From:	Darrell Clarke
To:	Pennebaker, Laura@DOT
Subject:	FW: Comment for Road Charge Technical Advisory Committee Meeting 1/23/15
Date:	Thursday, January 22, 2015 4:46:11 PM

To the members of the Road Usage Charge Technical Advisory Committee,

The Sierra Club looks forward to participating in your public process this year and will submit formal comments in the future.

For the first meeting I'd emphasize California's climate policy context for a road usage charge (RUC), especially executive order S-3-05 which calls for 80% reduction in greenhouse gas (GHG) emissions from 2020-2050 and B-16-2012 which calls for 1.5 million zero-emission vehicles (ZEVs) by 2025.

Therefore two key RUC principles are that driver incentives must remain against fossil fuel use, and that gasoline use will decline.

The current fuel excise and sales taxes are proportional to gasoline and diesel used and therefore GHG emissions. Any mileage-based replacement should dis-incent fossil fuel consumption at least as much, and incent use of ZEVs. Conversely a flat charge per mile driven would create a "gas guzzler loophole" where a Prius or Leaf would pay the same per mile as a Hummer.

Darrell Clarke
Sierra Club Beyond Oil Campaign national co-lead
darrell.clarke@sierraclub.org

(Please add me to your stakeholder list)

Mike Bullock
1800 Bayberry Drive
Oceanside, CA 92054
Telephone: (760) 754-8025
January 19, 2015

California Transportation Commission
Attn: Road Usage Charge Technical Advisory Committee (RUC TAC)
1120 N Street, MS-52
Sacramento, CA 95814
Via Email to ctc@dot.ca.gov

Re: Initial Comments on the Design of a RUC Pilot Program

Dear CTC Chair Guardino, CTC Members, and Members of the RUC TAC:

My Background

For 36 years, I worked as an engineer at Lockheed Martin in Sunnyvale, Ca. For most of that time, I was a satellite systems engineer. Since retiring, I have been working on the problem of how light-duty vehicle emission levels could support climate stabilization. Since this is as much a political problem as it is a technical problem, I have also been active in the California Democratic Party (CDP). I've served for 6 years as a state delegate and authored two, adopted California Democratic Party (CDP) resolutions: the 1st, *Battery Electric Vehicles* and the 2nd, *Long Range Plans Should Support Climate Stabilization*. See

- http://www.cadem.org/resources/resolutions?id=0686 &
- http://www.cadem.org/resources/resolutions?id=0018.)

I have also authored five CDP Platform changes. The 76th Assembly District Democratic voters elected me to the County Democratic Party Central Committee, where I have written five adopted resolutions. I am also a UCSD guest lecturer on Climate/Transportation and formulate regional transportation policies for an environmental organization. I have authored & presented the following peer-reviewed papers at the Air & Waste Management Association (AWMA) conferences:

- *The Development of California Light-Duty Vehicle Requirements to Support Climate Stabilization: Fleet-Emission Rates & Per-Capita Driving* and
- *A Climate-Killing Regional Transportation Plan Winds Up in Court: Background & Remedies*.

I coauthored the AWMA paper: *How to Efficiently & Conveniently Unbundle Car-Parking Cost*. (The AWMA papers are available upon request.. Email requests to: mike_bullock@earthlink.net.)

Before retiring and moving to Oceanside, I had the pleasure of working with the *Santa Clara County Leadership Group* in support of *Measure A*, a sales tax to fund extending BART to downtown San Jose.

SB 1077 and Our State's Climate and Pollution Mandates

SB 1077 provides little guidance on what principles should apply to a RUC. However, the recommendations you produce need to be consistent with existing California law, including AB 32 and the continuation proposed by SB 32 (Pavley). They also need to help and not harm the prospects for achieving the SB 375 driving-reduction targets, Executive Order S-3-05, as well as the Governor's recently announced target of up to a 50% reduction in oil use by 2030. On top of these climate-driven mandates, California is required to meet increasingly stringent federal air quality requirements, which means tailpipe emissions must be significantly reduced.

The following principles need to be applied to our RUC:

- Roads should be well maintained
- Drivers should pay the full cost of building and operating roads
- Drivers should pay for the environmental and health costs resulting from driving and
- On-road transportation GHG emissions should be low enough to support climate stabilization.

In addition, the damaging impact of a vehicle on the road surfaces is a function of weight. Given all of these considerations, the RUC TAC should produce a recommendation for a per-mile fee that is based on the characteristics of each vehicle model.

In terms of achieving the principle of full-cost pricing, there are studies that document the various cost impacts of vehicles and roadways. One of the most comprehensive is provided by the Victoria Transport Policy Institute (Ref. 1). The attached spreadsheet lists 23 internal and external costs that could be considered. Note for example the much lower impact costs per mile for an EV, compared to an internal combustion engine (ICE) vehicle. There are more details on the Victoria Transport Policy Institute website.

Economic Justice

Table 2 in Reference 2 indicates that, although California ranks fourth from the top, the principle of full-cost pricing is far from true today. Unfortunately, there is widespread confusion on this important point.

As an example of this confusion, on Page 12 of the January/February 2015 issue of the American Automobile's *Westways* magazine, the following misstatement appears:

> *The current tax on motor vehicle fuels pays for road construction and maintenance, as well as some mass transit projects.*

My hope is that the RUC TAC will consider all of these factors and its results will include comprehensive estimates of the health and environmental costs of driving.

The RUC TAC should include all the costs in its calculations as outlined in Ref. 1, including taxes lost to local governments because of the land roads occupy, plus the environmental, health, and social costs, including noise, toxic emissions, etc.

Road Maintenance

Reference 3 states:

> *The group cited a 2011 assessment conducted by the California Transportation Commission, which found that 58 percent of the state's roads require rehabilitation or pavement maintenance; 20 percent of bridges need major or preventive maintenance; and 6 percent of bridges require complete replacement.*

Highway engineers know that there are significant unfunded repair and maintenance costs, and the longer the state delays this work, the more expensive the repairs and replacements will be.

The Urgency of Climate and Its Impact on Revenue

Besides the economic justice and road maintenance imperatives, there is a need to have on-road vehicles support climate stabilization. If this topic is examined closely (Ref. 4), it is found that the sale of fossil-fueled internal combustion engine vehicles will need to be largely phased out, over the next 10 years or so. Therefore, bluntly put, since there is a dwindling future for internal combustion engine vehicles, there is a dwindling future for our vehicle-fuel excise taxes, and precious little time to waste in implementing a RUC. Reference 4 shows that road pricing is a necessary component of any realistic plan to have cars and light-duty trucks achieve GHG reductions sufficient to support climate stabilization.

Other Voices

Reducing the net subsidy to driving is a necessary mitigation measure of any state plan, or regional transportation plan, if it is going to support climate stabilization. Also, economic fairness must be considered.

As stated in the California Democratic Party's Platform (Ref. 5), we should (emphasis added):

- Work for *equitable and environmentally-sound road* and parking *operations*; and,
- Provide support for driving reduction targets shown to stabilize the climate at a livable level

I hope that Democrats, Republicans and others will recognize the value of these common-sense statements of fact.

High Level Features Leading to Technology Choices

Since we are early in the SB 1077 process, I will restrict my remaining comments to a listing of the key, high-level features of a RUC and statements about why they are important to the design of a pilot project.

Required features of a RUC:

1. Would cover all road-use costs, including the environmental and health costs caused by driving;
2. Could still include a fuel tax or fee;
3. Would mitigate impacts on low-income users;
4. Would protect privacy;
5. Would include congestion pricing when that technology becomes feasible;
6. Would keep the per-mile price incentive to drive energy-efficient cars at least as large as it is with today's fuel excise tax; and
7. Would appropriately distribute its earnings, after ensuring needed road maintenance, to all citizens and institutions that are losing money under the current system, in which:
    - general tax and other hidden subsidies (such as development fees used for roads) are used to operate and maintain roads and
    - environmental and health costs are paid by the general public.

The goal of Feature 7 is to achieve a set of full compensations.

Since few citizens can reasonably be expected to pay significantly more for transportation, Feature 1 must be offset by the careful design of Feature 7. Bluntly, the RUC should not be viewed as a "cash cow". Feature 5 is important because we will not bring on-road-transportation greenhouse gas (GHG) emissions down to levels supporting climate stabilization by only increasing vehicle efficiency; we must also have significant driving reductions. This means that congestion must be solved by congestion pricing, rather than by highway expansions (which has never worked, in any case.) The phrase "congestion pricing" will ultimately be understood to mean instantaneous pricing, as a function of traffic flow rates, so as to eliminate congestion. This leads to the important conclusion that the system most likely needs to be GPS based, with an overlay of additional information exchange. I unfortunately know of

only one current vendor that may be up to this challenge, that being *Pay by Sky* (Ref. 6.) I suggest that *Pay by Sky* (formerly *Skymeter,* their name when they solved the road-usage charge problem) and other interested vendors be brought into the SB 1077 process as soon as possible.

All of the other features can be guaranteed by the early adoption of a comprehensive and unambiguous systems engineering *Requirements Document*. Please bring systems engineers into your process as soon as possible.

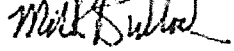
Concluding Remarks

Please let me know how I can help you in your important work. I note that the January/February 2015 issue of the American Automobile Association's magazine, *Westways*, states that the AAA will seek participation on your TAC. I hope that the environmental community will also be well represented on the TAC. If that is not possible, I hope that the views of the large environmental organizations will be sought out and fully considered.

We all have a large stake in achieving climate stabilization, economic justice, and well maintained roads.

Thank you for your leadership.

Sincerely,



Mike Bullock
1800 Bayberry Drive
Oceanside, CA 92054
760-754-8025
mike_bullock@earthlink.net
CDP Delegate, 76 AD
Elected Member of the San Diego County Democratic Party Central Committee
Satellite Systems Engineer for36 years (now retired)
Air and Waste Management Association published and presented papers:

1. ***The Development of California Light-Duty Vehicle (LDV) Requirements to Support Climate Stabilization: Fleet-Emission Rates & Per-Capita Driving***
2. ***A Climate-Killing Regional Transportation Plan Winds Up in Court: Background and Remedies***

Co-author, ***A Plan to Efficiently and Conveniently Unbundle Car Parking Cost***
http://www.sandiego.gov/environmental-services/pdf/sustainable/parkingcosts.pdf

References

1. *Transportation Cost Analysis*, Victoria Transport Policy Institute (www.vtpi.org)
2. *Gasoline Taxes and User Fees Pay for Only Half of State & Local Road Spending*, Joseph Henchman, Tax Foundation, January 3, 2014. http://taxfoundation.org/article/gasoline-taxes-and-user-fees-pay-only-half-state-local-road-spending
3. *Group Wants Tax Hike for Road Bridge Fixes,* Chris Nichols, San Diego Union Tribune, November 19, 2013. http://www.utsandiego.com/news/2013/Nov/19/tp-group-wants-tax-hike-for-road-bridge-fixes/
4. Bullock, M.; *The Development of California Light-Duty Vehicle (LDV) Requirements to Support Climate Stabilization: Fleet-Emission Rates & Per-Capita Driving*; Paper 2014-30793-AWMA, from the Air and Waste Management Association's 2014 Annual Conference and Exhibition; Long Beach, California, June 24-27, 2014 (Attached in the email containing this letter).
5. 2014 California Democratic Party Platform. http://www.cadem.org/resources?id=0003
6. Pay By Sky. http://paybysky.com/; http://www.snipview.com/q/Skymeter

The Development of California Light-Duty Vehicle (LDV) Requirements to Support Climate Stabilization: Fleet-Emission Rates & Per-Capita Driving

Paper #30793

Mike R. Bullock
Retired Satellite Engineer (36 years), 1800 Bayberry Drive, Oceanside, CA 92054

ABSTRACT

An Introduction to the topic is provided, including the importance of cars and light duty trucks (Light Duty Vehicles, LDVs), and an identification of the top-level LDV requirements.

The fundamentals of our climate crisis are presented, including its cause, its potential for harm, and existing mandates: *California's Executive Order S-3-05, California's Global Warming Solutions Act of 2006* (AB 32), and *California's Sustainable Communities and Climate Protection Act* (SB 375). An earlier calculation of a driving reduction target is described.

Reference year 2005 is identified. The latest climate-stabilizing greenhouse-gas (GHG) reduction target value, for 2030, is calculated, using unambiguous statements by recognized climate experts and California's expected 2020 emissions. The formula for GHG emissions, as a function of per-capita driving, population, fleet CO2 emissions per mile, and low-carbon fuel standards is given. From that expression, a mathematical relationship between defined factors associated with these variables is derived. These factors are the ratio of the value at the specified later year to the reference year. The factor of car-emission-per-mile driven, for year 2015, with respect to year 2005, is obtained.

Internal Combustion Engine (ICE) mileage values from 2000 to 2030 are identified, as either mandates or assumptions. A table is presented that estimates LDV fleet mileage, for year 2015.

Zero Emission Vehicle (ZEV) values to support a calculation of equivalent-fleet mileage with a significant fraction of ZEVs (ZEV LDVs) are given. A table is shown that uses assumptions about ZEVs, ICEs (ICE LDVs), and the fraction of electricity that comes from renewables, to compute the LDV fleet equivalent mileage, for year 2030. This set of assumptions is dubbed the "Heroic-Measures" (HM) case. It includes having the fraction of ZEVs quickly climb up to significant values, while the ICEs, for the years before significant fractions of ZEVs appear, are, to a significant degree, taken off the road or otherwise caused to be driven less, due to assumed strong governmental policies. The equivalent fleet mileage computed by this table is used, with population and the needed factor of emission reductions, to compute a needed per-capita driving reduction, for 2030, with respect to 2005. Policies to achieve this per-capita reduction are described, with reductions allocated to each policy.

The fleet-equivalent mileage for 2030 that would support a 2005 per-capita driving level is computed. A table is constructed to achieve that equivalent mileage. The assumptions in that table are said to define an "extra-heroic-measures" (EHM) case. They would probably be very difficult to achieve. The electricity required to power the HM case is estimated and compared to current usage.

INTRODUCTION

Humanity's top-level requirement is to reduce greenhouse gas (GHG) emissions enough to support stabilizing our climate at a livable level. This top-level requirement must flow down to LDVs, due to the significance of their emissions. As an example, LDVs emit 41% of the GHG in San Diego County[1].

From a systems engineering perspective, the needed requirements are an upper bound on greenhouse gas (GHG) emissions per mile driven (applicable to the entire fleet of LDVs on the road in the year of interest) and an upper bound on per-capita driving, given population growth. This paper will do a calculation of required driving levels, based on calculations of how clean our cars and fuels could be, predicted population growth, and the latest, science-based, climate-stabilizing target. All three categories of LDV emission-reduction strategies will be considered: cleaner cars, cleaner fuels, and less driving.

BACKGROUND: OUR CLIMATE PREDICAMENT

Basic Cause

Our climate crisis exists primarily because of these two facts[2]: First, our combustion of fossil fuels adds "great quantities" of CO_2 into our atmosphere. Second, atmospheric CO_2 traps heat.

California's First Two Climate Mandates

California's Governor's Executive Order S-3-05[3] is similar to the Kyoto Agreement and is based on the greenhouse gas (GHG) reductions recommended by climate scientists for industrialized nations, back in 2005. In 2005, climate scientists believed that the reduction-targets of S-3-05 would be sufficient to support stabilizing Earth's climate at a livable level, with a reasonably high level of certainty. More specifically, this executive order aims for an average, over-the-year, atmospheric temperature rise of "only" 2 degree Celsius, above the preindustrial temperature. It attempts to do this by limiting atmospheric CO_2_e to 450 PPM by 2050 and then reducing emissions further, so that atmospheric levels would come down to more tolerable levels in subsequent years. The S-3-05 emission targets are as follows: 2000 emission levels by 2010, 1990 levels by 2020, and 80% below 1990 levels by 2050.

It was thought that if the world achieved S-3-05, there might be a 50% chance that the maximum temperature rise will be less than 2 degrees Celsius, thus leaving a 50% chance that it would be larger than 2 degrees Celsius. A 2 degree increase would put over a billion people on the planet into a position described as "water stress" and it would mean a loss of 97% of our coral reefs.

There would also be a 30% chance that the temperature increase would be greater than 3 degrees Celsius. A temperature change of 3 degree Celsius is described in Reference 3 as being "exponentially worse" than a 2 degree Celsius increase.

The second California climate mandate is AB 32, the so-called *Global Warming Solutions Act of 2006*. It includes provisions for a cap and trade program, to ensure meeting S-3-05's 2020 target

of the 1990 level of emissions. It continues after 2020. Over all years, AB 32 requires CARB to implement measures that achieve the maximum *technologically feasible and cost-effective* (words taken from AB 32) greenhouse-gas-emission reductions.

California is on track to achieve its second (2020) target. However, the world emission levels have, for most years, been increasing, contrary to the S-3-05 trajectory. Because the world has effectively failed to achieve S-3-05, California, if it still is interested in leading the way to human survival, must do far better than S-3-05, going forward, as will be shown.

Failing to Achieve these Climate Mandates

What if we fail to achieve S-3-05 and AB 32 or we achieve them but they turn out to be too little too late and other states and countries follow our example?

It has been written[4] that, "A recent string of reports from impeccable mainstream institutions-the International Energy Agency, the World Bank, the accounting firm of PricewaterhouseCoopers-have warned that the Earth is on a trajectory to warm by at least 4 Degrees Celsius and that this would be incompatible with continued human survival."

It has also been written[5] that, "Lags in the replacement of fossil-fuel use by clean energy use have put the world on a pace for 6 degree Celsius by the end of this century. Such a large temperature rise occurred 250 million years ago and extinguished 90 percent of the life on Earth. The current rise is of the same magnitude but is occurring faster."

Pictures That Are Worth a Thousand Words

Figure 1 shows (1) atmospheric CO_2 (in blue) and (2) averaged-over-a-year-then-averaged-over-the surface-of-the-earth world atmospheric temperature (in red). This temperature is with respect to a recent preindustrial value. The data starts 800,000 years ago. It shows that the current value of atmospheric CO_2, which is now over 400 PPM, far exceeds the values of the last 800,000 years. It also shows that we should expect the corresponding temperature to eventually be about 12 or 13 degrees above preindustrial temperatures. This would bring about a human disaster[3,4,5].

Figure 2 shows the average yearly temperature with respect to the 1960-to-1990 baseline temperature (in blue). It also shows atmospheric levels of CO_2 (in red). The S-3-05 goal of 450 PPM is literally "off the chart", in Figure 2. Figure 2 shows that, as expected, temperatures are starting to rise along with the increasing levels of CO_2. The large variations in temperature are primarily due to the random nature of the amount of solar energy being received by the earth.

FURTHER BACKGROUND: CALIFORNIA'S SB 375 AND A PREVIOUS CALCULATION OF HOW MUCH WE CAN DRIVE

As shown in the Introduction, LDVs emit significant amounts of CO_2. The question arises: will driving need to be reduced or can cleaner cars and cleaner fuels arrive in time to avoid such behavioral change? Steve Winkelman, of the Center for Clean Air Policy (CCAP), has worked on this problem. Using CCAP data, an S-3-05-supporting driving reduction, for San Diego County, will be estimated.

SB 375, the *Sustainable Communities and Climate Protection Act of 2008*

Under SB 375, the California Air Resources Board (CARB) has given each Metropolitan Planning Organization (MPO) in California driving-reduction targets, for the years 2020 and

Figure 1. Atmospheric CO_2 and Mean Temperature from 800,000 Years Ago

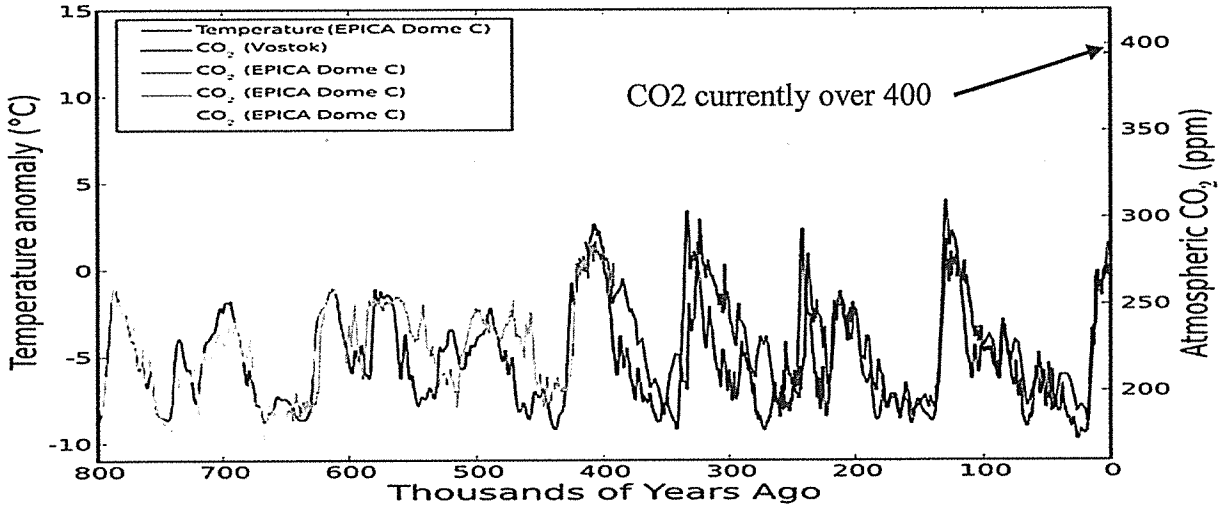
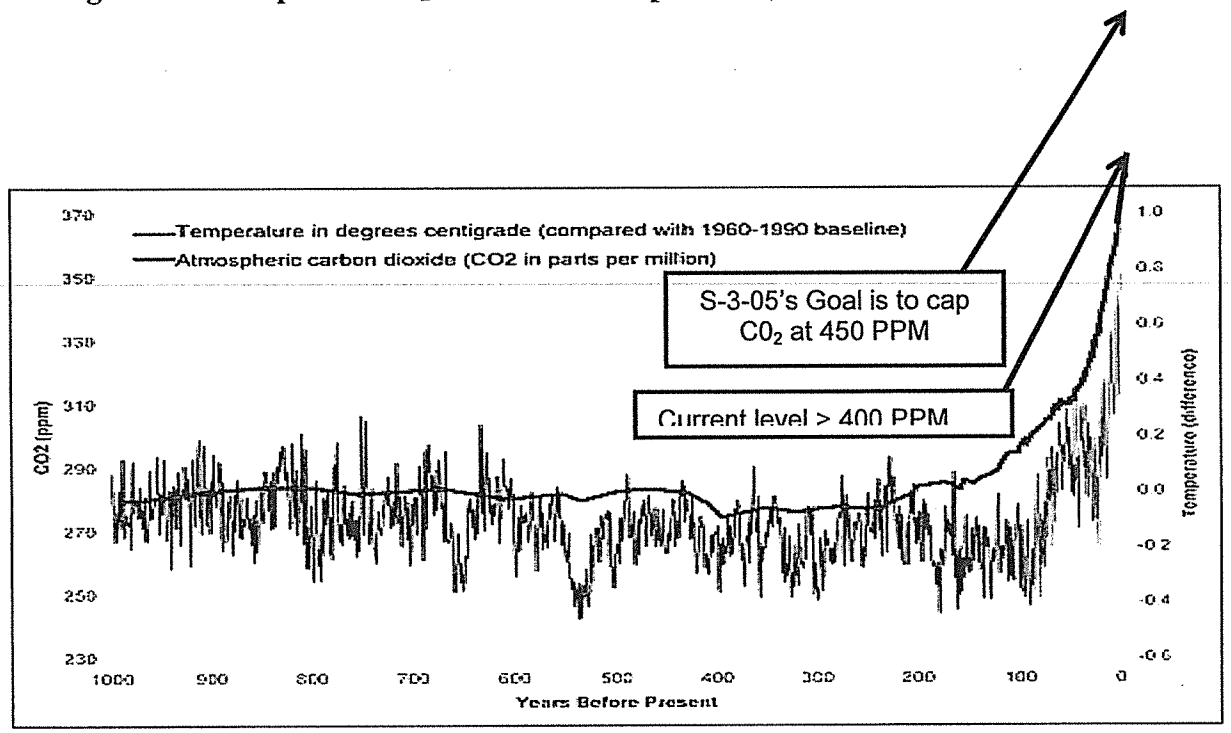


Figure 2. Atmospheric CO_2 and Mean Temperature, Over the Last 1,000 Years



2035. "Driving" means yearly, per capita, vehicle miles travelled (VMT), by LDVs, with respect to 2005. The CARB-provided values are shown at this Wikipedia link, http://en.wikipedia.org/wiki/SB_375.

Under SB 375, every Regional Transportation Plan (RTP) must include a section called a Sustainable Communities Strategy (SCS). The SCS must include driving reduction predictions corresponding to the CARB targets. Each SCS must include only *feasible* transportation, land use, and transportation-related policy data. If the SCS driving-reduction predictions fail to meet the CARB-provided targets, the MPO must prepare an Alternative Planning Strategy (APS), which must also appear in the MPO's RTP. An APS uses *infeasible* transportation, land use, and transportation-related policy assumptions. The total reductions, resulting from both the SCS and the APS, must at least meet the CARB-provided targets.

Factors Used to Compute the Required Driving Reduction

The definitions in Tables 1 and the two conventions in Table 2 will be used to compute the needed driving reductions, with respect to year 2005, from known and estimated variables and the S-3-05 GHG reductions that were thought to support climate stabilization, back in 2005. By SB 375 convention, Year "*i*", the reference year, is 2005.

The fractional reduction in per-capita personal driving, with respect to 2005 driving, needed to achieve any desired level of GHG emission, can be computed using predicted population growth and two of the variables shown in Figure 3[6]. The two needed values are the factor with respect to year 2005 of CO_2 emitted per mile driven (the green line, sometimes referred to as "Pavley", since AB 1493 was authored by Senator Fran Pavley) and the factor with respect to year 2005 of the advantage from achieving the low carbon fuel standards (LCFS, the purple line).

The variables plotted in Figure 3 are the factors which can be used to multiply the 2005 values to get the values for the years shown. For example, in 2030, the CO_2 emitted from the cars and light-duty trucks in California (the dark blue line), can be computed to be 1.12 times as large as it was in 2005. It can also be said that the value will be 12% larger than it was in 2005. Likewise, the green line, which is the average CO_2 emitted per mile driven, for California's fleet of LDVs, is predicted, in 2030, to be .73 times the 2005 value. This means the value is predicted to be reduced 27%, below its 2005 value. Figure 3 also shows that the 1990 value of emissions (on the light blue line) was about 13% less than it was in 2005.

The S-3-05 trajectory is shown as the gold (or dark yellow) line. It is the factors that can be used to convert 2005 values of emissions to values for the years shown. For example in 2030, emissions will need to be 37% lower than they were in 2005, to meet the S-3-05 mandate.

The SB 375 convention is for CARB to require and for the Metropolitan Planning Organizations (MPOs) to estimate and report their predicted per-capita driving reductions. To compute the per-capita driving reduction, the equation for computing the emissions is used. That equation is the product of the following four factors:

- the Low Carbon Fuel Standard, "*L*" (which reduces the CO2 emitted from each gallon of fuel burned),
- the fleet-average CO2 per mile driven (using the CO2 per gallon burned without accounting for "L"),

Table 1. Variable Definitions

Variable Definitions	
e_k	**LDV Emitted C02, in Year "*k*"**
L_k	**Low Carbon Fuel Standard (LCFS) Factor that reduces the Per-Gallon CO2 emissions, in Year "*k*"**
C_k	**LDV CO2 emitted per mile driven, average, in Year "*k*", not accounting for the Low Carbon Fuel Standard (LCFS) Factor**
c_k	**LDV CO2 emitted per mile driven, average, in Year "*k*", accounting for the Low Carbon Fuel Standard (LCFS) Factor**
p_k	**Population, in Year "*k*"**
d_k	**Per-capita LDV driving, in Year "*k*"**
D_k	**LDV Driving, in Year "*k*"**
M_k	**LDV Mileage, miles per gallon, in Year "*k*"**
m_k	**LDV Equivalent Mileage, miles per gallon, in Year "*k*" accounting for Low Carbon Fuel Standard (LCFS) Factor, so this is M_k/L_k**
N	**Number of pounds of CO2 per gallon of fuel but not accounting for the Low Carbon Fuel Standard (LCFS) Factor**

Table 2. Two Conventions

Two Conventions: Variable in a Given Year and Factors to Compute a Variable's Value in Year "*k*" from it's Value in Year "*i*"	
X_i	**Variable "*X*" in year "*i*"**
$f_{x_{k/i}}$	**Ratio of the value of "*X*" in year "*k*" to the value of "*X*" in Year "*i*", which could also be expressed as x_k/x_i. Note that this is the factor that could be used to multiply the value in Year "*i*" to get the value in Year "*k*".**

- the per-capita driving, and
- the population. (The per-capita driving multiplied by population gives the miles driven.)

$$e = L * C * d * p \qquad \textbf{(Eq. 1)}$$

For Year "*k*", this is the following:

$$e_k = L_k * C_k * d_k * p_k \qquad \textbf{(Eq. 2)}$$

For Year "*i*", this is the following:

$$e_i = L_i * C_i * d_i * p_i \qquad \textbf{(Eq. 3)}$$

Since the two sides of Equation 3 are equal, an equation can be formed by dividing the left side of Equation 2 by the left side of equation 3 and the right side of Equation 2 by the right side of Equation 3. Associating the terms on the right side of this new equation gives Equation 4

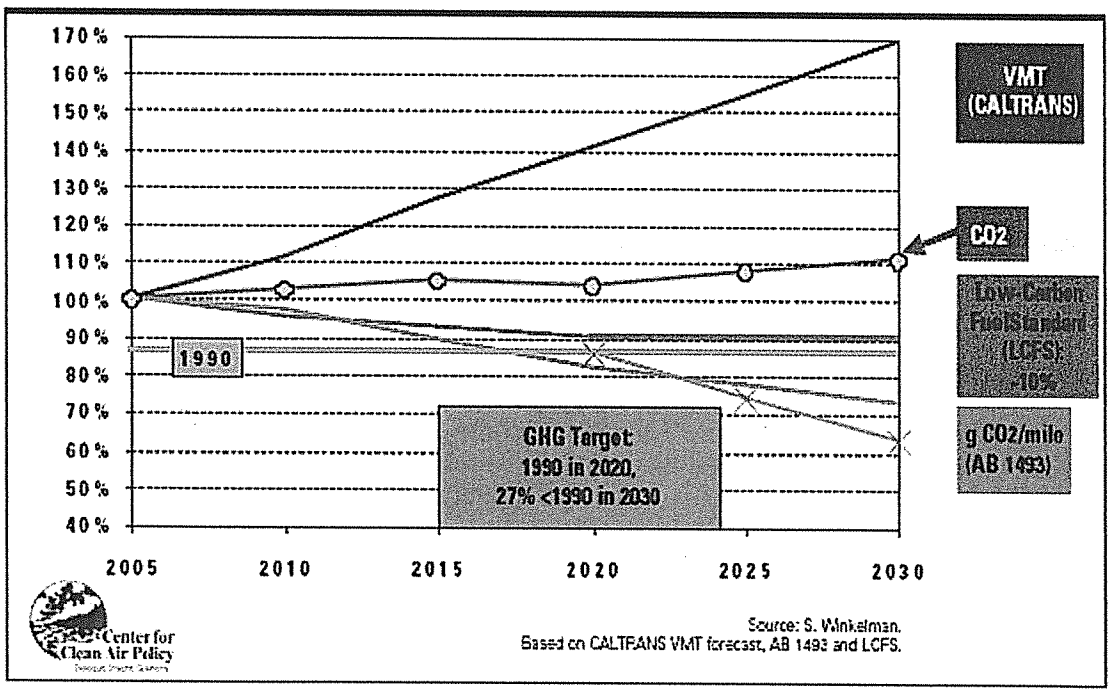
$$\frac{e_k}{e_i} = \frac{L_k}{L_i} * \frac{C_k}{C_i} * \frac{d_k}{d_i} * \frac{p_k}{p_i} \qquad \textbf{(Eq. 4)}$$

The convention of the 2nd row of Table 2 can be used to create Equation 5 from Equation 4.

$$f_{e_{k/i}} = f_{L_{k/i}} \times f_{C_{k/i}} \times f_{d_{k/i}} \times f_{p_{k/i}} \qquad \textbf{(Eq. 5)}$$

The first factor (from left to right) of the right side of Equation 5 is the purple line of Figure 3; the second factor of Equation 5 is the green line of Figure 3; and the product of the last two factors of

Figure 3 **The S-3-05 Trajectory (the Gold Line) AND the CO_2 Emitted from Personal Driving (the Blue Line), where that CO_2 is a Function (the Product) of the California-Fleet-Average CO_2 per Mile (the Green Line), The Predicted Driving (VMT, the Red Line), and the Low-Carbon Fuel Standard (the Purple Line)**



the right side of Equation 5 is the red line of Figure 3. Figure 3's, dark-blue-line values are the product of the purple-line values, the green-line values, and the red -line values. For example, in 2030, the dark-blue value of 1.12 can be computed by multiplying the purple-line value of 0.9 times the green-line value of 0.73, times the red-line value of 1.7, times the red-line value of 1.7. As a check, (0.9)*(0.73)*(1.7) = 1.1169, which is reasonably close to the (eye-ball-estimate) value of the dark-blue line, for year 2030, 1.12.

The Required Driving Reduction for San Diego County, for 2035, Using Winkelman's LDV and Fuel Efficiency Values and S-3-05

As described in Footnote 3 of this report, the CARB-supplied targets are per-capita driving reduction targets. Page 8, of http://arb.ca.gov/cc/sb375/staffreport_sb375080910.pdf, says, "The RTAC recommended that targets be expressed as a percent reduction in per-capita greenhouse gas emissions from a 2005 base year". However, Footnote 3 applies.

The Key Relationship and Derivation of the Needed Formula

They key relationship is Equation 5. Solving for the fractional reduction in per-capita driving, with respect to 2005, results in Equation 6.

$$f_{d_{k/i}} = \frac{f_{e_{k/i}}}{f_{L_{k/i}} \times f_{c_{k/i}} \times f_{p_{k/i}}} \qquad \textbf{(Eq. 6)}$$

This driving reduction is a per-capita value, matching the convention of the CARB-supplied target.

Getting the Values to Use in the Equation

Figure 3 will supply all of the needed values, except for the factor of population. Neither Figure 3's red-line values nor its blue-line values are used.

Getting the Net Factor of the Emissions of GHG, for Year 2035, With Respect to 2005

To get the factor of the emissions of GHG, for year 2035, with respect to year 2005, it is necessary to extrapolate the Governor's Executive Order target values (the gold line of Figure 3), out to year 2035. Figure 3's gold line shows that this factor is 0.87 in 2020 and is 0.64 in 2030. Therefore, in year 2035, the factor will be

$$0.64 + [(.64 - .87) / (2030\text{-}2020)] * (2035\text{-}2030) = 0.525$$

Getting the (Pavley) Factor of the Average CO2 per Mile Driven, in 2035, with Respect to 2005

To get the Pavley reduction factor, for Year 2035, it is necessary to extrapolate the average CO2 per mile driven, which is Figure 3's green line, out to Year 2035. It is 0.82 in 2020 and it is 0.73 in 2030. Therefore, in Year 2035 the statewide mileage factor data will be

$$0.73 + [(.73 - .82) / (2030\text{-}2020)] * (2035\text{-}2030) = 0.685$$

Getting the Factor of the Reduction of GHG Due to Fuels that Burn less Carbon

To get the factor of the reduction of GHG due to fuels that burn less carbon, it is only necessary to observe the purple line of Figure 3. It indicates that the factor will be 0.9 in 2035.

Getting the Factor of the Increase in Population

The factor for population in San Diego County is computed using the populations estimated in CARB's http://arb.ca.gov/cc/sb375/mpo.co2.reduction.calc.pdf, namely 3,034,388 people in 2005 and 3,984,753 people in 2035. So the factor, from 2005 to 2035 is 3,984,753/3,034,388 = 1.313.

Computing the Required Per-Capita Driving Reduction, for 2035

These 4 values are used in Eq. 6, to compute the required factor of per-capita driving (VMT), for 2035, with respect to 2006.

$$f_{d_{k/i}} = .525 \div (.685 \times 0.9 \times 1.313)$$

Therefore, $f_{d_{k/i}} = f_{Per\ Capita\ VMT} = .649.$

This corresponds to a 35.1% reduction in per-capita driving, in year 2035, compared to 2005.

Computing the Net Amount of Driving, in 2035, Compared to 2005 and its Significance

The net factor of driving in 2035, compared to 2005, is the product of the per-capita factor of driving (.649, as just computed) and the factor of population change (1.313, as computed above).

Factor of net driving in 2035 compared to 2005:

$$f_{VMT} = .649 \times 1.313 = 0.8515.$$

Based on this set of assumptions, even though San Diego County's population would grow by 31.3%, from 2005 to 2035, the people would have to drive 15% less than they did in 2005.

THE DEVELOPMENT OF CALIFORNIA'S TOP-LEVEL LDV REQUIREMENTS TO SUPPORT CLIMATE STABILIZATION

The above work is obsolete due to our latest understanding of how fast emissions will need to be reduced. It is also clear that cleaner cars will be needed and can probably be achieved. As will be seen, much cleaner cars will be needed if driving reductions are going to remain within what many people would consider achievable. Mileage and equivalent mileage will need to be specified. Some of the above equations will need to be modified, since a significant fleet-fraction of Zero-Emission Vehicles (ZEVs, either Battery-Electric LDVs or Hydrogen Fuel Cell LDVs) will be needed and mileage and equivalent mileage will be used instead of CO2 per mile driven.

Since the SB-375 work used 2005 as the reference year, it will remain the reference year here.

GHG Target to Support Climate Stabilization

The primary problem with S-3-05 is that California's resolve and actions have been largely ignored by other states, our federal government, and many countries. Therefore, rather than achieving 2000 levels by 2010 and being on a track to achieve 1990 levels by 2020, world emission have been increasing. Reference 7 states on Page 14 that the required rate of reduction, if commenced in 2020, would be 15%. That rate means that the factor of 0.85 must be achieved, year after year. If this were done for 10 years, the factor would be $(0.85)^{10} = 0.2$. We don't know where world emissions will be in 2020. However, it is fairly safe to assume that California will be emitting at its 1990 level in 2020, in accordance with S-3-05. This situation shows that the correct target for California is to achieve emissions that are reduced to 80% below California's 1990 value by 2030. Note that if the reductions start sooner, the rate of reduction of emissions can be less than 15% and the 2030 target could be relaxed somewhat. However, it is doubtful that the world will get the reduction rate anywhere near the needed 15% by 2020. Therefore, the target, of 80% below 1990 levels by 2030 is considered to be correct for California. Reference 7 also calls into question the advisability of aiming for a 2 degree Celsius increase, given the possibilities of positive feedbacks that would increase warming. This concern for positive feedbacks is another reason that this paper will work towards identifying LDV requirement sets that will support achieving 80% below 1990 values by 2030.

Using the top-row definition in Table 1, and this requirement, results in the following equation.

$$\frac{e_{2030}}{e_{1990}} = \mathbf{0.2} \qquad \textbf{(Eq. 7)}$$

From Figure 3,

$$\frac{e_{1990}}{e_{2005}} = \mathbf{0.87} \qquad \textbf{(Eq. 8)}$$

Multiplying the equations together give the following:

$$\frac{e_{2030}}{e_{2005}} = 0.87\,x\,0.2 = .174 \qquad \textbf{(Eq. 9)}$$

Using the convention shown in Table 2 gives this equation:

$$f_{e_{2030/2005}} = .174 \qquad \textbf{(Eq. 10)}$$

How Miles-Per-Gallon (MPG) Updates the LDV Efficiency Estimates

The number of pounds of CO2 per mile driven, defined as "C" in Table 1, is equal to the number of pounds of CO2, per gallon of fuel, divided by the number of miles travelled on that gallon of fuel. However, in different years, this amount can change from the standard value of "N" as defined in the last line of Table 1, because of the Low Carbon Fuel Standard. Therefore, using the definitions in Table 1, the following equation can be written:

$$c_k = \frac{NxL_k}{M_k} \qquad \textbf{(Eq. 11)}$$

For the baseline year "*i*", this is the following:

$$c_i = \frac{NxL_i}{M_i} \qquad \textbf{(Eq. 12)}$$

Using Table 1's definition of mileage that accounts for the Low Carbon Fuel Standard gives these equations, since m = M/L:

$$c_k = \frac{N}{m_k} \qquad \textbf{(Eq. 13)}$$

$$c_i = \frac{N}{m_i} \qquad \textbf{(Eq. 14)}$$

Using Table 2's second convention and dividing Equation 13 by Equation 14 gives:

$$f_{c_{k/i}} = \frac{c_k}{c_i} = \frac{m_i}{m_k} \qquad \textbf{(Eq. 15)}$$

This shows that to get the factor to convert CO2-emission-per-mile from the baseline value to a future-time value, the new value is divided by the baseline value. However, if the mileage values are used, the baseline value must be divided by the newer value.

It is also useful to use an intermediate year to get the factor from the baseline year to the year of interest. This can be done by using Equation 13 for different years to result in Equation 14 and Equation 15, where "j" denotes the intermediate year.

$$f_{c_{j/i}} = \frac{m_i}{m_j} \qquad \textbf{(Eq. 14)}$$

$$f_{c_{k/j}} = \frac{m_j}{m_k} \qquad \textbf{(Eq. 15)}$$

Multiplying these equations together results in Equation 16.

$$f_{c_{j/i}} \times f_{c_{k/j}} = \frac{m_i}{m_j} \times \frac{m_j}{m_k} = \frac{m_i}{m_k} \qquad \textbf{(Eq. 16)}$$

Recognizing the right side of Equation 16 shows that these factors can be strung together, as shown by Equation 17, which is a direct result of Equation 16.

$$f_{c_{k/i}} = f_{c_{j/i}} \times f_{c_{k/j}} \qquad \textbf{(Eq. 17)}$$

Since the low carbon fuel standard has been incorporated into the carbon emission per mile parameter, "c", the following equations result, using the definitions of Table 1.

For Year "*k*", this is the following:

$$e_k = c_k * d_k * p_k \qquad \textbf{(Eq. 18)}$$

For Year "*i*", this is the following:

$$e_i = c_i * d_i * p_i \qquad \textbf{(Eq. 19)}$$

Since the two sides of Equation 19 are equal, an equation can be formed by dividing the left side of Equation 18 by the left side of equation 19 and the right side of Equation 18 by the right side of Equation 19. Associating the terms on the right side of this new equation gives Equation 4

$$\frac{e_k}{e_i} = \frac{c_k}{c_i} * \frac{d_k}{d_i} * \frac{p_k}{p_i} \qquad \textbf{(Eq. 20)}$$

The convention of the 2nd row of Table 2 can be used to create Equation 5 from Equation 4.

$$f_{e_{k/i}} = f_{c_{k/i}} \times f_{d_{k/i}} \times f_{p_{k/i}} \qquad \textbf{(Eq. 21)}$$

This can be expanded by using Equation 17 to give the following.

$$f_{e_{k/i}} = f_{c_{j/i}} \times f_{c_{k/j}} \times f_{d_{k/i}} \times f_{p_{k/i}} \qquad \textbf{(Eq. 22)}$$

For the purposes here, the intermediate year "j" is 2015 and, recalling that "c" takes into account the Low Carbon Fuel Standard, Figure 3 shows that the following is true, where 0.9 is taken (eyeballed) from the green line at 2015 and the .93 is taken (eyeballed) from the purple line.

$$f_{c_{j/i}} = 0.9\ x\ 0.93 = 0.837 \qquad \textbf{(Eq. 23)}$$

Using Equation 22, to solve for the per-capita driving-reduction factor, results in Equation 24.

$$f_{d_{k/i}} = \frac{f_{e_{k/i}}}{f_{c_{j/i}} \times f_{c_{k/j}} \times f_{p_{k/i}}} \qquad \textbf{(Eq. 24)}$$

Reference 8 shows that California's population in 2005 was 35,985,582. Reference 9 shows that California's population in 2030 is predicted to be 44,279,354. Therefore,

$$f_{P_{k/i}} = 44279354 \div 35985582 = 1.2305 \qquad \textbf{(Eq. 25)}$$

Using the values in Equation 10, 23, and 25 gives Equation 26, where "j" is the intermediate year of 2015 and Equation 15 is also used.

$$f_{d_{k/i}} = \frac{0.174}{0.837 \times \frac{m_j}{m_k} \times 1.2305} \qquad \textbf{(Eq. 26)}$$

Evaluating the values shown and with j = 2015 and k = 2030 gives Equation 27.

$$f_{d_{k/i}} = 0.1689\ x\ \frac{m_{2030}}{m_{2015}} \qquad \textbf{(Eq. 27)}$$

If the per-capita driving factor was 1 (no per-capita driving reduction needed from 2005 to 2030), the 2030 fleet (all LDVs on the road) mileage would need to exceed the 2015 fleet mileage by a factor of 1 divided by 0.1689, which is 5.92. For example, if the mileage for the 2015 fleet is 25 MPG, then the 2030 value would need to be 148 MPG. Clearly, most LDVs in 2030 will need to be ZEVs.

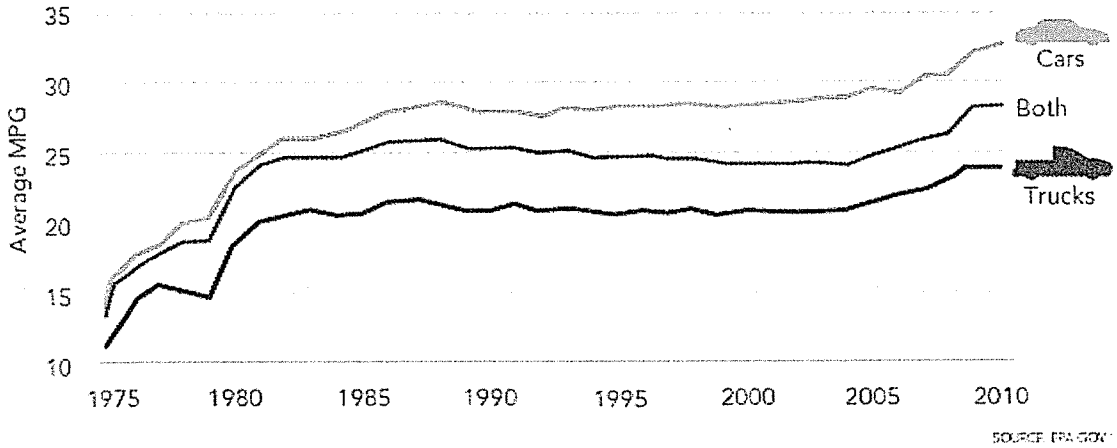
Internal Combustion Engine (ICE) Mileage, from Year 2000 to Year 2030

The years from 2000 to 2011 are taken from a plot produced by the PEW Environment Group,

http://www.pewenvironment.org/uploadedFiles/PEG/Publications/Fact_Sheet/History%20of%20Fuel%20Economy%20Clean%20Energy%20Factsheet.pdf

The plot is shown here as Figure 6. The "Both" values are used.

Figure 6 **Mileage Values From the PEW Environment Group**



The values from 2012 to 2025 are taken from the US Energy Information Agency (EIA) as shown on their website, http://www.c2es.org/federal/executive/vehicle-standards#ldv_2012_to_2025. They are the LDV Corporate Average Fleet Efficiency (CAFÉ) values enacted into law in the first term of President Obama. From 2025 to 2030, it is assumed that the yearly ICE improvement in CAFÉ will be 2.5 MPG.

Mileage of California's LDV Fleet in 2015

Table 3 uses these values of ICE mileage to compute the mileage of the LDV fleet in 2015. It assumes that the fraction of ZEVs being used over these years is small enough to be ignored. The 100 miles driven, nominally, by each set of cars, is an arbitrary value and inconsequential in the final calculation, because it will divide out. It is never-the-less used, so that it is possible to compare the gallons of fuel used for the different years. The "f" factor could be used to account for a set of cars being driven less. It was decided to not use this option by setting all of the values to 1. The Low Carbon Fuel Standard (LCFS) values are taken from Figure 3. The gallons of fuel are computed as shown in Equation 28, using the definition for L_k that is shown in Table 1.

$$\boldsymbol{Gallons\ Used\ per\ f * 100\ miles} = \frac{fx100}{(CAFE\ MPG)/L_k} \qquad \textbf{(Eq. 28)}$$

How ICE Mileage Values Will Be Used with ZEV Equivalent Mileage Values

As will be seen, after 2015, the net (computed using both ICEs and ZEVs) mileage values for each year are assumed to greatly improve by having a significant fraction of ZEVs. The ICE CAFÉ standards are used in this report as just the ICE contribution to fleet MPG. The ICE MPG values are inadequate by themselves and will therefore need to become less important because ZEVs will need to quickly take over the highways.

Federal requirements will need to change dramatically. Currently, federally-mandated corporate average fuel efficiency (CAFÉ) standards have been implemented, from 2000 to 2025. These standards require that each corporation produce and sell their fleet of cars and light-duty trucks in the needed proportions, so that the combined mileage of the cars they sell, at least meet the specified mileage.

Table 3.Calculation of the Fleet MPG for 2015

LDV Set	Years Old	Model Year	CAFE MPG	LCFS Factor L_{Year}	Factor Driven f	Gallons Used Per f*100 Miles
1	14-15	2001	24.0	1.0	1.0	4.17
2	13-14	2002	24.0	1.0	1.0	4.17
3	12-13	2003	24.0	1.0	1.0	4.17
4	11-12	2004	24.0	1.0	1.0	4.17
5	10-11	2005	25.0	1.0	1.0	4.00
6	9-10	2006	25.7	.9933	1.0	3.87
7	8-9	2007	26.3	.9867	1.0	3.75
8	7-8	2008	27.0	.9800	1.0	3.63
9	6-7	2009	28.0	.9733	1.0	3.48
10	5-6	2010	28.0	.9667	1.0	3.45
11	4-5	2011	29.1	.9600	1.0	3.30
12	3-4	2012	29.8	.9533	1.0	3.20
13	2-3	2013	30.6	.9467	1.0	3.09
14	1-2	2014	31.4	.9400	1.0	2.99
15	0-1	2015	32.6	.9333	1.0	2.86
					Sum of Gallons:	54.29
					Miles = 100*Sum(f's):	1500
					MPG = Miles/(Sum of Gallons):	27.63

The car companies want to maximize their profits while achieving the required CAFÉ standard. In California, the car companies will already be required to sell a specified number of electric vehicles, which have a particularly-high, equivalent-value of miles-per-gallon. If the laws are not changed,

this will allow these companies to sell more low-mileage, high profit cars and light-duty trucks, and still achieve the federal CAFÉ standard.

It will be better to apply the CAFÉ standards to only the ICEs and then require that the fleet of LDVs sold achieve some mandated fraction of ZEVs. The ZEVs will get better and better equivalent mileage, as our electrical grid is powered by more renewables. Therefore, their equivalent mileage is not fixed, but will improve over the years. Requirements developed here are for 2030. Therefore a high percentage of all the electricity generated in the state, including both the "in front of the meter" (known as the "Renewable Portfolio Standard" or "RPS") portion and the "behind the meter" portion is assumed to come from sources that do not emit CO2. The value of 80% is assumed.

ZEV Equivalent Mileage Values

To calculate the mileage of the 2030 fleet of LDVs, it is necessary to derive a formula to compute the equivalent mileage of ZEVs, as a function of the percent of electricity generated without emitting CO2, the equivalent ZEV mileage if the electricity is from 100% fossil fuel, and the equivalent ZEV mileage if the electricity is from 100% non-C02 sources. The variables defined in Table 4 are used.

Table 4. Variables Used in the Calculation of ZEV Equivalent Mileage

Variable	Definition
m_z	**ZEV Equivalent mileage**
m_{zr}	**ZEV Equivalent mileage if the electricity is from renewables**
m_{zf}	**ZEV Equivalent mileage if the electricity is from fossil fuels**
r	**fraction of electricity generated from sources not emitting CO2**
G	**Gallons of equivalent fuel used**
D	**Arbitrary distance travelled**
Num	$m_{zr} \times m_{zf}$
Den	$r \times m_{zf} + (1 - r) \times m_{zr}$

The derivation of the equation for equivalent ZEV mileage is based on the notion that the ZEV can be imagined to travel "r" fraction of the time on electricity generated from renewables and "(1-r)" fraction of the time on fossil fuel. If the vehicle travels "D" miles, then, using the definitions shown in Table 4, the following equation can be written.

$$G = \frac{r \times D}{m_{zr}} + \frac{(1-r) \times D}{m_{zf}} \qquad \textbf{(Eq. 29)}$$

$$m_z = D/G = D/\left(\frac{r \times D}{m_{zr}} + \frac{(1-r) \times D}{m_{zf}}\right) \qquad \textbf{(Eq. 30)}$$

Dividing the numerator and the denominator by D and multiplying them both by the product of the two equivalent mileage values results in Equations 31.

$$m_z = m_{zr} \times m_{zf} / \left(r \times m_{zf} + (1 - r) \times m_{zr}\right) \qquad \textbf{(Eq. 31)}$$

Again, using the definitions in Table 4 results in the following.

$$m_z = Num/(Den) \quad \text{(Eq. 32)}$$

Table 5 shows an assignment of assumed values and the result of a calculation, using Equations 31 and 32, to produce a ZEV equivalent mileage.

Table 5. Variable Assignment and the Resulting ZEV Mileage

m_{zr}	m_{zf}	r	1-r	Num	Den	m_z
5000	70	0.8	0.2	350000.00	1056.00	331.44

Computing an LDV Fleet Mileage Assuming Heroic Measures (HM)

Table 6 shows the additional definitions that will be used in this calculation. Table 7 computes the 2030 LDV mileage, assuming "Heroic Measures" to reduce the miles driven in poor-mileage ICE's, in building and selling a significant fraction of ZEVs, and in getting the Low Carbon Fuel Standards to continue to improve beyond the Table 3 minimum of 0.90.

Table 6. Additional Variables Used in the Calculation of 2030 LDV Mileage

Variable	Definition
D_i	Distance travelled by ICE vehicles
D_z	Distance travelled by ZEVs
G_i	Gallons of Equivalent fuel used by ICE vehicles
G_z	Gallons of Equivalent fuel used by ZEVs

As shown by the values for "f", government policies must be adopted to reduce the miles driven by the ICE's, from 2016 to 2023. The 2016 model ICE's are driven only 30% as much as the nominal amount. The 2017 year ICE's can be driving 10% more. This rate of change continues up to 2023, when the ICE's are doing less damage, due to the large fraction of ZEVs on the road.

As shown, the ZEV fraction of the fleet assumes the value of 5%, just 4 years from now. It then proceeds upward, to 10% in 2019, 25% in 2020, 40% in 2021, and so on, until it reaches 95%.

Achieving these fractions of ZEVs might be compared to what was done during World War II, when automobile productions lines were rapidly converted to produce tanks. This reduced the new cars that could be purchased. Besides this, rationing gasoline made it difficult to drive at times and, due to shortages of leather, which was being used to produce boots for soldiers, some citizens found it hard to even buy shoes. These rapid and inconvenient changes were tolerated, because most people agreed that the war needed to be won. The heroic measures assumed here may not be possible unless citizens and the political leaders they elect understand the dire consequences of climate destabilization and therefore accept, and even demand, the measures that are needed to support climate stabilization.

The equivalent miles per gallon of the LDV fleet in 2030, specifically 111.12 miles per gallon, will be considered as a potential 2030 LDV requirement.

Computing the Heroic-Measures (HM) Case Per-Capita and Net Driving Factor Requirements, Based on the Result Shown in Table 7

Plugging the

- equivalent MPG of the LDV fleet in Year 2030, taken from the bottom of Table 7, which is 111.12 MPG, and
- the MPG of the LDV fleet in Year 2015, taken from the bottom of Table 3, which is 27.63 MPG,

into Equation 27, gives the following result:

$$f_{d_{k/i}} = 0.1689\, x\, \frac{m_{2030}}{m_{2015}} = .1689 \times \frac{111.12}{27.63} = .6795 \qquad \text{(Eq. 31)}$$

This means that the per-capita driving will need to be about 32% less than in year 2005. The net driving can be computed by multiplying the per-capita driving, 0.6795, by the population factor of 1.2305, computed in Equation 25, resulting in 0.8361. This means that, even with the 23% increase in California's population, the net driving will have to drop by about 16%. If this LDV requirement set is selected, all of California's transportation money can be used to improve transit, improve active transportation (mainly walking and biking), and maintain, but not expand, roads.

Table 7. Calculation of 2030 LDV Mileage Assuming Heroic Measures

	ICE Parameters and Calculations						ZEVs			Yearly Totals		
Year	CAFÉ MPG	LCFS	Eq. MPG	f	D_i	G_i	z	D_z	G_z	Total Miles	Total Gallons	2030 MPG
2016	34.3	.9267	37.01	.3	30.0	.8105	0	0	.000	30.0	.8105	37.01
2017	35.1	.9200	38.15	.4	40.0	1.0484	0	0	.000	40.0	1.0484	38.15
2018	36.1	.9133	39.53	.5	47.5	1.2018	.05	5	.015	52.5	1.2168	43.14
2019	37.1	.9000	40.92	.6	54.0	1.3197	.10	10	.030	64.0	1.3498	47.41
2020	38.3	.8500	42.56	.7	52.5	1.2337	.25	25	.075	77.5	1.3091	59.20
2021	40.3	.8000	47.41	.8	48.0	1.0124	.40	40	.121	88.0	1.1331	77.66
2022	42.3	.8000	52.88	.9	40.5	.7660	.55	55	.166	95.5	.9319	102.48
2023	44.3	.8000	55.38	1.0	30.0	.5418	.70	70	.211	100.0	.7530	132.81
2024	46.5	.8000	58.13	1.0	15.0	.2581	.85	85	.257	100.0	.5145	194.36
2025	48.7	.8000	60.88	1.0	5.0	.0821	.95	95	.287	100.0	.3688	271.18
2026	51.2	.8000	64.00	1.0	5.0	.0781	.95	95	.287	100.0	.3648	274.16
2027	53.7	.8000	67.13	1.0	5.0	.0745	.95	95	.287	100.0	.3611	276.92
2028	56.2	.8000	70.25	1.0	5.0	.0712	.95	95	.287	100.0	.3578	279.48
2029	58.7	.8000	73.38	1.0	5.0	.0681	.95	95	.287	100.0	.3548	281.87
2030	61.2	.8000	76.50	1.0	5.0	.0654	.95	95	.287	100.0	.3520	284.10
Sum of Miles and then Gallons of Equivalent Fuel:										1247.5	11.23	
Equivalent MPG of LDV Fleet in 2030:										*111.12*		
Sum of ZEV Miles = **860**. Fraction of Miles Driven by ZEVs = **68.9%**												

Computing LDV Requirements that Support 2005 Per-Capita Driving

The first step is to use Equation 27 and the value of the mileage in 2015 to compute the needed LDV equivalent fleet mileage for 2030 so that $f_{d_{k/i}}$ is equal to 1.0.

$$m_{2030} = f_{d_{k/j}} \times \frac{m_{2015}}{0.1689} = 1.0 \times \frac{27.63}{0.1689} = 163.54 \text{ MPG} \qquad \text{(Eq. 32)}$$

Table 8 is constructed, with the fraction of ZEVs selected to achieve the needed equivalent fleet mileage of about 163.54 MPG. Since its ZEV fractions are larger and sooner than in the "Heroic Measures table, Table 8 is the "Extra-Heroic Measures" (EHM) case. The ICE "f" values are unchanged; as are the LCFS values. The EHM ZEV differences from the HM case are the highlighted "z" values.

This means that with the 23% increase in California's population, computed in Equation 25, the net driving would also increase by 23%. If this LDV requirement set were to be implemented, a lot of California's transportation money will be needed to expand the highway system, leaving less to improve transit, improve active transportation (mainly walking and biking), and maintain roads.

Comparing the ZEV Fraction Values of the "Heroic-Measures" (HM) Case to the "Extra-Heroic Measures" (EHM) Case

Table 9 shows the direct comparison of the ZEV fractions that are ZEV requirements for the HM Case and the EHM Case. The differences are highlighted.

ACHIEVING THE REQUIRED DRIVING REDUCTION OF THE HEROIC-MEASURES (HM) CASE

As shown in Equation 31, in 2030, the per-capita driving will need to at least 32% below the 2005 value. As shown in this link, http://en.wikipedia.org/wiki/SB_375, California's Metropolitan Planning Organizations (MPOs) are adopting Region Transportation Plans (RTPs) that will achieve reductions in year 2020 and 2035. As also shown there, the targets, for year 2035, range from 0% for Shasta to 16% for Sacramento Area Council of Governments Since this is for 2030 instead of 2035, and to be reasonably conservative, it is assumed here that the state will achieve a 10% reduction in per-capita driving, in 2030, compared to 2005. This leaves 22% to be achieved by new programs.

The title of each of the following subsections contains the estimated per-capita driving reduction each strategy will achieve, by 2030.

Reallocate Funds Earmarked for Highway Expansion to Transit and Consider Transit-Design Upgrades (3%)

San Diego County has a sales tax measure called "TransNet", which allocates one-third for highway expansion, one-third for transit, and one-third for road maintenance. It has a provision that allows for a reallocation of funds, if supported by at least two-thirds of SANDAG Board members, including a so-called weighted vote, where governments are given a portion of 100 votes, proportional to their

population. It is hereby proposed to reallocate the TransNet amount, earmarked for highway expansion, to transit and to do similar reallocations throughout California.

This money could be used to fund additional transit systems; improve transit operations; and/or the redesign and implementation of the redesign of existing transit systems. The redesign could include electrification and automation or even upgrading to a different technology.

A Comprehensive Road-Use Fee Pricing and Payout System to Unbundle the Cost of Operating Roads (7.5%)

Comprehensive means that pricing would be set to cover all costs (including road maintenance and externalities such as harm to the environment and health); that privacy and the interests of low-income drivers doing necessary driving would be protected; that the incentive to drive fuel-efficient cars would be at least as large as it is under the current fuels excise tax; and, as good technology becomes available, that congestion pricing is used to protect critical driving from congestion.

The words *payout* and *unbundle* mean that some of the money collected would go to people that are losing money under the current system.

Table 8. Calculation of 2030 LDV Mileage Assuming Extra-Heroic Measures

	ICE Parameters and Calculations						ZEVs			Yearly Totals		
Year	CAFÉ MPG	LCFS	Eq. MPG	f	D_i	G_i	z	D_z	G_z	Total Miles	Total Gallons	2030 MPG
2016	34.3	.9267	37.01	.3	30.0	.8105	.00	0	.000	30.0	.8105	37.01
2017	35.1	.9200	38.15	.4	36.0	.9436	.10	10	.030	46.0	.9738	47.24
2018	36.1	.9133	39.53	.5	35.0	.8855	.30	30	.091	65.0	.9760	66.60
2019	37.1	.9000	40.92	.6	30.0	.7332	.50	50	.151	80.0	.8840	90.50
2020	38.3	.8500	42.56	.7	21.0	.4935	.70	70	.211	91.0	.7047	129.14
2021	40.3	.8000	47.41	.8	8.0	.1687	.90	90	.272	98.0	.4403	222.59
2022	42.3	.8000	52.88	.9	4.5	.0851	.95	95	.287	95.5	.3717	267.66
2023	44.3	.8000	55.38	1.0	5.0	.0903	.95	95	.287	100.0	.3769	265.31
2024	46.5	.8000	58.13	1.0	5.0	.0860	.95	95	.287	100.0	.3727	268.35
2025	48.7	.8000	60.88	1.0	5.0	.0821	.95	95	.287	100.0	.3688	271.18
2026	51.2	.8000	64.00	1.0	5.0	.0781	.95	95	.287	100.0	.3648	274.16
2027	53.7	.8000	67.13	1.0	5.0	.0745	.95	95	.287	100.0	.3611	276.92
2028	56.2	.8000	70.25	1.0	5.0	.0712	.95	95	.287	100.0	.3578	279.48
2029	58.7	.8000	73.38	1.0	5.0	.0681	.95	95	.287	100.0	.3548	281.87
2030	61.2	.8000	76.50	1.0	5.0	.0654	.95	95	.287	100.0	.3520	284.10
Sum of Miles and then Gallons of Equivalent Fuel:										1309.5	8.07	
Equivalent MPG of LDV Fleet in 2030:										*162.27*		

Table 9. HM Case and the EHM Case Which Supports 2005 Per-Capita Driving

Cases	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
HM	.00	.00	.00	.05	.10	.25	.40	.55	.70	.85	.95	.95	.95	.95	.95	.95
EHM	.00	.10	.30	.50	.70	.90	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95

User fees (gas taxes and tolls) are not enough to cover road costs[10] and California is not properly maintaining its roads. Reference 10 shows that in California user fees amount to only 24.1% of what is spent on roads. Besides this, the improved mileage of the ICEs and the large number of ZEVs needed mean that gas tax revenues will drop precipitously.

This system could be used to help reduce the ICE LDV miles driven in 2016 to 2022, as shown in the "f" column of Tables 7 and 8. This system could probably be implemented in less than 5 years.

Unbundling the Cost of Car Parking (7.5%)

Unbundling the cost of car parking[11] throughout California is conservatively estimated to decrease driving by 7.5%, based on Table 1 of Reference 11. That table shows driving reductions due to introducing a price, for 10 cases. Its average reduction in driving is 25% and its smallest reduction is 15%.

Good Bicycle Projects and Bicycle Traffic Skills Education (3%)

The best criterion for spending money for bicycle transportation is the estimated reduction in driving per the amount spent. The following strategies may come close to maximizing this parameter.

Projects to Improve Bicycle Access

All of the smart-growth neighborhoods, central business districts, and other high trip destinations or origins, both existing and planned, should be checked to see if bicycle access could be substantially improved with either a traffic calming project, a "complete streets" project, more shoulder width, or a project to overcome some natural or made-made obstacle.

League of American Bicyclist Certified Instruction of "Traffic Skills 101"

Most serious injuries to bike riders occur in accidents that do not involve a motor vehicle[12]. Most car-bike accidents are caused by wrong-way riding and errors in intersections; the clear-cut-hit-from-behind accident is rare[12].

After attending *Traffic Skills 101,* students that pass a rigorous written test and demonstrate proficiency in riding in traffic and other challenging conditions could be paid for their time and effort.

As an example of what could be done in San Diego County, if the average class size was 3 riders per instructor and each rider passes both tests and earns $100 and if the instructor, with overhead, costs $500 dollars, for a total of $800 for each 3 students, that would mean that $160M could teach $160M/$800 = 200,000 classes of 3 students, for a total of 600,000 students. The population of San Diego County is around 3 million.

Eliminate or Greatly Increase the Maximum Height and Density Limits Close to Transit Stops that Meet Appropriate Service Standards (2%)

As sprawl is reduced, more compact, transit-oriented development (TOD) will need to be built. This strategy will incentivize a consideration of what level of transit service will be needed, how it can be achieved, and what levels of maximum height and density are appropriate. Having no limits at all is reasonable if models show that the development can function without harming the existing adjacent neighborhoods, given the level of transit service and other supporting transportation policies (such as car parking that unbundles the cost and supports the full sharing of parking[12]) that can be assumed.

Net Driving Reduction from All Identified Strategies

By 2030, the sum of these strategies should be realized. They total 23%, resulting in a 1% margin over the needed 22% (which is added to the existing 10% to get the needed 32%).

ADDITIONAL ELECTRICITY REQUIRED

The URL http://www.energy.ca.gov/2013_energypolicy/documents/2013-06-26_workshop/presentations/09_VMT-Bob_RAS_21Jun2013.pdf shows that Californians drove about 325 Billion miles per year, from 2002 to 2011. This value can be multiplied by the 0.8361 factor reduction of driving, computed right after the calculation shown in Equation 31, and the fraction of miles driven by ZEVs, shown at the bottom of Table 7, of 0.689 (from 68.9%), to give the 2030 miles driven by ZEVs = 325 Billion x 0.831 x 0.689 = 187 Billion miles per year.

Using the Tesla information here http://en.wikipedia.org/wiki/Tesla_Roadster, it is assumed that 21.7 kW-h is used per 100 miles, or 0.217 kW-h per mile. The total energy used per year is therefore 187 Billion miles x 0.217 kW-h = 40,648 GW-h.

http://www.cpuc.ca.gov/cfaqs/howhighiscaliforniaselectricitydemandandwheredoesthepowercomefrom.htm, shows that California is using about 265,000 GW-h per year. Therefore the electricity needed to power California's HM ZEV LDF fleet in 2030 is 100% x 40,648/265,000 = 15.34% of the amount of electricity California is currently using.

CONCLUSION

A requirement set named "Heroic Measures" (HM) is quantified. Table 9 shows that the HM LDV efficiency requirements are much easier to achieve than those needed to allow per-capita driving to remain close to its 2005 level. Strategies to achieve the required HM driving reductions are also allocated and described. They are perhaps about as difficult as achieving the HM LDV fleet efficiency. It is computed that the 2030 fleet of LDV HM ZEVs would require an amount of electricity which is equal to about 15% of what California is using today.

ABREVIATIONS AND ACRONYMS

AB 1493 California's Assembly Bill 1493 **ICE** Internal Combustion Engine LDV

AB 32	California's Assembly Bill 32	**kW-h**	Kilo Watt-hour
APS	Alternative Planning Strategy	**LCFS**	Low Carbon Fuel Standard
CAFE	Corporate Average Fleet Efficiency	**LDV**	Light-Duty Vehicle
CARB	California Air Resources Board	**MPO**	Metropolitan Planning Organization
CBD	Center for Biological Diversity	**Pavley**	Senator Pavley's AB 1493
CEQA	California Environmental Quality Act	**PPM**	Parts per Million
CCAP	Center for Clean Air Policy	**RPS**	Renewable Portfolio Standard
CNFF	Cleveland National Forest Foundation	**RTP**	Regional Transportation Plan
SB 375	California's Senate Bill 375	**S-3-05**	Governor's Executive Order S-3-05
CO_2	Carbon Dioxide	**SANDAG**	San Diego Association of Governments
CO_2_e	Carbon Dioxide Equivalent GHG	**SCS**	Sustainable Community Strategy
EHM	"Extra Heroic Measures" LDV Case	**TransNet**	San Diego County sales tax
GEO	Governor's Executive Order	**URL**	Universal Resource Locator
GHG	Greenhouse gas	**VMT**	Vehicle Miles Travelled
GW-h	Giga Watt-Hours	**ZEV**	Zero Emission Vehicle LDV
HM	"Heroic Measures" LDV Case		

ACKNOWLEGEMENTS

Darrell Clarke, Lead Volunteer for the Sierra Club's "Beyond Oil Campaign"; Dr. Dennis Martinek, Oceanside Planning Commissioner; Sandra Goldberg, formerly California Deputy Attorney General; Dr. Nilmini Silva-Send, Senior Policy Analyst of the Energy Policy Initiative Center; Diane Nygaard, Director of Preserve Calavera and founder of *Nelson Nygaard Consulting Associates*; Jack Shu, CNFF President; Joan Bullock; San Diego Sierra Club Executive Committee Chairs: Caroline Chase, John Stump, and (former Assembly Member) Lori Saldaña; Malinda Dickenson, *Law Offices of Malinda R. Dickenson*; Conservation Committee Chair Mollie Biggers; Ed Mainland and Jim Stewart, Co-Chairs, Energy-Climate Committee, Sierra Club California; Bern Grush, Chief Scientist, *Skymeter Corporation*; and SANDAG Staff: Susan Baldwin, Senior Regional Planner; Charles Stoll, Director of Land Use and Transportation Planning; and Stephan Vance, Senior Regional Planner.

REFERENCES

1 Anders, S. J.; De Haan, D. O.; Silva-Send, N.; Tanaka, S.T.; Tyner, L.; *San Diego County Greenhouse Gas Inventory*, September 2008, http://www.sandiego.edu/epic/ghginventory/

2 Tarbuck, E.; Lutgens, F.; *Earth Science*; Tenth Edition, published by Prentice Hall, 2003, page 539

3 Vespa, M.; *Comments on Survey of CEQA Documents on Greenhouse Gas Emissions Draft Work Plan and Development of GHG Threshold of Significance for Residential and Commercial Projects*, Letter from Center for Biological Diversity to Elaine Chang, Deputy Executive Officer of Planning, Rule Development, and Area Sources of the South Coast Air Quality Management District; dated April 15, 2009. http://www.aqmd.gov/ceqa/handbook/GHG/2009/april22mtg/CBDcomments.pdf

4 Hertsgaard, M; *Latino Climate Solution, the Nation*, Dec. 24/31, 2012.

5 Whitney E.; *How to Meet the Climate Crisis, UU World*, Volume XXVI No. 4, Winter 2012.

6 Adams, T.; Eaken, A.; Notthoff, A.; *Communities Tackle Global Warming, A Guide to California's SB 375,* June 2009, NRDC; http://www.nrdc.org/globalWarming/sb375/files/sb375.pdf

7 Hansen, James, Brief of Amicus Curiae, Exhibit A, Case3:11-cv-o22o3-EMC Document108 Filed 11/14/11. from http://ourchildrenstrust.org/sites/default/files/Hansen%20Amicus%20.pdf

8 State of California, Department of Finance, California County Population Estimates and Components of Change by Year, July 1, 2000-2010. Sacramento, California, December 2011, from http://www.dof.ca.gov/research/demographic/reports/estimates/e-2/2000-10/, the "E-2. California County Population Estimates and Components of Change by Year — July 1, 2000–2010"

9 Schwarm, Walter, Demographic Research Unit, California Department of Finance, *Total Population Projections for California and Counties: July 1, 2015 to 2060 in 5-year Increments*, from http://www.dof.ca.gov/research/demographic/reports/projections/P-1/, then "Report P-1 (County): State and County Total Population Projections, 2010-2060 (5-year increments) link, to open or download the EXCEL spreadsheet file.

10 Henchman, Joseph; *Gasoline Taxes and Tolls Pay for Only a Third of State & Local Road Spending*; January 17, 2013; http://taxfoundation.org/article/gasoline-taxes-and-tolls-pay-only-third-state-local-road-spending

11 Bullock, M.; Stewart, J.; *A Plan to Efficiently and Conveniently Unbundle Car Parking Costs*; Paper 2010-A-554-AWMA, from the Air and Waste Management Association's 103rd Annual Conference and Exhibition; Calgary, Canada, June 21-24, 2010. http://sierraclub.typepad.com/files/mike-bullock-parking-paper.pdf

12 Forester, J. *Effective Cycling*, MIT Press, 6th Edition, 1993.

KEYWORDS

Driving, climate, mandates, S-3-05, SB 375, RTP, CEQA, Unbundled, GHG, CAFÉ, ZEVs

Transportation Cost Analysis Spreadsheets

Victoria Transport Policy Institute (www.vtpi.org)

2-Jan-09

These spreadsheets calculate the full costs of different forms of transportation, and the cost savings that result from travel changes.
The spreadsheets include default cost values that can be modified as needed to reflect specific conditions and assumptions.
See "Transportation Cost And Benefit Analysis" (www.vtpi.org/tca) for detailed information on how these default values were estimated.
There are five individual spreadsheets, titled "Defaults," "Per-Vehicle Costs," "Per-Passenger Costs," "TDM Benefits" and "Graphs" Use the tabs below to move between spreadsheets.
Make changes in the "Per-Vehicle Costs" spreadsheet; input sells are highlighted in yellow. Other spreadsheets are protected.
Send questions and comments to: Todd Litman (litman@vtpi.org).

Default Values

This is the first spreadsheet. It contains default per vehicle-mile cost estimates from the report *Transportation Cost and Benefit Analysis: Techniques, Estimates and Implications*, Victoria
Do not change these values. Make changes in the "Per-Vehicle Costs" spreadsheet.

Units: ***2007 U.S. Dollars Per Vehicle-Mile***

Table 1, Urban Peak ***2007 U.S. Dollars Per Vehicle Mile***

	Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Internal	Fixed	Market
Units	Average Occupancy	1.1	1.1	1.1	1.1	1.0	25.0	30.0	1.0	1.0	1.0	1.0			
Veh-Mile	Vehicle Ownership	0.272	0.239	0.341	0.354	0.000	0.000	0.000	0.333	0.066	0.000	0.264	100%	100%	100%
Veh-Mile	Vehicle Operation	0.194	0.141	0.273	0.273	0.004	6.930	9.009	0.082	0.026	0.053	0.000	100%	0%	100%
Veh-Mile	Operating Subsidy	0.000	0.000	0.000	0.000	0.000	8.250	11.484	0.000	0.000	0.000	0.000	0%	100%	100%
Pass-Mile	Travel Time	0.288	0.288	0.288	0.288	0.225	0.438	0.438	0.288	0.438	1.250	0.000	100%	0%	0%
Pass-Mile	Internal Crash	0.083	0.092	0.083	0.083	0.083	0.004	0.004	0.577	0.083	0.083	0.000	100%	0%	20%
Veh-Mile	External Crash	0.055	0.053	0.055	0.055	0.000	0.264	0.264	0.102	0.003	0.003	0.000	0%	0%	20%
Pass-Mile	Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	100%	0%	20%
Pass-Mile	External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	0%	0%	20%
Veh-Mile	Internal Parking	0.080	0.072	0.080	0.080	0.000	0.000	0.000	0.064	0.005	0.000	0.000	100%	100%	100%
Veh-Mile	External Parking	0.150	0.143	0.150	0.150	0.000	0.000	0.000	0.113	0.008	0.000	0.000	0%	0%	100%
Veh-Mile	Congestion	0.130	0.130	0.130	0.130	0.000	0.270	0.270	0.130	0.010	0.003	0.000	0%	0%	50%
Veh-Mile	Road Facilities	0.026	0.026	0.064	0.035	0.000	0.048	0.048	0.014	0.002	0.002	0.000	0%	0%	100%
Veh-Mile	Land Value	0.034	0.034	0.034	0.034	0.000	0.034	0.034	0.034	0.002	0.002	0.000	0%	100%	100%
Veh-Mile	Traffic Services	0.020	0.020	0.020	0.020	0.000	0.020	0.020	0.020	0.002	0.002	0.002	0%	0%	100%
Veh-Mile	Transport Diversity	0.007	0.007	0.007	0.007	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Air Pollution	0.062	0.051	0.016	0.112	0.002	0.185	0.078	0.106	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	GHG	0.019	0.014	0.005	0.026	0.000	0.094	0.031	0.009	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Noise	0.013	0.013	0.004	0.013	0.000	0.066	0.040	0.132	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Resource Externalities	0.046	0.038	0.019	0.060	0.001	0.232	0.077	0.019	0.000	0.000	0.004	0%	0%	50%
Veh-Mile	Barrier Effect	0.023	0.023	0.023	0.023	0.000	0.038	0.038	0.023	0.001	0.000	0.000	0%	0%	0%
Veh-Mile	Land Use Impacts	0.083	0.083	0.083	0.083	0.000	0.000	0.000	0.083	0.000	0.000	0.083	0%	100%	50%
Veh-Mile	Water Pollution	0.014	0.014	0.007	0.014	0.000	0.014	0.007	0.014	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Waste	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004	0.0000	0.0000	0.0000	0%	0%	0%
	Totals	*1.599*	*1.481*	*1.682*	*1.840*	*0.315*	*16.887*	*21.842*	*2.150*	*0.456*	*0.918*	*0.353*			

Table 2, Urban Off-Peak ***2007 U.S. Dollars Per Vehicle Mile***

	Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Internal	Fixed	Market
Units	Average Occupancy	1.5	1.5	1.5	1.5	1.0	8.0	10.0	1.0	1.0	1.0	1.0			
Veh-Mile	Vehicle Ownership	0.272	0.239	0.341	0.354	0.000	0.000	0.000	0.333	0.066	0.000	0.264	100%	100%	100%

Veh-Mile	Vehicle Operation	0.169	0.123	0.238	0.238	0.004	1.386	1.802	0.071	0.026	0.053	0.000	100%	0%	100%
Veh-Mile	Operating Subsidy	0.000	0.000	0.000	0.000	0.000	2.640	3.828	0.000	0.000	0.000	0.000	0%	100%	100%
Pass-Mile	Travel Time	0.075	0.075	0.075	0.075	0.075	0.238	0.238	0.075	0.375	1.250	0.000	100%	0%	0%
Pass-Mile	Internal Crash	0.083	0.092	0.083	0.083	0.083	0.004	0.004	0.577	0.083	0.083	0.000	100%	0%	20%
Veh-Mile	External Crash	0.055	0.053	0.055	0.055	0.000	0.264	0.264	0.102	0.003	0.003	0.000	0%	0%	20%
Pass-Mile	Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	100%	0%	20%
Pass-Mile	External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	0%	0%	20%
Veh-Mile	Internal Parking	0.080	0.072	0.080	0.080	0.000	0.000	0.000	0.064	0.005	0.000	0.000	100%	100%	100%
Veh-Mile	External Parking	0.050	0.047	0.050	0.050	0.000	0.000	0.000	0.037	0.003	0.000	0.000	0%	0%	100%
Veh-Mile	Congestion	0.020	0.020	0.020	0.020	0.000	0.040	0.040	0.020	0.001	0.001	0.000	0%	0%	50%
Veh-Mile	Road Facilities	0.026	0.026	0.064	0.035	0.000	0.048	0.048	0.014	0.002	0.002	0.000	0%	0%	100%
Veh-Mile	Land Value	0.034	0.034	0.034	0.034	0.000	0.034	0.034	0.034	0.002	0.002	0.000	0%	100%	100%
Veh-Mile	Traffic Services	0.013	0.013	0.013	0.013	0.000	0.013	0.013	0.013	0.001	0.001	0.001	0%	0%	100%
Veh-Mile	Transport Diversity	0.007	0.007	0.007	0.007	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Air Pollution	0.052	0.042	0.013	0.094	0.002	0.160	0.065	0.086	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	GHG	0.017	0.013	0.004	0.024	0.000	0.086	0.028	0.009	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Noise	0.013	0.013	0.004	0.013	0.000	0.066	0.040	0.132	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Resource Externalities	0.040	0.033	0.016	0.052	0.001	0.200	0.067	0.016	0.000	0.000	0.004	0%	0%	50%
Veh-Mile	Barrier Effect	0.015	0.015	0.015	0.015	0.000	0.025	0.025	0.015	0.001	0.000	0.000	0%	0%	0%
Veh-Mile	Land Use Impacts	0.083	0.083	0.083	0.083	0.000	0.000	0.000	0.083	0.000	0.000	0.083	0%	100%	50%
Veh-Mile	Water Pollution	0.014	0.014	0.007	0.014	0.000	0.014	0.007	0.014	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Waste	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004	0.0000	0.0000	0.0000	0%	0%	0%
	Totals	*1.1184*	*1.0144*	*1.2024*	*1.3394*	*0.165*	*5.2179*	*6.5029*	*1.7024*	*0.378*	*0.915*	*0.352*			

Table 3, Rural Travel *2007 U.S. Dollars Per Vehicle Mile*

	Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Internal	Fixed	Market
Units	Average Occupancy	1.5	1.5	1.5	1.5	1.0	5.0	10.0	1.0	1.0	1.0	1.0			
Veh-Mile	Vehicle Ownership	0.272	0.239	0.341	0.354	0.000	0.000	0.000	0.333	0.066	0.000	0.264	100%	100%	100%
Veh-Mile	Vehicle Operation	0.144	0.104	0.202	0.202	0.003	1.386	1.802	0.066	0.026	0.053	0.000	100%	0%	100%
Veh-Mile	Operating Subsidy	0.000	0.000	0.000	0.000	0.000	1.650	3.828	0.000	0.000	0.000	0.000	0%	100%	100%
Pass-Mile	Travel Time	0.063	0.063	0.063	0.063	0.063	0.200	0.200	0.063	0.375	1.250	0.000	100%	0%	0%
Pass-Mile	Internal Crash	0.083	0.092	0.083	0.083	0.083	0.004	0.004	0.577	0.083	0.083	0.000	100%	0%	20%
Veh-Mile	External Crash	0.055	0.053	0.055	0.055	0.000	0.264	0.264	0.102	0.003	0.003	0.000	0%	0%	20%
Pass-Mile	Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	100%	0%	20%
Pass-Mile	External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	0%	0%	20%
Veh-Mile	Internal Parking	0.040	0.037	0.040	0.040	0.000	0.000	0.000	0.032	0.002	0.000	0.000	100%	100%	100%
Veh-Mile	External Parking	0.025	0.024	0.025	0.025	0.000	0.000	0.000	0.018	0.001	0.000	0.000	0%	0%	100%
Veh-Mile	Congestion	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0%	0%	50%
Veh-Mile	Road Facilities	0.016	0.016	0.038	0.021	0.000	0.029	0.029	0.008	0.001	0.001	0.000	0%	0%	100%
Veh-Mile	Land Value	0.034	0.034	0.034	0.034	0.000	0.034	0.034	0.034	0.002	0.002	0.000	0%	100%	100%
Veh-Mile	Traffic Services	0.007	0.007	0.007	0.007	0.000	0.007	0.007	0.007	0.000	0.000	0.000	0%	0%	100%
Veh-Mile	Transport Diversity	0.007	0.007	0.007	0.007	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Air Pollution	0.004	0.003	0.001	0.007	0.000	0.013	0.005	0.006	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	GHG	0.015	0.012	0.004	0.021	0.000	0.077	0.026	0.008	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Noise	0.007	0.007	0.004	0.007	0.000	0.033	0.020	0.066	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Resource Externalities	0.034	0.028	0.014	0.044	0.001	0.168	0.056	0.013	0.000	0.000	0.004	0%	0%	50%
Veh-Mile	Barrier Effect	0.008	0.008	0.008	0.008	0.000	0.013	0.013	0.008	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Land Use Impacts	0.042	0.042	0.042	0.042	0.000	0.000	0.000	0.042	0.000	0.000	0.042	0%	100%	50%
Veh-Mile	Water Pollution	0.014	0.014	0.007	0.014	0.000	0.014	0.007	0.014	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Waste	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004	0.0000	0.0000	0.0000	0%	0%	0%
	Totals	*0.869*	*0.789*	*0.974*	*1.033*	*0.150*	*3.892*	*6.295*	*1.403*	*0.369*	*0.912*	*0.310*			

Distribution of Vehicle Travel

Urban Peak	20%
Urban Off-Peak	40%
Rural	40%
sum	100%

Table 4, Average Travel *2007 U.S. Dollars Per Vehicle Mile*

Units	Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Internal	Fixed	Market
	Average Occupancy	1.42	1.42	1.42	1.42	1.00	10.20	14.00	1.00	1.00	1.00	1.00			
Veh-Mile	Vehicle Ownership	0.272	0.239	0.341	0.354	0.000	0.000	0.000	0.333	0.066	0.000	0.264	100%	100%	100%
Veh-Mile	Vehicle Operation	0.164	0.119	0.231	0.231	0.004	2.495	3.243	0.071	0.026	0.053	0.000	100%	0%	100%
Veh-Mile	Operating Subsidy	0.000	0.000	0.000	0.000	0.000	3.366	5.359	0.000	0.000	0.000	0.000	0%	100%	100%
Pass-Mile	Travel Time	0.113	0.113	0.113	0.113	0.100	0.263	0.263	0.113	0.388	1.250	0.000	100%	0%	0%
Pass-Mile	Internal Crash	0.083	0.092	0.083	0.083	0.083	0.004	0.004	0.577	0.083	0.083	0.000	100%	0%	20%
Veh-Mile	External Crash	0.055	0.053	0.055	0.055	0.000	0.264	0.264	0.102	0.003	0.003	0.000	0%	0%	20%
Pass-Mile	Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	100%	0%	20%
Pass-Mile	External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	0%	0%	20%
Veh-Mile	Internal Parking	0.064	0.058	0.064	0.064	0.000	0.000	0.000	0.051	0.004	0.000	0.000	100%	100%	100%
Veh-Mile	External Parking	0.060	0.057	0.060	0.060	0.000	0.000	0.000	0.045	0.003	0.000	0.000	0%	0%	100%
Veh-Mile	Congestion	0.034	0.034	0.034	0.034	0.000	0.070	0.070	0.034	0.002	0.001	0.000	0%	0%	50%
Veh-Mile	Road Facilities	0.022	0.022	0.054	0.029	0.000	0.040	0.040	0.012	0.002	0.002	0.000	0%	0%	100%
Veh-Mile	Land Value	0.034	0.034	0.034	0.034	0.000	0.034	0.034	0.034	0.002	0.002	0.000	0%	100%	100%
Veh-Mile	Traffic Services	0.012	0.012	0.012	0.012	0.000	0.012	0.012	0.012	0.001	0.001	0.001	0%	0%	100%
Veh-Mile	Transport Diversity	0.007	0.007	0.007	0.007	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Air Pollution	0.035	0.028	0.009	0.063	0.001	0.106	0.044	0.058	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	GHG	0.017	0.013	0.004	0.023	0.000	0.084	0.028	0.009	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Noise	0.011	0.011	0.004	0.011	0.000	0.053	0.032	0.106	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Resource Externalities	0.039	0.032	0.016	0.050	0.001	0.194	0.065	0.015	0.000	0.000	0.004	0%	0%	50%
Veh-Mile	Barrier Effect	0.014	0.014	0.014	0.014	0.000	0.023	0.023	0.014	0.001	0.000	0.000	0%	0%	0%
Veh-Mile	Land Use Impacts	0.066	0.066	0.066	0.066	0.000	0.000	0.000	0.066	0.000	0.000	0.066	0%	100%	50%
Veh-Mile	Water Pollution	0.014	0.014	0.007	0.014	0.000	0.014	0.007	0.014	0.000	0.000	0.000	0%	0%	0%
Veh-Mile	Waste	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004	0.0000	0.0000	0.0000	0%	0%	0%
	Totals	*1.115*	*1.018*	*1.207*	*1.317*	*0.189*	*7.022*	*9.488*	*1.672*	*0.390*	*0.914*	*0.335*			

Modes Defined

1. Average Automobile. A medium sized car that averages 21 mpg overall (16 mpg city driving, 24 mph highway driving), driven 12,500 miles per year. Automobile occupancy averages 1.5

2. Compact (Fuel Efficient) Car. A small four passenger car that averages 40 mpg overall (34 mpg city driving, 46 mpg highway driving).

3. Electric Car. A medium size battery powered electric car based on current technology, which consumes an average of 0.5 kWh per mile of travel.

4. Van or *Light Truck.* A 14 passenger van or light truck that averages 15 mpg overall (14 mpg city and 20 mph highway driving). Occupancy is same as an automobile.

5. Rideshare Passenger. The incremental cost of an additional carpool, vanpool or transit rider, assuming the vehicle would be traveling anyway. Fuel efficiency is estimated to

6. Diesel Bus. A 40 foot bus (total capacity 53 seated and 32 standing passenger) with 25 average passengers during peak periods, 8 average passengers during Urban Off-Peak, and 5 average

7. Electric Trolley. A 65 maximum trolley with a peak period occupancy of 40 passengers, 15 average passengers at other times, an overall average occupancy of 20 passengers, and averages 6

8. Motorcycle. A medium size motorcycle that averages 45 mpg under urban driving conditions, and 55 mph under rural driving conditions.

9. Bicycle. A moderate priced bicycle ridden an average of 10 mph.

10. Walk. A person walking an average of 3 mph.

11. Telework. This represents two 11 mile commute trips avoided when employees work from home. That may underestimate VMT savings since telecommuters tend to have longer than

Transportation Cost Analysis Spreadsheets

Victoria Transport Policy Institute (www.vtpi.org)
2-Jan-09

Per-Vehicle Costs

These are estimated costs per vehicle-mile or vehicle-kilometer.
You can use the default values, modified by conversion factors in the table below, or input your own values.
Highlighted cells contain input values. Adjust these values to reflect a particular situation or alternative assumptions.

Conversion Factors

Mileage/Kilometers	1.0	Use 1.0 for miles, 0.6 for kilometers
Exchange Rate	1.00	Change this value to reflect other denominations based on monetary exchange rates. For example, if one U.S. dollar is worth $1.53
Inflation since 2007	0%	Adjust to reflect analysis year.
Units Description	2007 U.S. Dollars per mile	Default units are 2007 U.S. dollars per mile. Note any changes here.

Units: *2007 U.S. Dollars per mile*

Table 1, Urban Peak *2007 U.S. Dollars per mile*

Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Average Occupancy	1.1	1.1	1.1	1.1	1	25	30	1	1	1	1	
Vehicle Ownership	0.272	0.239	0.341	0.354	0.000	0.000	0.000	0.333	0.066	0.000	0.264	Internal-Fixed
Vehicle Operation	0.194	0.141	0.273	0.273	0.004	6.930	9.009	0.082	0.026	0.053	0.000	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	8.250	11.484	0.000	0.000	0.000	0.000	External
Travel Time	0.316	0.316	0.316	0.316	0.225	10.938	13.125	0.288	0.438	1.250	0.000	Internal-Variable
Internal Crash	0.091	0.101	0.091	0.091	0.083	0.100	0.120	0.577	0.083	0.083	0.000	Internal-Variable
External Crash	0.055	0.053	0.055	0.055	0.000	0.264	0.264	0.102	0.003	0.003	0.000	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	External
Internal Parking	0.080	0.072	0.080	0.080	0.000	0.000	0.000	0.064	0.005	0.000	0.000	Internal-Fixed
External Parking	0.150	0.143	0.150	0.150	0.000	0.000	0.000	0.113	0.008	0.000	0.000	External
Congestion	0.130	0.130	0.130	0.130	0.000	0.270	0.270	0.130	0.010	0.003	0.000	External
Road Facilities	0.026	0.026	0.064	0.035	0.000	0.048	0.048	0.014	0.002	0.002	0.000	External
Land Value	0.034	0.034	0.034	0.034	0.000	0.034	0.034	0.034	0.002	0.002	0.000	External
Traffic Services	0.020	0.020	0.020	0.020	0.000	0.020	0.020	0.020	0.002	0.002	0.002	External
Transport Diversity	0.007	0.007	0.007	0.007	0.000	0.000	0.000	0.007	0.000	0.000	0.000	External
Air Pollution	0.062	0.051	0.016	0.112	0.002	0.185	0.078	0.106	0.000	0.000	0.000	External
GHG	0.019	0.014	0.005	0.026	0.000	0.094	0.031	0.009	0.000	0.000	0.000	External
Noise	0.013	0.013	0.004	0.013	0.000	0.066	0.040	0.132	0.000	0.000	0.000	External
Resource Externalities	0.046	0.038	0.019	0.060	0.001	0.232	0.077	0.019	0.000	0.000	0.004	External
Barrier Effect	0.023	0.023	0.023	0.023	0.000	0.038	0.038	0.023	0.001	0.000	0.000	External
Land Use Impacts	0.083	0.083	0.083	0.083	0.000	0.000	0.000	0.083	0.000	0.000	0.083	External
Water Pollution	0.014	0.014	0.007	0.014	0.000	0.014	0.007	0.014	0.000	0.000	0.000	External
Waste	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004	0.0000	0.0000	0.0000	External
Internal Fixed	*0.352*	*0.311*	*0.421*	*0.434*	*0.000*	*0.000*	*0.000*	*0.397*	*0.071*	*0.000*	*0.264*	
Internal Variable	*0.602*	*0.558*	*0.681*	*0.681*	*0.312*	*17.968*	*22.254*	*0.947*	*0.547*	*1.386*	*0.000*	
External	*0.682*	*0.649*	*0.617*	*0.762*	*0.003*	*9.515*	*12.391*	*0.806*	*0.028*	*0.012*	*0.089*	
Totals	*1.636*	*1.519*	*1.719*	*1.877*	*0.315*	*27.483*	*34.645*	*2.150*	*0.456*	*0.918*	*0.353*	

Table 2, Urban Off-Peak *2007 U.S. Dollars per mile*

Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Average Occupancy	1.5	1.5	1.5	1.5	1	8	10	1	1	1	1	
Vehicle Ownership	0.272	0.239	0.341	0.354	0.000	0.000	0.000	0.333	0.066	0.000	0.264	Internal-Fixed
Vehicle Operation	0.169	0.123	0.238	0.238	0.004	1.386	1.802	0.071	0.026	0.053	0.000	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	2.640	3.828	0.000	0.000	0.000	0.000	External
Travel Time	0.113	0.113	0.113	0.113	0.075	1.900	2.375	0.075	0.375	1.250	0.000	Internal-Variable
Internal Crash	0.125	0.138	0.125	0.125	0.083	0.032	0.040	0.577	0.083	0.083	0.000	Internal-Variable
External Crash	0.055	0.053	0.055	0.055	0.000	0.264	0.264	0.102	0.003	0.003	0.000	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	External
Internal Parking	0.080	0.072	0.080	0.080	0.000	0.000	0.000	0.064	0.005	0.000	0.000	Internal-Fixed
External Parking	0.050	0.047	0.050	0.050	0.000	0.000	0.000	0.037	0.003	0.000	0.000	External
Congestion	0.020	0.020	0.020	0.020	0.000	0.040	0.040	0.020	0.001	0.001	0.000	External
Road Facilities	0.026	0.026	0.064	0.035	0.000	0.048	0.048	0.014	0.002	0.002	0.000	External
Land Value	0.034	0.034	0.034	0.034	0.000	0.034	0.034	0.034	0.002	0.002	0.000	External
Traffic Services	0.013	0.013	0.013	0.013	0.000	0.013	0.013	0.013	0.001	0.001	0.001	External
Transport Diversity	0.007	0.007	0.007	0.007	0.000	0.000	0.000	0.007	0.000	0.000	0.000	External
Air Pollution	0.052	0.042	0.013	0.094	0.002	0.160	0.065	0.086	0.000	0.000	0.000	External
GHG	0.017	0.013	0.004	0.024	0.000	0.086	0.028	0.009	0.000	0.000	0.000	External
Noise	0.013	0.013	0.004	0.013	0.000	0.066	0.040	0.132	0.000	0.000	0.000	External
Resource Externalities	0.040	0.033	0.016	0.052	0.001	0.200	0.067	0.016	0.000	0.000	0.004	External
Barrier Effect	0.015	0.015	0.015	0.015	0.000	0.025	0.025	0.015	0.001	0.000	0.000	External
Land Use Impacts	0.083	0.083	0.083	0.083	0.000	0.000	0.000	0.083	0.000	0.000	0.083	External
Water Pollution	0.014	0.014	0.007	0.014	0.000	0.014	0.007	0.014	0.000	0.000	0.000	External
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Internal Fixed	*0.352*	*0.311*	*0.421*	*0.434*	*0.000*	*0.000*	*0.000*	*0.397*	*0.071*	*0.000*	*0.264*	
Internal Variable	*0.406*	*0.374*	*0.475*	*0.475*	*0.162*	*3.318*	*4.217*	*0.723*	*0.484*	*1.386*	*0.000*	
External	*0.439*	*0.413*	*0.385*	*0.509*	*0.003*	*3.590*	*4.459*	*0.582*	*0.013*	*0.009*	*0.088*	
Totals	*1.197*	*1.098*	*1.281*	*1.418*	*0.165*	*6.908*	*8.676*	*1.702*	*0.378*	*0.915*	*0.352*	

Table 3, Rural Travel *2007 U.S. Dollars per mile*

Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Average Occupancy	1.5	1.5	1.5	1.5	1	5	10	1	1	1	1	
Vehicle Ownership	0.272	0.239	0.341	0.354	0.000	0.000	0.000	0.333	0.066	0.000	0.264	Internal-Fixed
Vehicle Operation	0.144	0.104	0.202	0.202	0.003	1.386	1.802	0.066	0.026	0.053	0.000	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	1.650	3.828	0.000	0.000	0.000	0.000	External
Travel Time	0.094	0.094	0.094	0.094	0.063	1.000	2.000	0.063	0.375	1.250	0.000	Internal-Variable
Internal Crash	0.125	0.138	0.125	0.125	0.083	0.020	0.040	0.577	0.083	0.083	0.000	Internal-Variable
External Crash	0.055	0.053	0.055	0.055	0.000	0.264	0.264	0.102	0.003	0.003	0.000	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	External
Internal Parking	0.040	0.037	0.040	0.040	0.000	0.000	0.000	0.032	0.002	0.000	0.000	Internal-Fixed
External Parking	0.025	0.024	0.025	0.025	0.000	0.000	0.000	0.018	0.001	0.000	0.000	External
Congestion	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Road Facilities	0.016	0.016	0.038	0.021	0.000	0.029	0.029	0.008	0.001	0.001	0.000	External
Land Value	0.034	0.034	0.034	0.034	0.000	0.034	0.034	0.034	0.002	0.002	0.000	External
Traffic Services	0.007	0.007	0.007	0.007	0.000	0.007	0.007	0.007	0.000	0.000	0.000	External
Transport Diversity	0.007	0.007	0.007	0.007	0.000	0.000	0.000	0.007	0.000	0.000	0.000	External
Air Pollution	0.004	0.003	0.001	0.007	0.000	0.013	0.005	0.006	0.000	0.000	0.000	External
GHG	0.015	0.012	0.004	0.021	0.000	0.077	0.026	0.008	0.000	0.000	0.000	External
Noise	0.007	0.007	0.004	0.007	0.000	0.033	0.020	0.066	0.000	0.000	0.000	External
Resource Externalities	0.034	0.028	0.014	0.044	0.001	0.168	0.056	0.013	0.000	0.000	0.004	External
Barrier Effect	0.008	0.008	0.008	0.008	0.000	0.013	0.013	0.008	0.000	0.000	0.000	External
Land Use Impacts	0.042	0.042	0.042	0.042	0.000	0.000	0.000	0.042	0.000	0.000	0.042	External
Water Pollution	0.014	0.014	0.007	0.014	0.000	0.014	0.007	0.014	0.000	0.000	0.000	External
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Internal Fixed	*0.312*	*0.276*	*0.381*	*0.394*	*0.000*	*0.000*	*0.000*	*0.365*	*0.068*	*0.000*	*0.264*	
Internal Variable	*0.362*	*0.336*	*0.420*	*0.420*	*0.149*	*2.406*	*3.842*	*0.706*	*0.484*	*1.386*	*0.000*	
External	*0.268*	*0.255*	*0.246*	*0.292*	*0.001*	*2.302*	*4.289*	*0.333*	*0.007*	*0.006*	*0.046*	
Totals	*0.942*	*0.867*	*1.047*	*1.106*	*0.150*	*4.708*	*8.131*	*1.403*	*0.369*	*0.912*	*0.310*	

Distribution of Vehicle Travel

Urban Peak	20%
Urban Off-Peak	40%
Rural	40%
sum	100%

Table 4, Average Travel *2007 U.S. Dollars per mile*

Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Average Occupancy	1.42	1.42	1.42	1.42	1.00	10.20	14.00	1.00	1.00	1.00	1.00	
Vehicle Ownership	0.272	0.239	0.341	0.354	0.000	0.000	0.000	0.333	0.066	0.000	0.264	Internal-Fixed
Vehicle Operation	0.164	0.119	0.231	0.231	0.004	2.495	3.243	0.071	0.026	0.053	0.000	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	3.366	5.359	0.000	0.000	0.000	0.000	External
Travel Time	0.146	0.146	0.146	0.146	0.100	3.348	4.375	0.113	0.388	1.250	0.000	Internal-Variable
Internal Crash	0.118	0.131	0.118	0.118	0.083	0.041	0.056	0.577	0.083	0.083	0.000	Internal-Variable
External Crash	0.055	0.053	0.055	0.055	0.000	0.264	0.264	0.102	0.003	0.003	0.000	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	External
Internal Parking	0.064	0.058	0.064	0.064	0.000	0.000	0.000	0.051	0.004	0.000	0.000	Internal-Fixed
External Parking	0.060	0.057	0.060	0.060	0.000	0.000	0.000	0.045	0.003	0.000	0.000	External
Congestion	0.034	0.034	0.034	0.034	0.000	0.070	0.070	0.034	0.002	0.001	0.000	External
Road Facilities	0.022	0.022	0.054	0.029	0.000	0.040	0.040	0.012	0.002	0.002	0.000	External
Land Value	0.034	0.034	0.034	0.034	0.000	0.034	0.034	0.034	0.002	0.002	0.000	External
Traffic Services	0.012	0.012	0.012	0.012	0.000	0.012	0.012	0.012	0.001	0.001	0.001	External
Transport Diversity	0.007	0.007	0.007	0.007	0.000	0.000	0.000	0.007	0.000	0.000	0.000	External
Air Pollution	0.035	0.028	0.009	0.063	0.001	0.106	0.044	0.058	0.000	0.000	0.000	External
GHG	0.017	0.013	0.004	0.023	0.000	0.084	0.028	0.009	0.000	0.000	0.000	External
Noise	0.011	0.011	0.004	0.011	0.000	0.053	0.032	0.106	0.000	0.000	0.000	External
Resource Externalities	0.039	0.032	0.016	0.050	0.001	0.194	0.065	0.015	0.000	0.000	0.004	External
Barrier Effect	0.014	0.014	0.014	0.014	0.000	0.023	0.023	0.014	0.001	0.000	0.000	External
Land Use Impacts	0.066	0.066	0.066	0.066	0.000	0.000	0.000	0.066	0.000	0.000	0.066	External
Water Pollution	0.014	0.014	0.007	0.014	0.000	0.014	0.007	0.014	0.000	0.000	0.000	External
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Internal Fixed	*0.336*	*0.297*	*0.405*	*0.418*	*0.000*	*0.000*	*0.000*	*0.384*	*0.070*	*0.000*	*0.264*	
Internal Variable	*0.428*	*0.395*	*0.494*	*0.494*	*0.187*	*5.883*	*7.674*	*0.761*	*0.497*	*1.386*	*0.000*	
External	*0.419*	*0.397*	*0.376*	*0.473*	*0.002*	*4.260*	*5.978*	*0.527*	*0.014*	*0.008*	*0.071*	
Totals	*1.183*	*1.090*	*1.275*	*1.385*	*0.189*	*10.143*	*13.652*	*1.672*	*0.390*	*0.914*	*0.335*	

GHG Damage Cost Estimates for Sensitivity Analysis

	Average Car	Compact Car	Electric Car	Van/Light Truck	Rideshare Passenger	Diesel Bus	Electric Bus/Trolley	Motorcycle	Bicycle	Walk	Telework
Urban Peak	0.161	0.121	0.040	0.222	0.004	0.806	0.269	0.081	0.000	0.000	0.000
Urban Off-Peak	0.147	0.110	0.037	0.202	0.004	0.733	0.244	0.073	0.000	0.000	0.000
Rural	0.132	0.099	0.033	0.181	0.004	0.660	0.220	0.066	0.000	0.000	0.000

Transportation Cost Analysis Spreadsheets

Victoria Transport Policy Institute (www.vtpi.org)
2-Jan-09

Per-Passenger Costs

These are costs per passenger-mile, calculated by multiplying per-vehicle costs by average vehicle occupancy values.

Units: ***2007 U.S. Dollars per mile***

Table 1, Urban Peak ***2007 U.S. Dollars per mile***

Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Average Occupancy	1.1	1.1	1.1	1.1	1.0	25.0	30.0	1.0	1.0	1.0	1.0	
Vehicle Ownership	0.247	0.217	0.310	0.322	0.000	0.000	0.000	0.333	0.066	0.000	0.264	Internal-Fixed
Vehicle Operation	0.176	0.128	0.248	0.248	0.004	0.277	0.300	0.082	0.026	0.053	0.000	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	0.330	0.383	0.000	0.000	0.000	0.000	External
Travel Time	0.288	0.288	0.288	0.288	0.225	0.438	0.438	0.288	0.438	1.250	0.000	Internal-Variable
Internal Crash	0.083	0.092	0.083	0.083	0.083	0.004	0.004	0.577	0.083	0.083	0.000	Internal-Variable
External Crash	0.050	0.048	0.050	0.050	0.000	0.011	0.009	0.102	0.003	0.003	0.000	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	External
Internal Parking	0.073	0.065	0.073	0.073	0.000	0.000	0.000	0.064	0.005	0.000	0.000	Internal-Fixed
External Parking	0.136	0.130	0.136	0.136	0.000	0.000	0.000	0.113	0.008	0.000	0.000	External
Congestion	0.118	0.118	0.118	0.118	0.000	0.011	0.009	0.130	0.010	0.003	0.000	External
Road Facilities	0.024	0.024	0.058	0.032	0.000	0.002	0.002	0.014	0.002	0.002	0.000	External
Land Value	0.031	0.031	0.031	0.031	0.000	0.001	0.001	0.034	0.002	0.002	0.000	External
Traffic Services	0.018	0.018	0.018	0.018	0.000	0.001	0.001	0.020	0.002	0.002	0.002	External
Transport Diversity	0.006	0.006	0.006	0.006	0.000	0.000	0.000	0.007	0.000	0.000	0.000	External
Air Pollution	0.056	0.046	0.015	0.102	0.002	0.007	0.003	0.106	0.000	0.000	0.000	External
GHG	0.017	0.013	0.005	0.024	0.000	0.004	0.001	0.009	0.000	0.000	0.000	External
Noise	0.012	0.012	0.004	0.012	0.000	0.003	0.001	0.132	0.000	0.000	0.000	External
Resource Externalities	0.042	0.035	0.017	0.055	0.001	0.009	0.003	0.019	0.000	0.000	0.004	External
Barrier Effect	0.021	0.021	0.021	0.021	0.000	0.002	0.001	0.023	0.001	0.000	0.000	External
Land Use Impacts	0.075	0.075	0.075	0.075	0.000	0.000	0.000	0.083	0.000	0.000	0.083	External
Water Pollution	0.013	0.013	0.006	0.013	0.000	0.001	0.000	0.014	0.000	0.000	0.000	External
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Internal Fixed	*0.320*	*0.283*	*0.383*	*0.395*	*0.000*	*0.000*	*0.000*	*0.397*	*0.071*	*0.000*	*0.264*	
Internal Variable	*0.547*	*0.508*	*0.619*	*0.619*	*0.312*	*0.719*	*0.742*	*0.947*	*0.547*	*1.386*	*0.000*	
External	*0.620*	*0.590*	*0.561*	*0.693*	*0.003*	*0.381*	*0.413*	*0.806*	*0.028*	*0.012*	*0.089*	
Totals	*1.487*	*1.381*	*1.563*	*1.706*	*0.315*	*1.099*	*1.155*	*2.150*	*0.456*	*0.918*	*0.353*	

Table 2, Urban Off-Peak *2007 U.S. Dollars pe*

Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Average Occupancy	1.5	1.5	1.5	1.5	1.0	8.0	10.0	1.0	1.0	1.0	1.0	
Vehicle Ownership	0.181	0.159	0.227	0.236	0.000	0.000	0.000	0.333	0.066	0.000	0.264	Internal-Fixed
Vehicle Operation	0.113	0.082	0.159	0.159	0.004	0.173	0.180	0.071	0.026	0.053	0.000	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	0.330	0.383	0.000	0.000	0.000	0.000	External
Travel Time	0.075	0.075	0.075	0.075	0.075	0.238	0.238	0.075	0.375	1.250	0.000	Internal-Variable
Internal Crash	0.083	0.092	0.083	0.083	0.083	0.004	0.004	0.577	0.083	0.083	0.000	Internal-Variable
External Crash	0.037	0.035	0.037	0.037	0.000	0.033	0.026	0.102	0.003	0.003	0.000	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	External
Internal Parking	0.053	0.048	0.053	0.053	0.000	0.000	0.000	0.064	0.005	0.000	0.000	Internal-Fixed
External Parking	0.033	0.031	0.033	0.033	0.000	0.000	0.000	0.037	0.003	0.000	0.000	External
Congestion	0.013	0.013	0.013	0.013	0.000	0.005	0.004	0.020	0.001	0.001	0.000	External
Road Facilities	0.017	0.017	0.043	0.023	0.000	0.006	0.005	0.014	0.002	0.002	0.000	External
Land Value	0.023	0.023	0.023	0.023	0.000	0.004	0.003	0.034	0.002	0.002	0.000	External
Traffic Services	0.009	0.009	0.009	0.009	0.000	0.002	0.001	0.013	0.001	0.001	0.001	External
Transport Diversity	0.005	0.005	0.005	0.005	0.000	0.000	0.000	0.007	0.000	0.000	0.000	External
Air Pollution	0.035	0.028	0.009	0.063	0.002	0.020	0.007	0.086	0.000	0.000	0.000	External
GHG	0.011	0.009	0.003	0.016	0.000	0.011	0.003	0.009	0.000	0.000	0.000	External
Noise	0.009	0.009	0.003	0.009	0.000	0.008	0.004	0.132	0.000	0.000	0.000	External
Resource Externalities	0.027	0.022	0.011	0.035	0.001	0.025	0.007	0.016	0.000	0.000	0.004	External
Barrier Effect	0.010	0.010	0.010	0.010	0.000	0.003	0.003	0.015	0.001	0.000	0.000	External
Land Use Impacts	0.055	0.055	0.055	0.055	0.000	0.000	0.000	0.083	0.000	0.000	0.083	External
Water Pollution	0.009	0.009	0.005	0.009	0.000	0.002	0.001	0.014	0.000	0.000	0.000	External
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Internal Fixed	*0.235*	*0.207*	*0.281*	*0.289*	*0.000*	*0.000*	*0.000*	*0.397*	*0.071*	*0.000*	*0.264*	
Internal Variable	*0.271*	*0.249*	*0.317*	*0.317*	*0.162*	*0.415*	*0.422*	*0.723*	*0.484*	*1.386*	*0.000*	
External	*0.293*	*0.276*	*0.257*	*0.340*	*0.003*	*0.449*	*0.446*	*0.582*	*0.013*	*0.009*	*0.088*	
Totals	*0.798*	*0.732*	*0.854*	*0.946*	*0.165*	*0.864*	*0.868*	*1.702*	*0.378*	*0.915*	*0.352*	

Table 3, Rural Travel *2007 U.S. Dollars pe*

Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Average Occupancy	1.5	1.5	1.5	1.5	1.0	5.0	10.0	1.0	1.0	1.0	1.0	
Vehicle Ownership	0.181	0.159	0.227	0.236	0.000	0.000	0.000	0.333	0.066	0.000	0.264	Internal-Fixed
Vehicle Operation	0.096	0.069	0.135	0.135	0.003	0.277	0.180	0.066	0.026	0.053	0.000	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	0.330	0.383	0.000	0.000	0.000	0.000	External
Travel Time	0.063	0.063	0.063	0.063	0.063	0.200	0.200	0.063	0.375	1.250	0.000	Internal-Variable
Internal Crash	0.083	0.092	0.083	0.083	0.083	0.004	0.004	0.577	0.083	0.083	0.000	Internal-Variable
External Crash	0.037	0.035	0.037	0.037	0.000	0.053	0.026	0.102	0.003	0.003	0.000	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	External
Internal Parking	0.027	0.025	0.027	0.027	0.000	0.000	0.000	0.032	0.002	0.000	0.000	Internal-Fixed
External Parking	0.017	0.016	0.017	0.017	0.000	0.000	0.000	0.018	0.001	0.000	0.000	External
Congestion	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Road Facilities	0.011	0.011	0.025	0.014	0.000	0.006	0.003	0.008	0.001	0.001	0.000	External
Land Value	0.023	0.023	0.023	0.023	0.000	0.007	0.003	0.034	0.002	0.002	0.000	External
Traffic Services	0.005	0.005	0.005	0.005	0.000	0.001	0.001	0.007	0.000	0.000	0.000	External
Transport Diversity	0.005	0.005	0.005	0.005	0.000	0.000	0.000	0.007	0.000	0.000	0.000	External
Air Pollution	0.003	0.002	0.001	0.005	0.000	0.003	0.001	0.006	0.000	0.000	0.000	External
GHG	0.010	0.008	0.003	0.014	0.000	0.015	0.003	0.008	0.000	0.000	0.000	External
Noise	0.005	0.005	0.003	0.005	0.000	0.007	0.002	0.066	0.000	0.000	0.000	External
Resource Externalities	0.023	0.019	0.009	0.029	0.001	0.034	0.006	0.013	0.000	0.000	0.004	External
Barrier Effect	0.005	0.005	0.005	0.005	0.000	0.003	0.001	0.008	0.000	0.000	0.000	External
Land Use Impacts	0.028	0.028	0.028	0.028	0.000	0.000	0.000	0.042	0.000	0.000	0.042	External
Water Pollution	0.009	0.009	0.005	0.009	0.000	0.003	0.001	0.014	0.000	0.000	0.000	External
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Internal Fixed	*0.208*	*0.184*	*0.254*	*0.263*	*0.000*	*0.000*	*0.000*	*0.365*	*0.068*	*0.000*	*0.264*	
Internal Variable	*0.242*	*0.224*	*0.280*	*0.280*	*0.149*	*0.481*	*0.384*	*0.706*	*0.484*	*1.386*	*0.000*	
External	*0.179*	*0.170*	*0.164*	*0.195*	*0.001*	*0.460*	*0.429*	*0.333*	*0.007*	*0.006*	*0.046*	
Totals	*0.628*	*0.578*	*0.698*	*0.737*	*0.150*	*0.942*	*0.813*	*1.403*	*0.369*	*0.912*	*0.310*	

Distribution of Vehicle Tra

Urban Peak	20%
Urban Off-Peak	40%
Rural	40%
sum	100%

Table 4, Average Travel *2007 U.S. Dollars pe*

Mode	Average Car	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Average Occupancy	1.42	1.42	1.42	1.42	1.00	10.20	14.00	1.00	1.00	1.00	1.00	
Vehicle Ownership	0.195	0.171	0.244	0.253	0.000	0.000	0.000	0.333	0.066	0.000	0.264	Internal-Fixed
Vehicle Operation	0.119	0.086	0.167	0.167	0.004	0.236	0.204	0.071	0.026	0.053	0.000	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	0.330	0.383	0.000	0.000	0.000	0.000	External
Travel Time	0.113	0.113	0.113	0.113	0.100	0.263	0.263	0.113	0.388	1.250	0.000	Internal-Variable
Internal Crash	0.083	0.092	0.083	0.083	0.083	0.004	0.004	0.577	0.083	0.083	0.000	Internal-Variable
External Crash	0.039	0.038	0.039	0.039	0.000	0.036	0.023	0.102	0.003	0.003	0.000	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.095	-0.240	0.000	External
Internal Parking	0.047	0.042	0.047	0.047	0.000	0.000	0.000	0.051	0.004	0.000	0.000	Internal-Fixed
External Parking	0.047	0.045	0.047	0.047	0.000	0.000	0.000	0.045	0.003	0.000	0.000	External
Congestion	0.029	0.029	0.029	0.029	0.000	0.004	0.003	0.034	0.002	0.001	0.000	External
Road Facilities	0.016	0.016	0.039	0.021	0.000	0.005	0.003	0.012	0.002	0.002	0.000	External
Land Value	0.024	0.024	0.024	0.024	0.000	0.005	0.003	0.034	0.002	0.002	0.000	External
Traffic Services	0.009	0.009	0.009	0.009	0.000	0.001	0.001	0.012	0.001	0.001	0.001	External
Transport Diversity	0.005	0.005	0.005	0.005	0.000	0.000	0.000	0.007	0.000	0.000	0.000	External
Air Pollution	0.026	0.021	0.007	0.047	0.001	0.011	0.003	0.058	0.000	0.000	0.000	External
GHG	0.012	0.009	0.003	0.017	0.000	0.011	0.002	0.009	0.000	0.000	0.000	External
Noise	0.008	0.008	0.003	0.008	0.000	0.006	0.003	0.106	0.000	0.000	0.000	External
Resource Externalities	0.028	0.023	0.011	0.037	0.001	0.025	0.005	0.015	0.000	0.000	0.004	External
Barrier Effect	0.010	0.010	0.010	0.010	0.000	0.003	0.002	0.014	0.001	0.000	0.000	External
Land Use Impacts	0.048	0.048	0.048	0.048	0.000	0.000	0.000	0.066	0.000	0.000	0.066	External
Water Pollution	0.010	0.010	0.005	0.010	0.000	0.002	0.001	0.014	0.000	0.000	0.000	External
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Internal Fixed	*0.241*	*0.213*	*0.290*	*0.300*	*0.000*	*0.000*	*0.000*	*0.384*	*0.070*	*0.000*	*0.264*	
Internal Variable	*0.314*	*0.291*	*0.362*	*0.362*	*0.187*	*0.502*	*0.471*	*0.761*	*0.497*	*1.386*	*0.000*	
External	*0.313*	*0.296*	*0.281*	*0.352*	*0.002*	*0.440*	*0.433*	*0.527*	*0.014*	*0.008*	*0.071*	
Totals	*0.868*	*0.800*	*0.933*	*1.014*	*0.189*	*0.942*	*0.903*	*1.672*	*0.390*	*0.914*	*0.335*	

Transportation Cost Analysis Spreadsheets

Victoria Transport Policy Institute (www.vtpi.org)
2-Jan-09

TDM Benefits

These are estimated benefits from travel shifts, calculated based on the difference in costs between "Average Automobile" and other modes.
"Peak Shifting" reflects the difference between peak and off-peak travel.

Units: ***2007 U.S. Dollars per mile***

Table 1, Urban Peak ***2007 U.S. Dollars per m***

Mode	Peak Shifting	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Vehicle Ownership	0.000	0.030	-0.063	-0.075	0.247	0.247	0.247	-0.086	0.181	0.247	-0.017	Internal-Fixed
Vehicle Operation	0.064	0.048	-0.072	-0.072	0.172	-0.101	-0.124	0.094	0.150	0.123	0.176	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	-0.330	-0.383	0.000	0.000	0.000	0.000	External
Travel Time	0.213	0.000	0.000	0.000	0.063	-0.150	-0.150	0.000	-0.150	-0.963	0.288	Internal-Variable
Internal Crash	0.000	-0.009	0.000	0.000	0.000	0.079	0.079	-0.494	0.000	0.000	0.083	Internal-Variable
External Crash	0.013	0.002	0.000	0.000	0.050	0.039	0.041	-0.052	0.047	0.047	0.050	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.240	0.000	External
Internal Parking	0.019	0.007	0.000	0.000	0.073	0.073	0.073	0.009	0.068	0.073	0.073	Internal-Fixed
External Parking	0.103	0.006	0.000	0.000	0.136	0.136	0.136	0.023	0.128	0.136	0.136	External
Congestion	0.105	0.000	0.000	0.000	0.118	0.107	0.109	-0.012	0.108	0.115	0.118	External
Road Facilities	0.006	0.000	-0.035	-0.008	0.024	0.022	0.022	0.010	0.022	0.022	0.024	External
Land Value	0.008	0.000	0.000	0.000	0.031	0.030	0.030	-0.003	0.029	0.029	0.031	External
Traffic Services	0.010	0.000	0.000	0.000	0.018	0.017	0.018	-0.002	0.016	0.016	0.016	External
Transport Diversity	0.002	0.000	0.000	0.000	0.006	0.006	0.006	-0.001	0.006	0.006	0.006	External
Air Pollution	0.022	0.010	0.042	-0.045	0.054	0.049	0.054	-0.050	0.056	0.056	0.056	External
GHG	0.006	0.005	0.013	-0.006	0.017	0.014	0.016	0.008	0.017	0.017	0.017	External
Noise	0.003	0.000	0.008	0.000	0.012	0.009	0.010	-0.120	0.012	0.012	0.012	External
Resource Externalities	0.015	0.007	0.025	-0.013	0.041	0.033	0.039	0.023	0.042	0.042	0.038	External
Barrier Effect	0.011	0.000	0.000	0.000	0.021	0.019	0.020	-0.002	0.020	0.021	0.021	External
Land Use Impacts	0.020	0.000	0.000	0.000	0.075	0.075	0.075	-0.008	0.075	0.075	-0.008	External
Water Pollution	0.003	0.000	0.006	0.000	0.013	0.012	0.012	-0.001	0.013	0.013	0.013	External
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Totals	*0.623*	*0.106*	*-0.075*	*-0.219*	*1.172*	*0.388*	*0.332*	*-0.663*	*1.032*	*0.569*	*1.134*	
External Totals	0.327	0.030	0.059	-0.073	0.617	0.240	0.207	-0.186	0.687	0.848	0.531	

Table 2, Urban Off-Peak *2007 U.S. D*

Mode	Peak Shifting	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Vehicle Ownership	0.000	0.022	-0.046	-0.055	0.181	0.181	0.181	-0.152	0.115	0.181	-0.083	Internal-Fixed
Vehicle Operation	0.000	0.031	-0.046	-0.046	0.109	-0.061	-0.068	0.042	0.087	0.060	0.113	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	-0.330	-0.383	0.000	0.000	0.000	0.000	External
Travel Time	0.000	0.000	0.000	0.000	0.000	-0.163	-0.163	0.000	-0.300	-1.175	0.075	Internal-Variable
Internal Crash	0.000	-0.009	0.000	0.000	0.000	0.079	0.079	-0.494	0.000	0.000	0.083	Internal-Variable
External Crash	0.000	0.001	0.000	0.000	0.037	0.004	0.010	-0.065	0.034	0.034	0.037	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.240	0.000	External
Internal Parking	0.000	0.005	0.000	0.000	0.053	0.053	0.053	-0.011	0.048	0.053	0.053	Internal-Fixed
External Parking	0.000	0.002	0.000	0.000	0.033	0.033	0.033	-0.004	0.030	0.033	0.033	External
Congestion	0.000	0.000	0.000	0.000	0.013	0.008	0.009	-0.007	0.012	0.012	0.013	External
Road Facilities	0.000	0.000	-0.025	-0.006	0.017	0.011	0.013	0.003	0.015	0.015	0.017	External
Land Value	0.000	0.000	0.000	0.000	0.023	0.018	0.019	-0.011	0.021	0.021	0.023	External
Traffic Services	0.000	0.000	0.000	0.000	0.009	0.007	0.007	-0.004	0.008	0.008	0.008	External
Transport Diversity	0.000	0.000	0.000	0.000	0.005	0.005	0.005	-0.002	0.005	0.005	0.005	External
Air Pollution	0.000	0.007	0.026	-0.028	0.033	0.015	0.028	-0.051	0.035	0.035	0.035	External
GHG	0.000	0.003	0.009	-0.005	0.011	0.001	0.009	0.002	0.011	0.011	0.011	External
Noise	0.000	0.000	0.006	0.000	0.009	0.000	0.005	-0.123	0.009	0.009	0.009	External
Resource Externalities	0.000	0.005	0.016	-0.008	0.026	0.002	0.020	0.011	0.027	0.027	0.023	External
Barrier Effect	0.000	0.000	0.000	0.000	0.010	0.007	0.008	-0.005	0.009	0.010	0.010	External
Land Use Impacts	0.000	0.000	0.000	0.000	0.055	0.055	0.055	-0.028	0.055	0.055	-0.028	External
Water Pollution	0.000	0.000	0.005	0.000	0.009	0.008	0.009	-0.005	0.009	0.009	0.009	External
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Totals	*0.000*	*0.066*	*-0.056*	*-0.147*	*0.633*	*-0.065*	*-0.069*	*-0.904*	*0.420*	*-0.117*	*0.446*	
External Totals	0.000	0.017	0.036	-0.047	0.290	-0.156	-0.153	-0.289	0.375	0.524	0.205	

Table 3, Rural Travel *2007 U.S. Dollars per n*

Mode	Peak Shifting	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Vehicle Ownership	0.000	0.022	-0.046	-0.055	0.181	0.181	0.181	-0.152	0.115	0.181	-0.083	Internal-Fixed
Vehicle Operation	0.000	0.027	-0.039	-0.039	0.093	-0.181	-0.084	0.030	0.070	0.043	0.096	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	-0.330	-0.383	0.000	0.000	0.000	0.000	External
Travel Time	0.000	0.000	0.000	0.000	0.000	-0.138	-0.138	0.000	-0.313	-1.188	0.063	Internal-Variable
Internal Crash	0.000	-0.009	0.000	0.000	0.000	0.079	0.079	-0.494	0.000	0.000	0.083	Internal-Variable
External Crash	0.000	0.001	0.000	0.000	0.037	-0.016	0.010	-0.065	0.034	0.034	0.037	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.240	0.000	External
Internal Parking	0.000	0.002	0.000	0.000	0.027	0.027	0.027	-0.005	0.025	0.027	0.027	Internal-Fixed
External Parking	0.000	0.001	0.000	0.000	0.017	0.017	0.017	-0.001	0.016	0.017	0.017	External
Congestion	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Road Facilities	0.000	0.000	-0.015	-0.003	0.011	0.005	0.008	0.003	0.010	0.010	0.011	External
Land Value	0.000	0.000	0.000	0.000	0.023	0.016	0.019	-0.011	0.021	0.021	0.023	External
Traffic Services	0.000	0.000	0.000	0.000	0.005	0.003	0.004	-0.002	0.005	0.005	0.005	External
Transport Diversity	0.000	0.000	0.000	0.000	0.005	0.005	0.005	-0.002	0.005	0.005	0.005	External
Air Pollution	0.000	0.001	0.002	-0.002	0.003	0.000	0.002	-0.003	0.003	0.003	0.003	External
GHG	0.000	0.002	0.007	-0.004	0.010	-0.005	0.007	0.002	0.010	0.010	0.010	External
Noise	0.000	0.000	0.002	0.000	0.005	-0.002	0.003	-0.061	0.005	0.005	0.005	External
Resource Externalities	0.000	0.004	0.013	-0.007	0.022	-0.011	0.017	0.010	0.023	0.023	0.019	External
Barrier Effect	0.000	0.000	0.000	0.000	0.005	0.003	0.004	-0.003	0.005	0.005	0.005	External
Land Use Impacts	0.000	0.000	0.000	0.000	0.028	0.028	0.028	-0.014	0.028	0.028	-0.014	External
Water Pollution	0.000	0.000	0.005	0.000	0.009	0.007	0.009	-0.005	0.009	0.009	0.009	External
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Totals	*0.000*	*0.050*	*-0.070*	*-0.109*	*0.479*	*-0.314*	*-0.185*	*-0.775*	*0.259*	*-0.284*	*0.319*	
External Totals	0.000	0.009	0.015	-0.016	0.178	-0.282	-0.250	-0.154	0.267	0.413	0.133	

Distribution of Vehicle Tra

Urban Peak	20%
Urban Off-Peak	40%
Rural	40%
sum	100%

Table 4, Average Travel *2007 U.S. Dollars per n*

Mode	Peak Shifting	Compact Car	Electric Car	Van or Pickup	Rideshare Passenger	Diesel Bus	Electric Trolley	Motor-cycle	Bicycle	Walk	Telework	Distribution
Vehicle Ownership	0.000	0.024	-0.049	-0.059	0.195	0.195	0.195	-0.138	0.129	0.195	-0.069	Internal-Fixed
Vehicle Operation	0.013	0.033	-0.048	-0.048	0.115	-0.117	-0.085	0.048	0.093	0.066	0.119	Internal-Variable
Operating Subsidy	0.000	0.000	0.000	0.000	0.000	-0.330	-0.383	0.000	0.000	0.000	0.000	External
Travel Time	0.043	0.000	0.000	0.000	0.013	-0.150	-0.150	0.000	-0.275	-1.138	0.113	Internal-Variable
Internal Crash	0.000	-0.009	0.000	0.000	0.000	0.079	0.079	-0.494	0.000	0.000	0.083	Internal-Variable
External Crash	0.003	0.001	0.000	0.000	0.039	0.003	0.016	-0.063	0.036	0.036	0.039	External
Internal Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.240	0.000	Internal-Variable
External Health Ben.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.240	0.000	External
Internal Parking	0.004	0.004	0.000	0.000	0.047	0.047	0.047	-0.005	0.043	0.047	0.047	Internal-Fixed
External Parking	0.021	0.002	0.000	0.000	0.047	0.047	0.047	0.003	0.044	0.047	0.047	External
Congestion	0.021	0.000	0.000	0.000	0.029	0.025	0.026	-0.005	0.027	0.028	0.029	External
Road Facilities	0.001	0.000	-0.023	-0.005	0.016	0.011	0.013	0.004	0.014	0.014	0.016	External
Land Value	0.002	0.000	0.000	0.000	0.024	0.020	0.021	-0.010	0.022	0.022	0.024	External
Traffic Services	0.002	0.000	0.000	0.000	0.009	0.008	0.008	-0.003	0.008	0.008	0.008	External
Transport Diversity	0.000	0.000	0.000	0.000	0.005	0.005	0.005	-0.002	0.005	0.005	0.005	External
Air Pollution	0.004	0.005	0.020	-0.021	0.025	0.016	0.023	-0.032	0.026	0.026	0.026	External
GHG	0.001	0.003	0.009	-0.005	0.012	0.001	0.010	0.003	0.012	0.012	0.012	External
Noise	0.001	0.000	0.005	0.000	0.008	0.001	0.005	-0.098	0.008	0.008	0.008	External
Resource Externalities	0.003	0.005	0.017	-0.008	0.027	0.003	0.023	0.013	0.028	0.028	0.024	External
Barrier Effect	0.002	0.000	0.000	0.000	0.010	0.008	0.009	-0.003	0.010	0.010	0.010	External
Land Use Impacts	0.004	0.000	0.000	0.000	0.048	0.048	0.048	-0.018	0.048	0.048	-0.018	External
Water Pollution	0.001	0.000	0.005	0.000	0.010	0.008	0.009	-0.004	0.010	0.010	0.010	External
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	External
Totals	*0.125*	*0.068*	*-0.065*	*-0.146*	*0.679*	*-0.074*	*-0.035*	*-0.804*	*0.478*	*-0.046*	*0.533*	
External Totals	0.065	0.016	0.032	-0.040	0.310	-0.127	-0.120	-0.215	0.394	0.544	0.241	
External Totals	0.000											

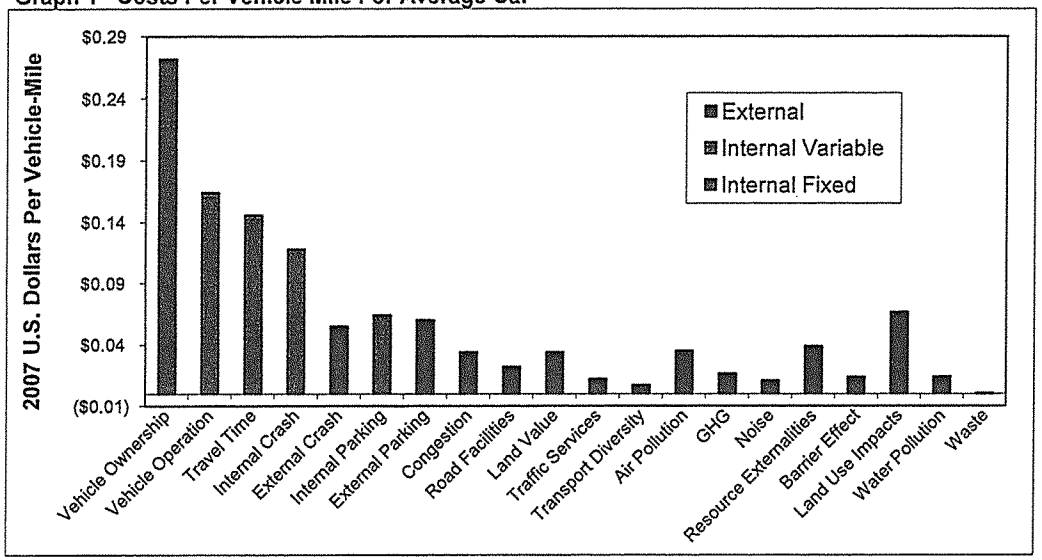
Transportation Cost Analysis Spreadsheets

Victoria Transport Policy Institute (www.vtpi.org)
2-Jan-09

Graphs

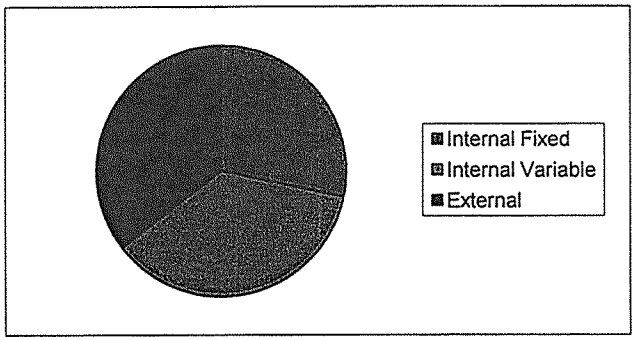
This spreadsheet contains various graphs that compare transportation costs. They are updated whenever input values are adjusted. By changing the linked cells below each graph it is possible to change which costs and modes are shown in a graph.

Graph 1 Costs Per Vehicle Mile For Average Car



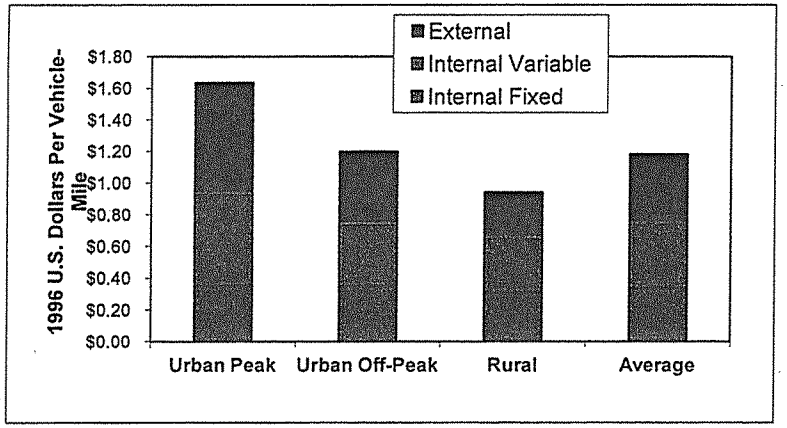
	Internal Fixed	Internal Variable	External
Vehicle Ownership	0.272		
Vehicle Operation		0.164	
Travel Time		0.146	
Internal Crash		0.118	
External Crash			0.055
Internal Parking	0.064		
External Parking			0.060
Congestion			0.034
Road Facilities			0.022
Land Value			0.034
Traffic Services			0.012
Transport Diversity			0.007
Air Pollution			0.035
GHG			0.017
Noise			0.011
Resource Externalities			0.039
Barrier Effect			0.014
Land Use Impacts			0.066
Water Pollution			0.014
Waste			0.000

Graph 2 Distribution of Average Car Costs



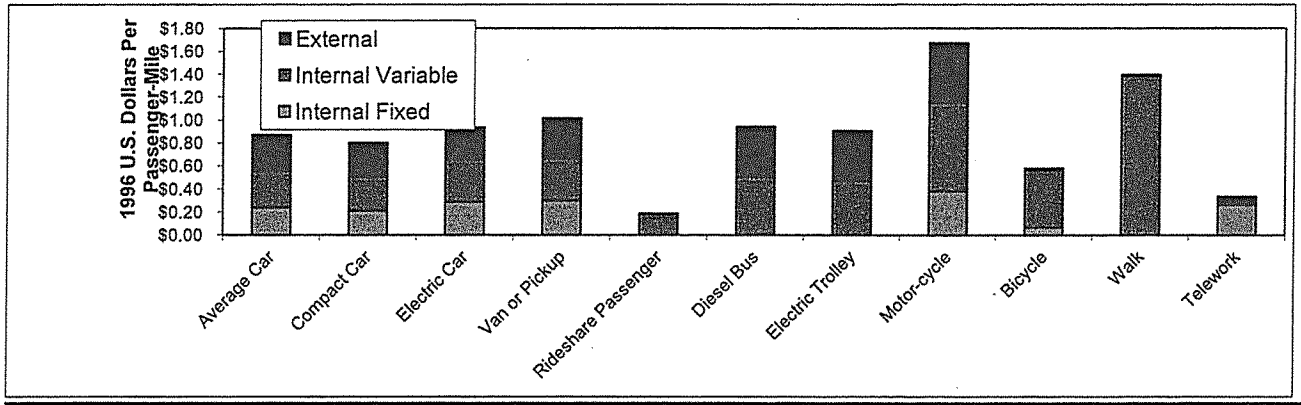
Internal Fixed	0.336
Internal Variable	0.428
External	0.419

Graph 3 Average Car Cost Distribution By Driving Conditions



	Urban Peak	Urban Off-Peak	Rural	Average
Internal Fixed	0.352	0.352	0.312	0.336
Internal Variable	0.602	0.406	0.362	0.428
External	0.682	0.439	0.268	0.419

Graph 4 Cost Distribution By Mode



	Average Car	Compact Car	Electric Car	Van or Pick	Rideshare F	Diesel Bus	Electric Trol	Motor-cycle	Bicycle	Walk	Telework
Internal Fixed	0.241	0.213	0.290	0.300	0.000	0.000	0.000	0.384	0.070	0.000	0.264
Internal Variable	0.314	0.291	0.362	0.362	0.187	0.502	0.471	0.761	0.497	1.386	0.000
External	0.313	0.296	0.281	0.352	0.002	0.440	0.433	0.527	0.014	0.008	0.071