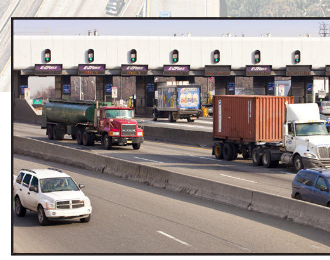
Potential Changes in Emissions Due to Improvements in Travel Efficiency –

Supplemental Report: Analysis of Potential Co-Benefits



United States Environmental Protection Agency

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Potential Changes in Emissions Due to Improvements in Travel Efficiency –

Supplemental Report: Analysis of Potential Co-Benefits

Transportation and Climate Division
Office of Transportation and Air Quality
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1. Introduction

The EPA report, *Potential Changes in Emissions Due to Improvements in Travel Efficiency – Final Report*, analyzed the impacts of combinations of travel demand management, land use, transit, and road pricing strategies on trip making, vehicle miles traveled (VMT), and vehicle emissions using the Travel Efficiency Assessment Method (TEAM).[1] The analysis demonstrated potential reductions in vehicle trips and trip lengths, shifting of trips from peak to off-peak periods, and travelers' shift from single occupancy vehicles to transit, ridesharing, and non-motorized modes. The analysis was done for urban areas; hence, the reductions in VMT and emissions represent those occurring from changes in urban travel activity. Data collected for the previous study was obtained from urban areas and the strategies analyzed are also most applicable in urban areas facing issues such as peak period congestion and associated air pollution and greenhouse gas emissions. Rural areas are not expected to be affected by these strategies.

A primary benefit of the changes in travel activity occurring from the analyzed strategies is a reduction in emissions due to reduced travel and reduced congestion, but there are several other ancillary benefits. In this supplemental report, these ancillary benefits are referred to as co-benefits because they are additional to the emissions benefits resulting from the implementation of the travel efficiency strategies or combinations of strategies (referred to as scenarios) described in the EPA report.

The co-benefits from implementation of these scenarios include a reduction in health impacts associated with air pollution, reduced traffic congestion, reduced user costs for operating vehicles, improved energy security through reduced energy costs and dependency on oil imports, and reduction in vehicle crashes and accidents. When co-benefits are accounted for, transportation strategies aimed at reducing emissions show additional positive impacts. Therefore, it is important to carefully consider co-benefits in terms of their present value when evaluating strategies or scenarios for implementation.

This supplemental report focuses on the potential co-benefits resulting from the seven scenarios analyzed in the EPA report. Although there are several potential co-benefits, the national level results for potential reductions in VMT and emissions from the previous analysis were used to quantify two key co-benefits that are straightforward to quantify. As with the VMT and emissions reduction, the co-benefits were quantified on a daily basis for each decade from 2010 out to 2050 for each scenario and discounted to their value in 2010 dollars. The White House Office of Management and Budget (OMB) provides guidance on discount rates to assume, recommending the use of 3% and 7%. The guidance states that when regulation primarily and directly affects private consumption (e.g., through higher consumer prices for goods and services) rather than the allocation of capital, the lower discount rate of 3 percent is appropriate. The calculations are therefore, shown using a 3 percent discount rate. Nevertheless, following OMB's overall guidance, the Appendix of this report (Table A-2) also includes co-benefits calculated at the higher discount rate of 7%. The co-benefits estimated in this report are:

1) **Vehicle operating cost savings –** If vehicle owners make fewer trips and drive shorter distances, their vehicle maintenance and operation costs can be reduced. In total, the seven scenarios analyzed in the EPA report are expected to result in light duty vehicle

[1] U.S. Environmental Protection Agency (EPA). (2011). *Potential Changes in Emissions Due to Improvements in Travel Efficiency – Final Report*. EPA-420-R-11-003. March. Available at: http://www.epa.gov/oms/stateresources/policy/420r11003.pdf

operating cost savings ranging from about $8.5 million to over $282 million in 2050 in 2010 dollars, using a 3% discount rate.[2]

Savings in fuel costs **–** Less fuel consumed means travelers pay less at the pump. This is a component of vehicle operating cost savings but is calculated separately because it is of particular interest. Not only is it the component of operating costs that is typically most directly observed by travelers, but there is often a lot of uncertainty surrounding fuel costs in future years. This depends on a multitude of economic and political factors out of the scope of this discussion. The seven scenarios are expected to result in fuel cost savings for light duty vehicles ranging from $1.4 to $48 million in 2050 (2010 dollars, using 3% discount rate).

2) **Gallons of fuel saved –** Strategies aimed at reducing transportation emissions are also likely to reduce fuel consumption, both from reduced VMT and from vehicles spending less time in congested conditions (which leads to excess fuel consumption due to idling). The seven scenarios are expected to result in fuel savings ranging from about 0.85 to 28 million gallons in 2050.

The summary results from the analysis of co-benefits for each scenario in 2030 and 2050 are shown in Table 1. The baseline year for the previous analysis is 2010 and therefore, all co-benefit values in this report are presented in 2010 dollars. The co-benefits of vehicle fuel and operating cost savings were estimated for each future year on a daily basis and then discounted at the rate of three percent to derive the net present value. Figure 1 shows the daily vehicle operating cost savings resulting in each mentioned year from implementation of each of the seven scenarios, as compared to a business-as-usual baseline.

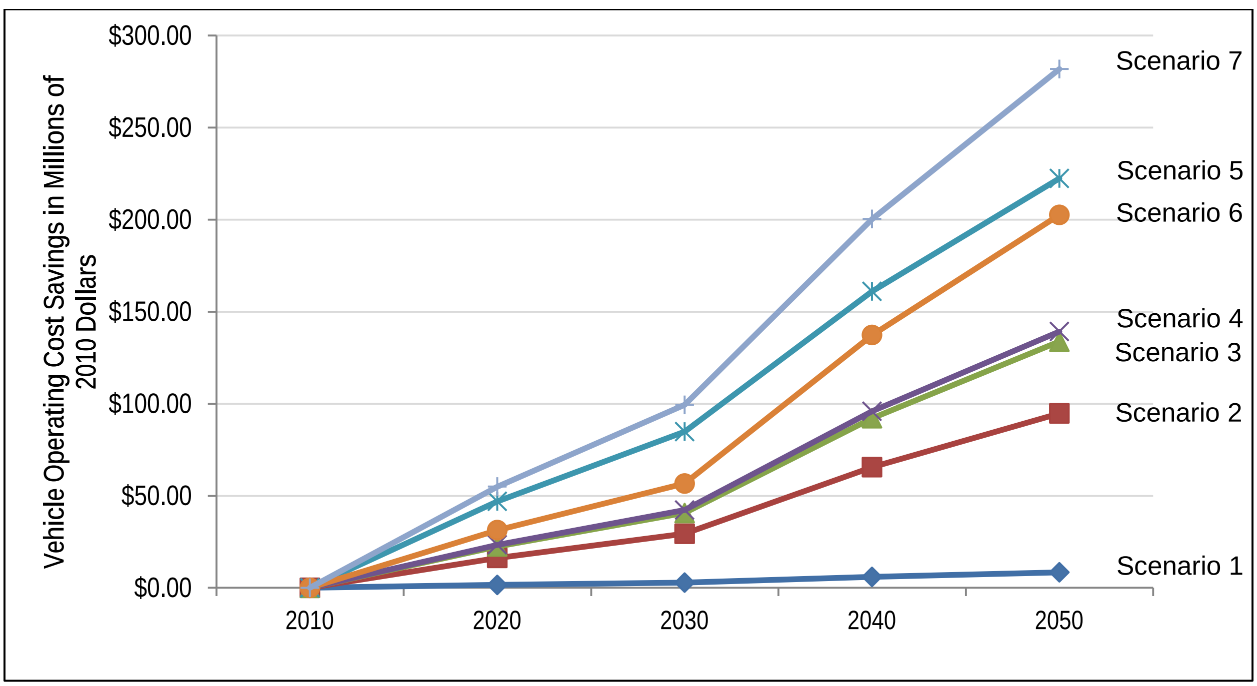
The analysis uses data widely available from public databases and literature and is based on standard assumptions followed in cost-benefit analysis studies and existing research on the analysis of co-benefits. The following sections of the report describe the data, assumptions, methodologies, and results for the analysis of co-benefits based on the outputs of the TEAM approach used to estimate travel activity and emission reductions in the previous EPA report, *Potential Changes in Emissions Due to Improvements in Travel Efficiency – Final Report*.

[2] White House Office of Management and Budget's Circular A-4 provides guidance on discount rates (pp 31-35), recommending the use of 3% and 7%; available at: http://www.whitehouse.gov/sites/default/files/omb/assets/regulatory_matters_pdf/a-4.pdf

Table 1. Summary of Daily Co-Benefits from Implementing Scenarios				
	Co-Benefits			
	2030		2050	
Scenario	Vehicle operating cost savings ($ millions)*	Fuel savings (million gallons)	Vehicle operating cost savings ($ millions)*	Fuel savings (million gallons)
1- Region-wide TDM	$2.84	0.27	$8.43	0.85
2 - TDM + land use changes	$29.38	2.79	$94.75	9.51
3 - TDM + land use changes + transit fare reduction	$40.63	3.86	$133.72	13.42
4 - TDM + land use changes + transit fare reduction + transit service improvements	$42.25	4.02	$139.23	13.97
5 - TDM + land use changes + transit fare reduction + transit service improvements + parking fees	$84.86	8.06	$222.37	22.31
6 - TDM + land use changes + transit fare reduction + transit service improvements + mileage fees	$56.65	5.38	$202.57	20.32
7 - TDM + land use changes + transit fare reduction + transit service improvements + parking fees + mileage fees	$99.36	9.44	$281.80	28.28

* All values in 2010 dollars

Figure 1. Daily Vehicle Operating Cost Savings Resulting from Implementing Scenarios, 2010-2050, compared to Business-as-Usual scenario



2. Background/Consideration of Existing Research

The study began with a review of current national research on the co-benefits resulting from a wide range of strategies aimed at reducing transportation emissions. The literature review considered several major reports: *Multi-pollutant Emissions Benefits of Transportation Strategies* (FHWA 2006), *Growing Cooler* (Ewing et al. 2008), *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions* (Cambridge Systematics 2009), and NCHRP Report 462 *Quantifying Air Quality and Other Benefits and Costs of Transportation Control Measures* (2001).

The literature review identified a range of benefits[3] or cost savings estimated as part of studies focusing on measures to reduce vehicle miles traveled (VMT) and/or emissions. Costs and benefits can be experienced either by travelers themselves or can be imposed by travelers on the rest of society. The latter are considered social costs/benefits, or externalities, because they are external to the traveler's experience and are typically ignored by travelers when making travel decisions. The benefits or cost savings most commonly estimated are listed below as well as whether they perceived by the individual traveler or by society:

- Change in travel costs (time and out-of-pocket costs): traveler cost/benefit
- Change in fuel consumption costs: traveler cost/benefit
- Change in accident and crash costs: traveler and social cost/benefit
- Change in costs of congestion delays caused to others: social cost/benefit
- Change in health costs related to air pollution: social cost/benefit
- Change in costs of damages related to global climate change: social cost/benefit
- Change in noise costs: social cost/benefit

Other benefits that are not typically considered because they are either not applicable in all cases or are difficult to quantify are the costs of land (e.g., for parking), economic costs/benefits associated with changes in travel demand (e.g., change in property values, which results in higher property tax revenue for jurisdictions), and the economic costs of fuel consumption and imports (e.g., fuel cost subsidies to keep prices low and costs of maintaining the Strategic Petroleum Reserve to cushion the economy in case of interruptions in fuel supply). A qualitative discussion of some of these measures is included later in this report. EPA's final rule on Light Duty Vehicle GHG Emissions Standards includes quantitative estimates of energy security benefits from fuel savings that the reader can refer to for further analysis.[4] Lifecycle costs and benefits associated with the production and distribution of vehicles and fuels are typically not considered in transportation demand analyses.

[3] Savings in cost measures such as health costs or congestion costs are the same as benefits, i.e. negative values for costs imply positive benefits of the same magnitude.

[4] U.S. Environmental Protection Agency, 40 CFR Parts 85, 86, and 600; U.S. Department of Transportation, National Highway Traffic Safety Administration, 49 CFR Parts 531, 533, 536, 537 and 538 [EPA–HQ–OAR–2009–0472; FRL–9134–6; NHTSA–2009–0059], "Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule," published on May 7, 2010, available at: http://edocket.access.gpo.gov/2010/pdf/2010-8159.pdf

3. Analysis Methodology

This section describes the benefits identified for the analysis that could be quantified based on the values of VMT and emissions reduction from each scenario estimated in the previous analysis.[5] The benefits for each decade from 2010 to 2050 are calculated on a daily basis and presented in current (2010) dollars.

3.1. Benefit/Social Cost Measures Identified for Quantification

In the EPA report, the reductions in VMT were estimated using the TRIMMS (Trip Reduction Impacts for Mobility Management Strategies) model. The analysis associated with the EPA report used regional data as inputs to the TRIMMS model in order to test scenarios and determine potential VMT reductions from each. In order to apply the results to a national-level view, regional outcomes were applied to similar regions across the country and then aggregated to illustrate national results.

Although TRIMMS can analyze co-benefits associated with calculated VMT and emissions reductions in each region, these regional results from TRIMMS were not directly used for the present national scale analysis. The TRIMMS model is designed for analysis at a project or regional scale at the start of the analysis and the user must select a region from 85 regions represented in TRIMMS. In calculating benefits and costs, the model uses region-specific data on wage rates to determine values of time, data on average speeds to determine congestion costs, and state-level data on fatality rates to calculate vehicle crash costs for each region. TRIMMS also scales the costs to account for cost of living differentials between regions. Although these underlying assumptions within TRIMMS make it inappropriate for the present analysis, the methodology and data sources referenced provide some guidance for the calculation of costs and benefits. This analysis relied on assumptions suited to a national analysis, but users may follow the methodology described here with regional values for assumptions such as fuel prices and auto operating costs.

Table 2 shows the full list of benefit/cost measures that can be estimated by the TRIMMS model along with a brief description of each measure and the proposed methodology to support the TEAM analysis. The methodology describes the calculations and data sources that may be used to quantify each of the avoided costs, based on the VMT and emissions reductions already calculated. While being guided by the methodology used in TRIMMS, this analysis used updated cost values available from literature and various national databases to apply to the national reductions in VMT and emissions previously calculated.[6] The methodology used for each measure in the TRIMMS model is shown in the Appendix.

Change in vehicle operating costs is the only direct user benefit in the list that accrues to travelers themselves; all others are social benefits.

[5] See EPA report, *Potential Changes in Emissions Due to Improvements in Travel Efficiency – Final Report*, available at: http://www.epa.gov/oms/stateresources/policy/420r11003.pdf

[6] Note that while regional analyses using the TEAM approach could rely on TRIMMS, the TEAM approach and the methodologies described here allow regions to use more up-to-date emissions, travel, and cost data than is available in TRIMMS.

Table 2. Proposed TEAM Methodology for Measures Quantifiable in TRIMMS		
Measure	Description	Proposed TEAM Methodology
Savings in Vehicle Operating Costs	Costs of vehicle ownership, operations, and maintenance	Auto operating cost savings from reduced VMT can be calculated based on available values in $/mile for the current year (2010 in this analysis).
Savings in Health Damage Costs Due to Air Pollution	Costs of damage to human health, visibility, materials, agriculture, and forests from vehicle exhaust emissions, including CO, VOCs, and NOx	Emission factors from EPA's MOVES model can be applied to the change in national VMT to calculate total reduction in emissions for a range of pollutants. Emissions damage costs in $/kg obtained from EPA (2010) can be used to quantify benefits.[7]
Reduction in Congestion Delays	Costs associated with congestion delay produced by motor vehicle use, i.e., the added delay imposed on all users when an additional vehicle is introduced into the traffic stream. These costs only pertain to the costs of added delay to others.	Marginal added hours of delay per thousands of passenger-car equivalent (pce) VMT (assumed to be 61.26 hours of delay per 1,000 pce VMT in TRIMMS) x change in VMT estimated x value of time ($/hour = 40% of national average wage rate Note: Can also be calculated using EPA's estimates of external costs of congestion from EPA (2010).
Reduction in Excess Fuel Consumption	Costs of excess fuel consumed as a result of added congestion	National average fuel economy data from EPA and average fuel price available from the EIA can be used to estimate the benefits from savings in fuel consumed based on the calculated VMT reduction.
Reduction in Impacts from Global Climate Change	Costs related to damages associated with global climate change	Emissions factors for CO_2, N_2O and CH_4 from MOVES can be applied to the change in national VMT. Comprehensive GHG cost values in $/ton available from EPA (2010) can be used to quantify benefits.
Reduction in Costs Related to Accident s and Crashes	Costs associated with crashes, such as property and personal injury damages caused by accidents	The change in comprehensive health and safety costs is based on the change in the number of vehicle crashes resulting from each scenario. This can be calculated using NHTSA data on average national crash rates by severity class per million VMT. NHTSA guidance on cost factors for crashes in different severity classes can be used to quantify benefits. Estimates for external costs of accidents are also available from EPA (2010).
Reduction in Noise Pollution	Costs of damage imposed on others through noise from engine acceleration and vibration, from tire contact on road surfaces, and from brake and horn usage	Average noise costs for urban areas in $/VMT available from EPA (2010) can be multiplied by total national reduction in VMT to quantify benefits.

[7] See EPA Rule "Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule," published on May 7, 2010 (values available in Table II.F-2), available at: http://edocket.access.gpo.gov/2010/pdf/2010-8159.pdf

In this analysis, the following key co-benefits were estimated for each scenario:

1) **Vehicle operating cost savings:** A reduction in trip-making and VMT is likely to reduce vehicle operating costs for ownership, operations, and maintenance, resulting in savings for travelers. These costs encompass fuel costs, which were also separately calculated.

   Savings in fuel costs: On average, about twenty percent of total auto operating costs are attributable to fuel costs,[8] therefore, a reduction in vehicle travel and VMT is likely to result in fuel cost savings that are measured as a co-benefit. In projecting fuel costs in future years, a greater or lower proportion of total costs may represent fuel. These cost savings may be considered a component of the total savings in vehicle operating costs.

2) **Gallons of fuel saved:** Strategies aimed at reducing transportation emissions are also likely to reduce fuel consumption resulting from vehicle operations overall and particularly when vehicles are operated in congested conditions. These fuel savings are measured as a co-benefit to society. The full range of benefits associated with reduced fuel consumption is not quantified here, but some of the related indirect benefits are discussed qualitatively in the results section. To quantify the energy security benefits related to fuel savings, the reader may refer to EPA (2010) for estimates of the economic benefits from reducing oil imports.

The above two co-benefits were selected for analysis because they are straightforward to calculate and because there is generally less uncertainty in estimating these co-benefits than the others listed.

3.2. Resources for Data and Assumptions

This section describes the resources that were used to analyze the above illustrative co-benefits.

Vehicle operating and fuel costs. Three primary resources support the determination of vehicle operating cost savings: (i) Standard Mileage Rate from the Internal Revenue Service (IRS) set every year by the federal government and reflecting actual operating costs,[9] (ii) estimates of operating costs broken down by cost category from annual publication "Your Driving Costs" published by the American Automobile Association (AAA) since 1950,[10] and (iii) growth rates in fuel prices based on projections in the U.S. Energy Information Administration (EIA)'s Annual Energy Outlook (AEO) published annually.[11]

Either the IRS or AAA values may be used as the assumption for actual vehicle operating costs. The advantage of the AAA resource is that the operating costs are broken down in detail by cost category and ranges are provided for different types of vehicles (small, medium, and large sedans, minivans and sport utility vehicles) along with average values. In addition, ranges of costs are provided for different levels of mileage driven in a year (10,000 miles, 15,000 miles, and 20,000 miles). This allows the user to identify particular cost categories they are interested in for a detailed analysis. Similarly, for a regional analysis, the user may refer to the AAA

[8] AAA (2010), "Your Driving Costs"; available at: http://www.aaaexchange.com/Assets/Files/201048935480.Driving%20Costs%202010.pdf
[9] IRS Standard Mileage Rate, 2010; http://www.irs.gov/newsroom/article/0,,id=216048,00.html
[10] AAA (2010), "Your Driving Costs"; available at: http://www.aaaexchange.com/Assets/Files/201048935480.Driving%20Costs%202010.pdf
[11] AEO (2011) projections for motor fuel and diesel prices are available at: http://www.eia.gov/forecasts/aeo/topic_prices.cfm

resource for national average values of ownership and maintenance costs, while substituting actual fuel costs for their region.

The IRS mileage rate simply provides an average composite value that reflects the combined fixed and variable costs of vehicle ownership, operation, maintenance, repair, depreciation, and insurance. The most common use of this mileage rate is to reimburse employees for expenses involving use of their own cars for business purposes. The reimbursement rate applies to the broadly defined term "cars," which includes passenger vehicles, sports utility vehicles or SUVs, vans, and pickup trucks. The rate is also provided separately for three categories: business miles, medical/moving, and miles driven in the service of charitable organizations. The business miles category is applicable in this analysis. The IRS revises the rate annually and sometimes more than once per year if a particular component of the operating costs changes significantly. In the year 2010, the IRS mileage rate was 50 cents per mile.

In this analysis, the IRS rate of 50 cents per mile in 2010 was selected since it is a widely used value for vehicle operating costs. Prior to conducting this analysis, the AAA values were compared with the IRS value. The costs reported by AAA in its 2010 publication range from 47.6 to 73.9 cents per mile depending on the vehicle type and annual mileage driven. The total costs per mile for an average-sized sedan driven about 15,000 miles per year are estimated by AAA to be 56.6 cents. Because the AAA rate is close to the IRS rate of 50 cents per mile, it supports this reasonableness of the selected rate.

The AEO is primarily useful in projecting operating costs in future years as it provides fuel price projections out to 2035. In this analysis, the 2009-2035 growth rate in fuel prices was used to project fuel costs in 2040 and 2050.[12] The non-fuel components of auto operating costs were assumed to grow with inflation. The inflation rate for the period 2009-2035 was assumed to be 2.2. percent per year, based on the assumptions used in the AEO.

Fuel consumption. The analysis of fuel savings is based on data from the U.S. EPA on average light duty vehicle fuel economy. Future year fuel savings are based on projections from the AEO on how average light duty vehicle fuel economy is expected to grow. The annual growth rate for vehicle fuel economy from the AEO projects improvements in fuel economy out to 2035. Again, the growth rate from 2009 to 2035 was assumed to determine average fuel economy in 2040 and 2050.

Table 3 shows the assumptions used in the analysis and Table 4 shows the estimated values for fuel prices and fuel economy used for the analysis of co-benefits in future years.

[12] AEO (2011) projections for motor fuel and diesel prices are available at: http://www.eia.gov/forecasts/aeo/topic_prices.cfm

Table 3. Assumptions Used in the Analysis of Co-Benefits			
Assumptions	**Value**	**Unit**	**Source**
Calculating change in vehicle operating and fuel costs			
Auto operating costs including ownership costs, 2011	50.0	cents/mile	IRS Standard Mileage Rate, 2010
Average annual inflation rate for 2001-2011	2.20%	per year	EIA, AEO 2011 Assumption
Calculating change in fuel consumption separately			
Average light duty vehicle (LDV) fuel economy in 2010	22.4	miles/gallon	EPA, Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2010
Average LDV fuel price in 2010	$2.70	per gallon	EIA, Average US gas price in 2010
Growth rate in fuel economy	0.72%	per year	EIA, AEO 2011 average fuel economy growth rate for diesel and gasoline light duty vehicles
Growth rate in fuel price	1.80%	per year	EIA, AEO 2011 for motor fuel

Table 4. Estimated Values for Fuel Prices and Fuel Economy Used in the Analysis, 2010-2050 (in 2010 dollars)					
Measure	**2010**	**2020**	**2030**	**2040**	**2050**
Average fuel economy in miles per gallon	22.40	24.07	25.86	27.78	29.85
Average fuel price per gallon	$2.70	$3.23	$3.86	$4.61	$5.51
Average fuel cost per mile	$0.12	$0.13	$0.15	$0.17	$0.18
Average non-fuel costs (ownership, etc.) per mile	$0.38	$0.47	$0.59	$0.73	$0.91
Total operating costs per mile	$0.50	$0.61	$0.74	$0.89	$1.09

3.3. Methodology for Calculating Co-Benefits

Based on the resources and assumptions described in the previous section, the illustrative co-benefits were calculated using the following methodologies.

1) Vehicle operating cost savings:

In the analysis, light duty vehicle operating costs in 2010 were assumed to be 50 cents per mile, based on the IRS rate.[13] The VMT reduction for each scenario obtained from the earlier TRIMMS analysis was multiplied by the total per-mile operating costs to estimate the savings in vehicle operating costs resulting from each scenario. Vehicle operating costs were assumed to grow in each year based on the expected growth in fuel prices in future years and assuming that other costs (such as costs of ownership including licensing and registration costs, depreciation, taxes, and insurance, as well as costs of tires and maintenance) will increase with inflation. Using the cost components from AAA, fuel costs represent roughly 20-25 percent of total auto operating costs, while insurance coverage,

[13] IRS Standard Mileage Rate for 2010; http://www.irs.gov/newsroom/article/0,,id=216048,00.html

licensing and registration taxes, depreciation, and finance charges cover the remaining 75-80 percent. This analysis used the growth rate in fuel economy and expected growth rate in fuel prices available from the U.S. Energy Information Administration (EIA)'s Annual Energy Outlook (AEO) 2011.[14] Total auto operating costs in future years were estimated using these data and an average annual inflation rate of 2.2 percent for the non-fuel costs, based on assumptions in the AEO.

Savings in fuel costs:
The baseline average gasoline price in the U.S. is assumed to be $2.70 in 2010 based on data available from the Energy Information Administration (EIA).[15] Prices for gasoline and diesel are assumed to be the same to simplify the analysis.[16] The AEO projects an average annual growth rate of 1.8% in prices of both fuels for the period 2009-2035.[17] This analysis assumes the same growth rate out to 2050 to estimate fuel prices in miles per gallon for each future decade. Savings in fuel cost were obtained by multiplying the fuel price by the gallons of fuel saved calculated in the second co-benefit. These costs may be considered a component of the total savings in vehicle operating costs calculated above.

2) Gallons of fuel saved

Data from the U.S. Environmental Protection Agency (EPA) show that the average light duty vehicle fuel economy in the year 2010 was 22.4 miles per gallon.[18] For the baseline year (2010), the reduction in fuel consumption was calculated by dividing the reduction in VMT by the fuel economy in that year. The 2011 AEO assumes that the fuel economy of light duty vehicles will grow annually by 0.72% on average for diesel and gasoline-fueled vehicles.[19] This growth rate was applied to estimate light duty vehicle fuel economy for all decades out to 2050. As for the baseline year, gallons of fuel saved in all decades were calculated using the reduction in VMT and fuel economy estimates.

[14] U.S. EIA, Annual Energy Outlook (AEO) 2011, table titled "New Light-Duty Vehicle Fuel Economy, Reference Case (miles per gallon)"

[15] U.S. Energy Information Administration (EIA), Gasoline and Diesel Fuel update, 07/25/11; available at: http://www.eia.gov/oog/info/gdu/gasdiesel.asp

[16] The price of diesel is about 0.25 cents per gallon higher than gasoline; however, accounting for the different prices of both fuels would require data on vehicle population fueled by each. This difference between diesel and gasoline prices was ignored to simplify the analysis.

[17] U.S. EIA, Annual Energy Outlook (AEO) 2011, table titled "Petroleum Product Prices in 2009 dollars per gallon".

[18] U.S. EPA (2010). Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2010; available at: http://www.epa.gov/oms/fetrends.htm#archive

[19] Average fuel economy growth rate for diesel and gasoline light duty vehicles is available from AEO, 2011.

4. Results and Conclusion

4.1. Results from Analysis of Co-benefits

The intent of this supplemental report was to analyze and illustrate key co-benefits of improvements in travel efficiency after the potential reductions in VMT and emissions have been estimated using the TEAM approach. The analysis focused on estimating savings in vehicle operating costs for travelers including savings in fuel costs, as well as savings in fuel consumption resulting from the seven scenarios defined in the EPA report. These co-benefits were analyzed for all decades from 2010 to 2050 on a daily basis.

The key results are:

- In total, the seven scenarios are expected to result in daily light duty vehicle operating cost savings ranging from about $8.4 million for the least aggressive scenario to $282 million for the most aggressive scenario in 2050 (in 2010 dollars), compared to the business-as-usual scenario.
- In total, the seven scenarios are expected to result in daily fuel cost savings for light duty vehicles ranging from $1.45 to $48.5 million in 2050 (in 2010 dollars), compared to the business-as-usual scenario.
- Expected daily fuel savings for the seven scenarios range from 0.85 to 28 million gallons in 2050, compared to the business-as-usual scenario.

Table 5 shows the results of this analysis in detail.

	Table 5. Co-Benefits Resulting from Daily Reduction in Vehicle Miles Traveled (discounted @ 3%) (in 2010 dollars)					
	Scenario	**2010**	**2020**	**2030**	**2040**	**2050**
	Baseline national urban VMT (business-as-usual), in millions	5,118	5,889	7,130	8,254	9,555
1	**Regionwide TDM**					
	VMT Reduction from BAU baseline, in millions	0.00	3.49	6.98	16.12	25.26
	Auto operating cost savings, in $millions	$0.00	$1.57	$2.84	$5.94	$8.43
	Savings in fuel costs only, in $millions	$0.00	$0.35	$0.59	$1.12	$1.45
	Gallons of fuel saved, in millions	0.00	0.14	0.27	0.58	0.85
2	**Land use changes + TDM**					
	VMT Reduction from BAU baseline, in millions	0.00	36.10	72.20	177.97	283.75
	Auto operating cost savings, in $millions	$0.00	$16.27	$29.38	$65.55	$94.75
	Savings in fuel costs only, in $millions	$0.00	$3.66	$6.05	$12.35	$16.30
	Gallons of fuel saved, in millions	0.00	1.50	2.79	6.41	9.51
3	**Land use changes + Transit fare change + TDM**					
	VMT Reduction from BAU baseline, in millions	0.00	49.92	99.84	250.14	400.45
	Auto operating cost savings, in $millions	$0.00	$22.49	$40.63	$92.13	$133.72
	Savings in fuel costs only, in $millions	$0.00	$5.05	$8.37	$17.36	$23.01
	Gallons of fuel saved, in millions	0.00	2.07	3.86	9.00	13.42
4	**Land use changes + Transit fare change + Transit service improvements + TDM**					
	VMT Reduction from BAU baseline, in millions	0.00	51.91	103.81	260.38	416.94
	Auto operating cost savings, in $millions	$0.00	$23.39	$42.25	$95.90	$139.23
	Savings in fuel costs only, in $millions	$0.00	$5.26	$8.70	$18.07	$23.95
	Gallons of fuel saved, in millions	0.00	2.16	4.02	9.37	13.97
5	**Land use changes + Transit fare change + Transit service improvements + Parking Fees + TDM**					
	VMT Reduction from BAU baseline, in millions	0.00	104.26	208.52	437.22	665.92
	Auto operating cost savings, in $millions	$0.00	$46.98	$84.86	$161.03	$222.37
	Savings in fuel costs only, in $millions	$0.00	$10.56	$17.48	$30.34	$38.26
	Gallons of fuel saved, in millions	0.00	4.33	8.06	15.74	22.31
6	**Land use changes + Transit fare change + Transit service improvements + Mileage Fees + TDM**					
	VMT Reduction from BAU baseline, in millions	0.00	69.60	139.19	372.90	606.60
	Auto operating cost savings, in $millions	$0.00	$31.36	$56.65	$137.34	$202.57
	Savings in fuel costs only, in $millions	$0.00	$7.05	$11.67	$25.88	$34.85
	Gallons of fuel saved, in millions	0.00	2.89	5.38	13.42	20.32
7	**Land use changes + Transit fare change + Transit service improvements + Parking Fees + Mileage Fees + TDM**					
	VMT Reduction from BAU baseline, in millions	0.00	122.07	244.15	544.01	843.88
	Auto operating cost savings, in $millions	$0.00	$55.01	$99.36	$200.36	$281.80
	Savings in fuel costs only, in $millions	$0.00	$12.36	$20.47	$37.75	$48.48
	Gallons of fuel saved, in millions	0.00	5.07	9.44	19.58	28.28

4.2. Indirect Benefits

The reduction of VMT and emissions from the analyzed travel efficiency strategies is likely to have benefits beyond those listed in Tables 2 and 5. These may be termed as indirect benefits because they are not directly related to the amount of travel reduced but could be indirectly affected by implementation of the strategies. They are often not easily quantifiable since it is difficult to attribute these benefits solely to the transportation strategies considered. Several other external factors can have an influence, for instance, economic and political conditions governing fuel trade.

- Transit improvements constructed within a smart growth framework can lead to changes in the use and value of properties located near transit or near new infill developments. This increase in economic value is an indirect benefit of the transportation improvement.
- Improvements in transit service and intelligent transportation solutions (ITS) strategies could lead to greater reliability benefits for travelers, leading to enhanced productivity and more time spent in desirable pursuits rather than waiting at transit stations or sitting in congested traffic congestions. Tangible economic benefits can thus accrue from ITS strategies that lead to improvements in traffic flow and reduction in delays.
- Land use strategies like smart growth that involve compact development can increase regional accessibility and reduce the need for new infrastructure to be built further out in the region. These outcomes can lead to regional economic benefits from enhanced accessibility to employment and reduced costs for infrastructure provision.
- Shifting to non-motorized transportation modes like walking and cycling can lead to additional health benefits associated with a physically active lifestyle and can reduce the incidence of obesity, other illnesses, and the stress of being “stuck in traffic”. The savings in health costs arising from using these modes are difficult to estimate because a traveler may choose to use these modes or not for other reasons, not directly related to the adopted strategy.
- Reducing fuel consumption by reducing VMT has the additional benefit to the U.S. economy of lowering the economic costs that result from U.S. petroleum consumption and imports. These external costs include subsidies on fuel prices, costs associated with the disruption in the flow of oil imports, outlays to support U.S. military activities to secure the flow of oil imports, and outlays to cushion the economy against possible interruption in oil imports by maintaining the Strategic Petroleum Reserve. Although these benefits can be quantified from guidance available from the Oak Ridge National Laboratories there is debate around the assumptions.

4.3. Conclusion

The analysis of co-benefits is crucial to understanding the full impacts of strategies aimed at reducing vehicle emissions and improving travel efficiency. It allows consideration of factors not directly perceived by travelers but with important social and economic implications. Given that transportation investment decisions frequently involve considerations beyond travel activity and emissions, it is important to be able to account for these co-benefits. Knowledge of the co-benefits allows transportation practitioners to evaluate projects and strategies in a more robust way, leading to a better allocation of resources. This supplement report provides quantitative and qualitative information for evaluating key-co-benefits that can prove helpful in decision making. The methodology used in this analysis may be applied to estimates of VMT reduction from implementing transportation strategies obtained using the TEAM approach and other methods.

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Appendix

Information about the TRIMMS model

TRIMMS evaluates strategies that directly affect the cost of travel, like transit fare subsidies, parking pricing, pay-as-you-go pricing initiatives and other financial incentives. TRIMMS also evaluates the impact of strategies affecting access and travel times. The model allows the user to account for employer-based program support strategies, such as flexible working hours, teleworking, and guaranteed ride home programs. It allows the analyst to use local data or defaults from national research findings. The VMT impacts of a given mix of strategies are subsequently calculated.

TRIMMS is a sketch planning tool that can be used to analyze many types of strategies at a regional or sub-area scale. However, strategies involving construction of new infrastructure such as new HOV/HOT lanes, new transit lines, and new bicycle/pedestrian facilities, can be analyzed most effectively using a regional travel demand model. In the TRIMMS model, such strategies can be modeled using the change in travel times and travel costs that such strategies represent. The TRIMMS model does not use trip tables. It requires average regional mode shares, average trip lengths and travel time by mode, average vehicle occupancy, parking costs, and trip costs as inputs. The user can change the price and travel time elasticity values. The tool provides changes in mode shares, trips, and VMT as outputs.

Table A-1. Methodology Used to Estimate Co-Benefits in TRIMMS

Measure	TRIMMS Methodology
Change in Air Pollution	Use of emission factors from EPA MOBILE6 model for 85 geographic regions represented in TRIMMS. Emissions damage costs in $/kg obtained from Delucchi (2005), inflated to 2009 dollars, and scaled for different urban areas, based on regional cost of living differences and population densities.
Change in Congestion	Marginal added hours of delay per thousands of passenger-car equivalent (pce) VMT (assumed to be 61.26 hours of delay per 1,000 pce VMT) x change in VMT estimated by TRIMMS x value of time ($/hour = 40% of average wage rate by occupation type, scaled to account for cost of living differences between regions). Only pertains to the costs of added delay to others.
Change in Excess Fuel Consumption	Uses data on average travel speeds for 85 urban areas from the Texas Transportation Institute's Urban Mobility Report to determine average fuel economy, and data on fuel prices in each urban area from the EIA.
Change in Impacts from Global Climate Change	Uses value of $50/metric ton of CO2 emissions from literature x (change in VMT) x CO2 emissions factor from MOBILE6. Considers damages associated with CO2 only, following EPA guidance that other GHGs (N2O and CH4) are more volatile and difficult to estimate.
Change in Health and Safety	Change in comprehensive health and safety costs is based on changes in the number of vehicle crashes resulting from each scenario.
Change in Noise Pollution	Changes in noise are calculated based on VMT ($/VMT) by mode type for urban areas. The costs are scaled to account for cost of living differentials between national averages and each regional area. Cost figures taken from Litman (2009).

	Table A-2. Co-Benefits Resulting from Daily Reduction in Vehicle Miles Traveled (discounted @ 7%) (in 2010 dollars)					
	Scenario	2010	2020	2030	2040	2050
	Baseline national urban VMT (business-as-usual), in millions	5,118	5,889	7,130	8,254	9,555
1	Regionwide TDM					
	VMT Reduction from BAU baseline, in millions	0.00	3.49	6.98	16.12	25.26
	Auto operating cost savings, in $millions	$0.00	$1.07	$1.33	$1.89	$1.84
	Savings in fuel costs only, in $millions	$0.00	$0.24	$0.27	$0.36	$0.32
	Gallons of fuel saved, in millions	0.00	0.14	0.27	0.58	0.85
2	Land use changes + TDM					
	VMT Reduction from BAU baseline, in millions	0.00	36.10	72.20	177.97	283.75
	Auto operating cost savings, in $millions	$0.00	$11.11	$13.71	$20.90	$20.64
	Savings in fuel costs only, in $millions	$0.00	$2.50	$2.82	$3.94	$3.55
	Gallons of fuel saved, in millions	0.00	1.50	2.79	6.41	9.51
3	Land use changes + Transit fare change + TDM					
	VMT Reduction from BAU baseline, in millions	0.00	49.92	99.84	250.14	400.45
	Auto operating cost savings, in $millions	$0.00	$15.37	$18.96	$29.38	$29.13
	Savings in fuel costs only, in $millions	$0.00	$3.45	$3.91	$5.54	$5.01
	Gallons of fuel saved, in millions	0.00	2.07	3.86	9.00	13.42
4	Land use changes + Transit fare change + Transit service improvements + TDM					
	VMT Reduction from BAU baseline, in millions	0.00	51.91	103.81	260.38	416.94
	Auto operating cost savings, in $millions	$0.00	$15.98	$19.72	$30.58	$30.33
	Savings in fuel costs only, in $millions	$0.00	$3.59	$4.06	$5.76	$5.22
	Gallons of fuel saved, in millions	0.00	2.16	4.02	9.37	13.97
5	Land use changes + Transit fare change + Transit service improvements + Parking Fees + TDM					
	VMT Reduction from BAU baseline, in millions	0.00	104.26	208.52	437.22	665.92
	Auto operating cost savings, in $millions	$0.00	$32.10	$39.61	$51.35	$48.44
	Savings in fuel costs only, in $millions	$0.00	$7.21	$8.16	$9.67	$8.33
	Gallons of fuel saved, in millions	0.00	4.33	8.06	15.74	22.31
6	Land use changes + Transit fare change + Transit service improvements + Mileage Fees + TDM					
	VMT Reduction from BAU baseline, in millions	0.00	69.60	139.19	372.90	606.60
	Auto operating cost savings, in $millions	$0.00	$21.43	$26.44	$43.79	$44.13
	Savings in fuel costs only, in $millions	$0.00	$4.81	$5.45	$8.25	$7.59
	Gallons of fuel saved, in millions	0.00	2.89	5.38	13.42	20.32
7	Land use changes + Transit fare change + Transit service improvements + Parking Fees + Mileage Fees + TDM					
	VMT Reduction from BAU baseline, in millions	0.00	122.07	244.15	544.01	843.88
	Auto operating cost savings, in $millions	$0.00	$37.58	$46.38	$63.89	$61.39
	Savings in fuel costs only, in $millions	$0.00	$8.45	$9.55	$12.04	$10.56
	Gallons of fuel saved, in millions	0.00	5.07	9.44	19.58	28.28