Freight Transport Management</td>
<td>Encourage businesses to use more efficient transportation options.</td>
<td>Reduced truck transport.</td>
</tr>
</tbody>
</table>

*This table summarizes the impacts of various Win-Win strategies.*

All of these strategies have been successfully implemented, although no community has implemented all that are cost effective, considering all benefits and costs. Table 3 indicates typical travel impacts. It is difficult to predict the total impacts of comprehensive Win-Win programs because of their overlapping and synergistic effects, but if implemented to the maximum degree economically justified, an integrated program is likely to reduce total vehicle travel 30-60% compared with current practices (Litman 2017). This would provide substantial emission reductions and other economic, social and environmental benefits. Some of these strategies provide particularly large benefits because they reduce high-impact travel. For example, a 10% reduction in urban-peak driving or freight vehicle mileage can reduce congestion, parking, and pollution costs by 10-30%. Although some strategies take years to implement, their effects are durable and so are ideal for solving long-term problems such as climate change.
Table 3: Travel Impacts (Win-Win Evaluation Spreadsheet, www.vtpi.org/Win-Win.xls)

<table>
<thead>
<tr>
<th>Name</th>
<th>Portion of Vehicle Travel Affected</th>
<th>Typical Reductions Of Affected Travel</th>
<th>Total Reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning Reforms</td>
<td>100%</td>
<td>10-30%</td>
<td>10-20%</td>
</tr>
<tr>
<td>Transit &amp; TOD</td>
<td>30%. Mainly urban travel</td>
<td>10-30%</td>
<td>3-9%</td>
</tr>
<tr>
<td>Walking &amp; Cycling</td>
<td>20%. Shorter-distance trips</td>
<td>10-30%</td>
<td>2-6%</td>
</tr>
<tr>
<td>Micromobilities</td>
<td>40%. Medium-distance trips</td>
<td>10-30%</td>
<td>4-12%</td>
</tr>
<tr>
<td>Carsharing</td>
<td>5%. Suitable households</td>
<td>20-40%</td>
<td>1-2%</td>
</tr>
<tr>
<td>Road Pricing</td>
<td>30%. On new or congested roads</td>
<td>10-20%</td>
<td>3-6%</td>
</tr>
<tr>
<td>Parking Cash-Out</td>
<td>20%. Commute travel</td>
<td>10-30%</td>
<td>2-6%</td>
</tr>
<tr>
<td>Parking Pricing</td>
<td>40%. Mainly urban travel</td>
<td>10-20%</td>
<td>4-8%</td>
</tr>
<tr>
<td>Pay-As-You-Drive Pricing</td>
<td>80%. Private automobile travel</td>
<td>10-12%</td>
<td>8-10%</td>
</tr>
<tr>
<td>Fuel Taxes - Tax Shifting</td>
<td>100%</td>
<td>5-15%</td>
<td>5-15%</td>
</tr>
<tr>
<td>TDM Programs</td>
<td>40%. Travel affected by programs</td>
<td>10-30%</td>
<td>4-12%</td>
</tr>
<tr>
<td>Smart Growth Reforms</td>
<td>50%. Mainly urban travel</td>
<td>20-50%</td>
<td>10-25%</td>
</tr>
<tr>
<td>Freight Transport Man.</td>
<td>10%. Freight and commercial travel</td>
<td>5-20%</td>
<td>0.5-2%</td>
</tr>
</tbody>
</table>

This table indicates the magnitude of reductions that can be achieved by various Win-Win strategies.

International comparisons support these estimates. Residents of wealthy countries with more multimodal transport systems and efficient pricing drive 30-60% less than in the U.S. (Figure 3), although none has implemented all cost-effective Win-Win strategies. Similarly, recent experience during the Covid-19 pandemic indicates that, given incentives, many people can significantly reduce their vehicle travel by using telework and delivery services, and relying on local services. Replogle and Fulton (2014) and Wheeler and Kammen (2018) also conclude that TDM and Smart Growth policies can provide large cost effective emission reductions.

Figure 3: Annual Vehicle Travel Compared (International Comparisons)

Residents of wealthy countries such as Germany, Norway and France drive less than half as many kilometers as in the U.S. due to policies and planning practices that encourage transport efficiency.
Comparing Costs and Benefits
This section compares the costs and benefits of electric vehicle incentives with a vehicle travel reduction program.

Electric Vehicle Costs
Electric vehicles currently receive CAFE credits averaging $3,000-6,000 per vehicle (for example, during the second quarter of 2020 Tesla sold 90,000 vehicles and received $428 million in credits, averaging $4,700 per vehicle), purchase subsidies averaging about $5,000 per vehicle, public investments in recharging stations that often provide free electricity (commercial stations typically charge $2.50 per recharge), plus road user fuel tax exemptions averaging about $310 per vehicle-year, as summarized below.

Table 4 Typical Electric Vehicle Subsidies (www.fueleconomy.gov)

<table>
<thead>
<tr>
<th>Subsidy</th>
<th>Annual Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate Average Fuel Economy (CAFE) credits ($4,700 over 15 years)</td>
<td>$313</td>
</tr>
<tr>
<td>Purchase subsidy (5,000 over a 15-year vehicle life)</td>
<td>$333</td>
</tr>
<tr>
<td>Electric vehicle recharging stations (50 free annual recharges costing $2.50)</td>
<td>$125</td>
</tr>
<tr>
<td>Road user fee exemption (12,500 annual miles, 20 mpg, 50₵ tax per gallon)</td>
<td>$310</td>
</tr>
<tr>
<td>Total Annual Subsidy</td>
<td>$1,081</td>
</tr>
</tbody>
</table>

Electric vehicles currently receive more than $1,000 annual subsidies and reduce approximately five metric tons of carbon-equivalent per year, averaging $200 cost per ton reduced.

This indicates that for the foreseeable future, electric vehicle subsidies total $500-1,500 per vehicle-year. Figure 4 compares lifecycle emissions of various cars. Hybrids typically produce a third less, and electric cars two-thirds lower emissions than comparable fossil fuel cars. A typical gasoline car produces approximately seven annual metric tons of carbon, compared with five tons for a hybrid and two tons for an electric car, indicating that shifting to electric reduces about five tons, at a cost of $100-300 per ton.

Figure 4 Life-cycle Greenhouse Emissions (Hausfather 2020)

Electric vehicles typically reduce emissions 50-70% compared with a comparable fossil-fuel vehicle.
The need for subsidies may decline somewhat as electric vehicle technology improves, but until a vehicle-miles tax is applied, electric vehicles will continue to receive more than $300 annual subsidy in avoided road user taxes, representing approximately $60 cost per ton of emissions reduced. Other studies find similar costs (Gillingham and Stock 2018). For example, the study, Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost (McKinsey 2007) estimated that electric vehicle emission reductions cost $22-97 per ton ($28-120 in current dollars), which is higher than most other strategies.

**Vehicle Travel Reduction Program Costs**
An integrated vehicle travel reduction program typically includes increased investments in active and public transport, efficient parking pricing, commute trip reduction programs, and Smart Growth development policies that allow more compact infill in walkable urban neighborhoods.

In 2018, U.S. transit expenditures totaled $49 billion, of which $33 billion is public subsidies that average about $100 per capita (APTA 2020). Doubling or tripling transit service is therefore estimated to cost an additional $100-200 subsidy per capita. The Federal Highway Administration’s Nonmotorized Transportation Pilot Program, which invested about $100 per capita in active travel improvements in four typical communities, increased walking 23% and bicycling 48%, and reduced driving about 3% (FHWA 2014). Washington State’s 2020 Draft Active Transportation Plan estimates that upgrading the state’s transportation system to maximize active travel would cost $5.7 billion, approximately $750 per capita or about $75 annual per capita over a 10-year period (WSDOT 2020). Road and parking pricing generate revenues. TDM programs typically cost $50-150 annually per effected commuter, but those costs are often offset by parking cost savings. Smart Growth policies involve some planning costs but tend to provide infrastructure cost savings (Gordon 2012; Litman 2018).

This suggests that an integrated vehicle travel reduction program is likely to cost an additional $200-500 annual per capita for active and public transport improvements, TDM programs, and Smart Growth policy development, but these costs are generally repaid through infrastructure and consumer savings, as discussed in the next section.

**Estimates**
This analysis considers the economic impacts described below. It assumes that fossil-fuel vehicle owners drive 10,000 annual vehicle-miles, electric vehicle owners drive 12,500 annual vehicle-miles due to the rebound effect, and people affected by the TDM and Smart Growth program drive 7,500 annual vehicle-miles.

**User Travel Expenses**
Electric vehicles currently cost significantly more than comparable fossil fuel vehicles, although this cost premium is declining and partly offset by fuel cost savings (Lutsey and Nicholas 2019). A typical electric car uses 3-12¢ worth of electricity per mile, about half the fuel costs of an equivalent gasoline car. However, their batteries must be replaced
about every 100,000 miles, which currently costs $3,000-15,000 or 3-10¢ per vehicle-mile, and their additional battery weight increases tire replacement costs (Edmunds 2019). As a result, electric vehicle lifecycle costs are comparable to fossil fuel vehicles.

Motorists currently spend about $5,000 annually per vehicle-year, of which about $3,500 consists of fixed costs (depreciation, financing, insurance, registration fees and scheduled maintenance) and $1,500 variable costs (fuel, tire wear, tolls, and mileage-based depreciation). Because most costs are fixed, marginal reductions in annual mileage provide only modest savings, but if TDM and Smart Growth policies allow some households to reduce their vehicle ownership (for example, shedding a second household car, or becoming car-free), they can achieve large savings. These savings may be partly offset by additional expenses for shoes, bicycles, taxis, carsharing and public transit fares, but most households that significantly reduce their vehicle travel achieve significant net savings. This analysis assumes that net user savings are half of vehicle travel reductions, so if motorists reduce their driving by 20% their costs decline by 10%.

**Roadway Costs**
In 2018 the U.S. spent $225 billion on roads, which averages about $825 per motor vehicle. About half of these costs are paid through fuel taxes and road tolls, and about half are funded through general taxes that residents pay regardless of how they travel.

**Parking Facility Costs**
A typical community has 2-6 government-mandated off-street parking spaces per vehicle (Hoehne, et al. 2019; Scharnhorst 2018). Considering land, construction and operating costs a surface parking space has $500-1,500 annual value, and structured parking two or three times higher (“Parking Costs,” Litman 2019). This indicates that parking costs typically average $2,000-4,000 per vehicle, most of which is paid indirectly through higher taxes, rents and higher prices for other goods. Electric vehicles require more expensive parking facilities that include rechargers.

**Traffic Congestion**
Traffic congestion refers to the delay that a vehicle imposes on other vehicles in traffic. The Texas Transportation Institute’s Urban Mobility Report (TTI 2019) estimates that U.S. traffic congestion costs a total of $179 billion, or about $665 per motor vehicle, but other studies estimate somewhat lower costs (“Congestion Costs,” Litman 2019). This analysis assumes $400 per year for an average car.

**Barrier Effects**
The barrier effect refers to the delay and avoidance costs that motor vehicle traffic imposes on pedestrian and bicyclists (“Barrier Effects,” Litman 2019). It is typically estimated at 2-6¢ per urban vehicle-mile, or $100-300 per vehicle-year, assuming that half of travel is on urban streets (Anciæas, Jones and Mindell 2016).
Crash Damages
Various studies have monetized (measured in monetary units) crash damage costs (“Crash Costs,” Litman 2019). A comprehensive study for the National Highway Traffic Safety Administration estimated that in 2010 U.S. traffic crash costs totaled $242 billion in economic costs and $836 billion non-market costs (pain and suffering from injuries and deaths), which averaged $800-2,600 per vehicle-year (Blincoe, et al. 2015). This analysis assumes that uncompensated crash costs average $1,000 per vehicle-year.

Fossil Fuel External Costs
Fossil fuel external costs include various uncompensated costs of fuel production and distribution, and therefore the benefits of fossil fuel conservation. These costs include production subsidies, petroleum extraction environmental damages, danger when transporting fuels, international security risks to maintain access to petroleum, and macroeconomic costs to regions that devote a large portion of their export exchange to importing fuel (Malik, Behan and Kalapos 2014; NRC 2009). This study assumes that these costs average $200 per fossil-fuel vehicle-year, which reflects the lower range of published estimates (Crane, Burger and Wachs 2011; Litman 2019).

Pollution Emissions
Motor vehicles produce air and noise pollution. Various studies have monetized these costs (Litman 2019). For example, a major U.S. National Academy of Sciences study estimated that non-climate change emission costs average about $150 per vehicle-year (NAR 2009), and a major European study estimated that local air pollution costs average 0.0114 Euro and noise costs average 0.009 Euro per vehicle-kilometer, totaling about $400 per vehicle-year (CE Delft 2019). This study assumes that fossil fuel pollution costs currently average $400 per vehicle-year. Electric vehicles eliminate tailpipe emissions but still produce particulate pollution, embodied emissions, and tire noise, with costs estimated to average about $100 per vehicle-year (OECD 2020).

Carbon emissions can also be monetized, based either on damage costs, which reflect the environmental and economic harms caused by emissions, or on avoidance costs, which reflect the marginal costs of reducing emissions. Because of the extreme risks of climate change (which could cause catastrophic losses), damage costs could be infinite, but avoidance costs are generally estimated at $20-50 per metric ton. This analysis assumes $50 per ton, which equals $100 for an electric car, $350 for a gasoline car driven 10,000 annual miles, and $263 for a gasoline car driven 7,500 annual miles.

Analysis Results
Table 5 and Figure 5 summarize the analysis results. It assumes that most costs are proportional to vehicle travel, so electric cars’ 25% increase in annual mileage increases road, parking, congestion and crash costs by that amount, and the 25% mileage reduction caused by TDM and Smart Growth reduces these costs by that amount. This may exaggerate some effects, for example, mileage changes do not cause proportional savings in fixed vehicle expenses, and motorists who reduce mileage may need to spend some of the savings on other modes. On the other hand, TDM and Smart Growth allow
some households to reduce their vehicle ownership (compact community residents own about half as many vehicles as in automobile-dependent areas), and often reduce higher cost travel, such as urban-peak driving, providing relatively large savings, which justifies assuming proportional cost impacts.

**Table 5** Estimated Costs (Litman 2021)

<table>
<thead>
<tr>
<th></th>
<th>Electric Car</th>
<th>Fossil Fuel Car</th>
<th>TDM/Smart Growth</th>
<th>Car-Free</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual VMT</strong></td>
<td>12,000</td>
<td>10,000</td>
<td>7,500</td>
<td>2,000</td>
</tr>
<tr>
<td>Program costs/subsidies</td>
<td>$1,000</td>
<td>$0</td>
<td>$350</td>
<td>$350</td>
</tr>
<tr>
<td>Vehicle expenses</td>
<td>$5,000</td>
<td>$5,000</td>
<td>$3,750</td>
<td>$2,000</td>
</tr>
<tr>
<td>Roadway costs</td>
<td>$1,000</td>
<td>$800</td>
<td>$619</td>
<td>$155</td>
</tr>
<tr>
<td>Parking facility costs</td>
<td>$2,500</td>
<td>$2,000</td>
<td>$1,500</td>
<td>$100</td>
</tr>
<tr>
<td>Traffic congestion</td>
<td>$500</td>
<td>$400</td>
<td>$375</td>
<td>$94</td>
</tr>
<tr>
<td>Barrier effect</td>
<td>$250</td>
<td>$200</td>
<td>$150</td>
<td>$0</td>
</tr>
<tr>
<td>Crash damages</td>
<td>$1,250</td>
<td>$1,000</td>
<td>$750</td>
<td>$188</td>
</tr>
<tr>
<td>Resource external costs</td>
<td>$50</td>
<td>$200</td>
<td>$150</td>
<td>$38</td>
</tr>
<tr>
<td>Pollution</td>
<td>$100</td>
<td>$400</td>
<td>$300</td>
<td>$75</td>
</tr>
<tr>
<td>Carbon emissions</td>
<td>$100</td>
<td>350</td>
<td>$263</td>
<td>$66</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>$11,750</td>
<td>$10,350</td>
<td>$8,207</td>
<td>$3,066</td>
</tr>
</tbody>
</table>

This table compares the estimated costs of an electric car, a fossil fuel car, a fossil fuel car with reduced mileage due to TDM and Smart Growth policies, and a car-free lifestyle.

**Figure 5** Total Costs Compared

This figure illustrates the estimated costs of various transportation patterns.

This analysis indicates that electric vehicles tend to have higher total costs than conventional cars because the value of their fuel savings and emission reductions do not offset their program costs or the additional congestion, facility and crash costs caused by their increased vehicle travel. In contrast, TDM and Smart Growth policies provide significant co-benefits which more than offset their program costs.
Additional Considerations
These additional factors should be considered when comparing clean vehicle and Win-Win solutions (Creutzig, et al. 2018).

Implementation Speed
Many vehicle travel reduction strategies can be implemented more quickly than clean vehicles. Electric vehicle technology is relatively new, with high prices, few models (particularly for SUVs, light trucks and vans), and face operational obstacles such as limited recharging stations. Less than 5% of 2020 North American vehicle sales were electric. By 2030, up to half of new vehicles may be electric, but because only about 5% of the vehicle fleet is replaced each year, new technologies take two or three decades to penetrate the fleet, so it will probably be the 2040s before most vehicle travel will be electric. Many Win-Win strategies can be implemented much more quickly. These include fuel and carbon tax increases, efficient transport pricing, active and micro mode improvements, transit service improvements, and TDM programs. Smart Growth policies can allow most future growth to occur in compact, multimodal neighborhoods.

Consumer Impacts
People sometimes assume that, since mobility provides benefits, vehicle travel reductions harms consumers. As evidence they describe examples of trips most efficiently made by automobile, such as commuting to isolated worksites, carrying heavy loads, or transporting people with mobility impairments. But the fact that some trips are most efficiently made by automobile does not prove that all trips should be by automobile, or that it is infeasible to reduce vehicle travel. Given better options and incentives, many travellers will drive less, rely more on resource-efficient modes, and be better off overall as a result. Vehicle travel reductions that results from positive incentives, such as better travel options or financial rewards from reduced driving directly benefits consumers, and even negative incentives such as new road tolls or parking fees can benefit consumers overall by providing new ways to save money. When roads and parking facilities are financed indirectly through general taxes or rents, people pay regardless of how they travel, but if users pay directly, consumers save money when they reduce peak period driving or use a cheaper parking space.

Many Win-Win strategies respond to travel consumer demands and so increase social welfare. Current demographic and economic trends are causing demand for automobile travel to peak, and demand for other modes and for housing in compact neighborhoods to increase (NAR 2017). By increasing transportation system diversity, Win-Win solutions also increase transportation system resilience; they allow individuals and communities to respond to physical and economic shocks that constrain automobile travel, for example, if a motorist is suddenly unable to drive, a household’s income declines, or if a transportation link fails. TDM and Smart Growth policies can help communities respond to these demand changes.
**Equity Impacts**

Many vehicle travel reduction strategies help achieve equity goals. Clean vehicle subsidies primarily benefit affluent households that purchase new vehicles. In contrast, many TDM strategies and Smart Growth policies directly benefit disadvantaged groups by improving affordable modes; providing financial benefits such as parking cash out and unbundling, reducing external costs that vehicle traffic imposes on other people, and create more affordable housing in walkable urban neighborhoods.

**Strategic Goals**

Vehicle travel reduction strategies tend to support strategic goals. During the last century, transportation planning favored automobile travel over other modes, and sprawl over compact infill, creating automobile-dependent communities (Litman 2006; Shill 2020). Many communities now have goals to become more multimodal and compact. Unless implemented with TDM and Smart Growth policies, clean vehicles subsidies tend to increase driving and sprawl. In contrast, vehicle travel reduction strategies help create more diverse and efficient transport systems, and more compact and multimodal communities.

**Economic Impacts**

Many people assume that since many economic activities depend on vehicle travel, vehicle travel reductions must reduce productivity. But Win-Win strategies can support economic development in various ways. Although a certain amount of vehicle travel supports economic activity, beyond an optimal level, additional mobility is economically harmful (marginal costs exceed marginal benefits). Many Win-Win strategies correct current market distortions that result in economically inefficient vehicle travel. This increases overall economic efficiency and equity, and reduce problems such as traffic congestion, crash risk and pollution damages. Win-Win strategies are a type of preventive medicine, equivalent to putting a transport system on a healthier diet.

**Figure 11** Per Capita GDP and VMT for U.S. States (Litman 2014)

Per capita economic productivity increases as vehicle travel declines. (Each dot is a U.S. state.)
Integrated Emission Reduction Planning

In the past, transportation emission reduction plans were reductionist: they only considered emission reduction goals, ignoring their rebound effects and co-benefits (Mckinsey 2007; Project Drawdown). This tends to favor clean vehicle strategies. A recent review of National Determined Contributions (NDC), which identifies the actions that each country plans to take to achieve Paris Agreement emission reduction targets, found that 57% of the actions rely on clean vehicle implementation, while only 6% rely primarily on vehicle travel reduction strategies (Taeger 2021). This indicates that current emission plans do not support TDM and Smart Growth to an optimal degree.

However, planning is increasingly comprehensive and integrated. For example, New Zealand’s independent Climate Change Commission, He Pou a Rangi (Maori for “A Pillar of the Sky”) incorporates broad social goals into emission reduction planning, including social equity and public health, and so recommends integrated solutions (He Pou a Rangi 2021). Similarly, many strategic transportation plans incorporate emission reduction goals, and so will favor traffic or parking congestion reduction strategies that also help reduce emissions, and avoid those that may induce more vehicle travel and pollution (Volker, Lee, and Handy 2020; STTI 2018).

Many jurisdictions are implementing vehicle travel reduction policies to achieve various goals (Pollution Probe 2020). For example, California and Washington State have VMT reduction targets to reduce congestion and consumer costs as well as emissions (GOPR 2018; WSL 2008). Cities such as London, New York, Paris and Los Angeles, are implementing TDM and Smart Growth policies to reduce traffic congestion and crash risks, and support livability goals (ACEEE 2019; Klein 2019). The City of Vancouver’s Climate Emergency Action Plan, includes goals that by 2030, two-thirds of trips within the city will be by active and public transport modes, and 90% of residents will live in compact, multimodal neighborhoods where most services and activities are easy to access by walking and bicycling. Experts increasingly recommend that vehicle travel reduction strategies receive at least as much consideration as clean vehicle programs (Milovanoff, Posen and MacLean 2020; Manjoo 2021; Nadel and Ungar 2019; Small 2019; Vaughan 2019).

Many clean vehicle advocates now recognize the negative impacts of rebound effects, and so recommend integrated programs that include travel reduction strategies. For example, Daniel Sperling’s book, Three Revolutions, highlights the potential benefits of automated, electric and shared vehicles, but recognizes potential problems if they increase vehicle travel and sprawl (Sperling 2018). Similarly, the Greenline Institute’s report, Autonomous Vehicle Heaven or Hell? Creating a Transportation Revolution that Benefits All, recommends policies that favor Fleets of “Autonomous Vehicles that are Electric and Shared” (FAVES) to avoid transportation hell (Creger, Espino and Sanchez 2019). The Shared Mobility Principles for Livable Cities supports resource-efficient transportation (Figure 6). This integrates TDM incentives and Smart Growth policies to maximize the benefits of new technologies.
The Shared Mobility Principles for Livable Cities emphasize the importance of favoring resource-efficient over resource-intensive travel options. TDM and Smart Growth policies make this happen.
Conclusions
There are many possible ways to conserve resources and reduce pollution emissions. Some are more efficient and equitable than others. Clean vehicle strategies reduce per-mile emission rates but tend to induce more vehicle travel that increases external costs and contradicts strategic goals. In contrast, Win-Win strategies that improve resource-efficient travel options, encourage travellers to use the most efficient mode for each trip, and create more accessible communities, can provide large and diverse co-benefits. Most people benefit more overall if their community’s emission reduction programs convince their neighbors to drive less, and therefore reduces traffic problems, than if the program simply subsidizes the purchase of more electric cars.

Conventional planning tends to overlook and undervalue many of these impacts, and so tends to undervalue Win-Win solutions. When evaluating and comparing potential emission reduction strategies it is important to use a comprehensive analysis framework that accounts for:

- Lifecycle emission impacts, including embodied and upstream emissions.
- Rebound effects, including the additional external costs of increased vehicle travel.
- Co-benefits of vehicle travel reduction strategies.
- Social equity impacts, including the benefits of improvements to affordable travel modes.

Most Win-Win strategies affect a small portion of total vehicle travel, so their benefits seem modest, but their impacts tend to be cumulative and synergistic; they become more effective and beneficial if implemented as a coordinated package. An integrated Win-Win program can reduce affected people’s vehicle travel by 30-60% while achieving other economic, social and environmental goals.

Win-Win strategies have other advantages over clean vehicle incentives. They tend to be more cost effective overall, considering all impacts. Many can be implemented quickly. They respond to unmet consumer demands, which increases social welfare and transport system resilience. They tend to be more equitable, providing substantial benefits to physically, economically and socially disadvantaged people. Win-Win solutions support strategic goals to create more diverse and efficient transportation systems, and more compact and affordable neighborhoods. In contrast, clean vehicle strategies tend to increase automobile dependency and sprawl.

A comprehensive emission reduction program should include both clean vehicle and Win-Win strategies. It is particularly important to use clean vehicles for public transit and other public fleets, and clean-vehicles should be implemented with vehicle travel reduction strategies to avoid rebound effects and achieve a wider range of benefits. A useful rule of thumb is that at least half of transportation emission reduction targets should be achieved with Win-Win strategies.
References and Information Resources


Asian Cobenefits Partnership (www.cobenefit.org) is a coalition that supports mainstreaming co-benefits into sectoral development plans, policies and projects in Asia.


Austin L. Brown, et al. (2021), *Driving California’s Transportation Emissions to Zero*, Institute of Transportation Studies (); at https://escholarship.org/uc/item/3np3p2t0.


Co-Benefits of Climate Action (www.changingtheconversation.ca/co-benefits).

CoolClimate Calculator (https://coolclimate.berkeley.edu) estimates household transportation, housing, food, goods and services carbon emissions for U.S communities.

Keith Crane, Nicholas Burger and Martin Wachs (2011), The Option of an Oil Tax to Fund Transportation and Infrastructure, Rand Corporation (www.rand.org); at https://bit.ly/3bPiIWb.


Drawdown (www.drawdown.org) describes GHG emission reduction strategies.

Edmunds (2019), The True Cost of Powering an Electric Car, (www.edmunds.com); at https://edmu.in/2CT1k5s.


**Shared Mobility Principles for Livable Communities** (www.sharedmobilityprinciples.org)


**Street Smart** (www.thinkstreetsmart.org) is a clearinghouse that provides information for integrating climate change, public health, and equity concerns into transport planning.

SUM4All (2019), *Catalogue of Policy Measures Toward Sustainable Mobility*, Sustainable Mobility for All (www.sum4all.org); at https://sum4all.org/key-products. Also see Global Roadmap of Action Toward Sustainable Mobility.


www.vtpi.org/wwclimate.pdf