TECHNICAL APPENDICES

Moving Cooler

An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions

Prepared for
***Moving Cooler* Steering Committee**

Prepared by
Cambridge Systematics, Inc.

Revised October 2009

Urban Land Institute

Table of Contents

List of Tables

Appendix C

Assumptions and Methodology Used in Moving Cooler Cost Analysis

Assumptions and Methodology Used in *Moving Cooler* Cost Analysis

This Appendix provides background information regarding the major assumptions, data sources, and analytic approach used to assess the costs and cost-effectiveness of individual strategies and measures in reducing greenhouse gases (GHG).

Section I: General Cost-Effectiveness Methodology – Section I presents details behind the methodology, and what costs are and are not included in the determination of cost-effectiveness across the range of measures in *Moving Cooler*.

Section II: Fuel and Vehicle Operating Cost Assumptions – Section II presents the major assumptions about overall trend fuel and vehicle operating costs that are used in the analysis to determine cost savings associated with reductions in vehicle miles traveled (VMT) or fuel consumption.

Section III: Strategy-Specific Cost Assumptions – Section III presents the specific assumptions, data and analytic methodologies applied in developing costs of measures in each of the nine strategy groups.

I. General Cost-Effectiveness Methodology

The primary focus of the cost-effectiveness analysis is in determining readily quantifiable social costs and benefits of each measure and calculating a net present value (NPV) for various time horizons. The methodology does not represent a comprehensive measure of social welfare associated with each strategy. The NPV is divided by the total tonnes of CO_2e reduced during the same time period to estimate cost-effectiveness in terms of cost per tonne. The primary elements of costs and benefits considered in *Moving Cooler*:

- Implementation Costs
  - Direct capital, annual operating, and maintenance costs
  - Administrative or other program costs;
- Vehicle Costs
  - Fuel costs (savings) due to reduced VMT or improved traffic flow; and
  - Vehicle costs (savings) (other than fuel) due to reduced VMT.

Externalities and benefits that are not direct monetary savings (value of time saved, safety benefits, and air quality improvements) are not included in the cost-effectiveness (CE) analysis.

The primary assumptions that apply to the *Moving Cooler* cost-effectiveness methodology are described below:

- **Calculation of Cost-Effectiveness –** CE will be calculated by dividing cumulative discounted net costs (net present value of total implementation costs minus vehicle costs) by cumulative GHG reductions over the same time period.

- **Discount Rate –** A discount rate of four percent will be applied to future investments and vehicle costs. (The McKinsey report[69] used a seven percent discount rate, but many agencies such as state DOTs utilize a four percent or lower discount rate. If the same methodology were used as was used in the 1992 Office of Management and

[69] McKinsey & Company, Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost? U.S. Greenhouse Gas Abatement Mapping Initiative, Executive Report. (Washington, D.C.: McKinsey & Company, 2007).

Budget (OMB) directive[70], which specified a seven percent discount rate at that time, a discount rate of around three percent would now be used.)

Emission reductions are not discounted. This is consistent with the standard approach to calculating cost-effectiveness of emission reductions (as in the McKinsey report and the Center for Climate Strategies (CCS) methodology for more than a dozen states). The approach recognizes that although the value of money lessens over time, GHG emissions effectively do not due to their long lifetimes (50- to 200-year lifetime for CO_2).

- **Taxes, Tolls, Subsidies, and Other Transfers –** Taxes, tolls, subsidies, and other fees or incentives do not change the total societal cost of a given GHG reduction strategy, but rather affect the costs to individual actors – effectively, they are transfers from one actor to another. Therefore, these are not included in the cost-effectiveness estimates. They are highlighted in the *Moving Cooler* report Section 4.13 and in the equity appendix because they are very important to each group involved in the transfer.

70 OMB Circular A-94, Guidelines and Discount Rates for Benefit–Cost Analysis of Federal Programs (October 29, 1992) and OMB Circular A-130, Management of Federal Information Resources

II. Fuel and Vehicle Operating Cost Assumptions

These are the costs to private and commerical vehicle operators (excluding taxes and fees, which are regarded as a transfer payment). These include fuel costs, vehicle maintenance, and vehicle ownership costs. These costs are an important component of net societal costs and are generally included in agency cost/benefit calculations, but do not appear on the balance sheet of public agencies and the private sector when it comes to raising sufficient funds for project implementation. The following vehicle costs are included in the *Moving Cooler* cost-effectiveness analysis:

- Fuel cost savings due to reduced VMT or improved traffic flow; and
- Vehicle operating cost savings due to reduced VMT.

Depending on specific strategy definitions, each strategy incorporates either fuel cost savings due to VMT and/or improved traffic flow and vehicle operating cost savings.

Fuel Cost Savings from Reduced VMT

Annual reductions in VMT by strategy are multiplied by baseline fuel economy forecasts and baseline fuel costs per gallon to obtain total fuel cost savings. Cordon pricing, congestion pricing and speed limits which impact both light-duty vehicle and truck VMT use a VMT weighted average fuel economy to determine fuel savings and average fuel cost (diesel and gasoline) to determine total cost savings. In researching the Energy Information Administration (EIA) average fuel price data, from 1994 to present, diesel retail prices averaged three percent higher than gasoline retail prices. The Annual Energy Outlook (AEO) 2009[71] price projections indicate approximately the same relationship. *Moving Cooler* is not analyzing fuel types. For the purposes of *Moving Cooler* analysis, diesel and gasoline prices are assumed to be the same.

Fuel economy forecasts for the on-road light-duty vehicle and truck fleets are the 1.91 percent and 0.63 percent annual growth rates detailed in Appendix B.

---

[71] Energy Information Administration. Annual Energy Outlook 2009. http://www.eia.doe.gov/oiaf/aeo/index.html.

The baseline fuel price is assumed to begin at $3.70 in 2009 and then to increase annually at 1.2 percent. This price growth rate is based on the EIA AEO 2008. Although short-term market volatility will likely continue, this is not assumed to effect long-term trends or results. Fuel prices have fluctuated since this forecast assumption was made.

Fuel Cost Savings from Improved Traffic Flow

Annual reductions of fuel consumption result from improved traffic flow (Cordon & Congestion Pricing, VMT/Gas/Carbon Tax, HOV, Speed Limits, Operations, Bottleneck Relief and Capacity Expansion strategies), improved freight load factors (longer combination vehicle and shipping container permits) and reduced idling for some freight strategies (weigh station bypasses, truck stop electrification and heating and cooling systems for sleeper cabs). Total annual reduction in fuel consumption is multiplied by average annual fuel cost per gallon to obtain total savings. These were calculated based on relationships between fuel consumption rates and changes in hours of delay per 1,000 VMT as estimated through FHWA HERS model runs completed for *Moving Cooler*.

Operating Cost Savings from Reduced VMT

Operating cost savings include all costs attributed to operating a vehicle. Thus, the cost of operating a vehicle on a given section is a function of costs for oil, tires, maintenance and repair, and mileage-related depreciation. For strategies affecting both passenger car and freight VMT (cordon pricing, congestion pricing, intercity tolls, and speed limits), the passenger vehicle and truck combined VMT weighted operating costs are used. The cost per mile for light-duty vehicles and trucks through 2050 are obtained from IRS data for light-duty vehicles (58.5 cents in 2008, adjusted for higher fuel prices to 60 cents per mile, and further adjusted for all vehicles based on cost ratios between light-duty and all vehicles from the Highway Economic Requirements System (HERS) model.[72]) This data is presented in Table 1.

[72] The Highway Economic Requirements System (HERS) model was developed by the Federal Highway Administration (FHWA) to examine the relationship between national investment levels and the condition and performance of the nation's highway system. FHWA uses the model to estimate future investment required to either maintain or improve the nation's highway system. http://www.fhwa.dot.gov/infrastructure/asstmgmt/.

Table 1. Average Vehicle Operating Costs

	Dollars/Mile		
Operating Costs/Vehicle Type	**2010**	**2030**	**2050**
Passenger Vehicles Only	$0.60	$0.59	$0.59
Passenger Vehicles and Trucks	$0.68	$0.68	$0.68

Truck operating cost savings for freight-specific strategies are discussed within each strategy methodology as they vary depending on strategy definition (see Section III, 9.0 Freight Strategies).

III. Strategy-Specific Cost Assumptions

The following sections outline the analytic approach and specific cost assumptions applied to each of the nine strategy groups defined by the report. These groups are:

1. Pricing strategies;
2. Land use and smart growth strategies;
3. Nonmotorized transportation strategies;
4. Public transportation improvement strategies;
5. Regional ride-sharing, car-sharing and commuting strategies;
6. Regulatory strategies;
7. Operational and intelligent transportation system (ITS) strategies;
8. Bottleneck relief and capacity expansion strategies; and
9. Multimodal freight strategies.

1.0 Pricing Strategies

1.1 Parking Pricing

There are three individual measures qualified as parking pricing strategies, all with consistent cost assumptions (GHG reduction methodologies do vary by measure). These are:

1. Central Business District (CBD)/Activity Center on-street parking pricing to encourage "park-once" behavior (Level A – complete over eight years, Level B – complete over six years, Level C – complete over four years);

2. Introduce tax/higher tax on free private parking lots (Level B >100 spaces, Level C >50 spaces); and

3. Require residential parking permit of on-street parking in residential areas (Level B = $200 biennially, Level C= $400 biennially, plus multi-zone permits for delivery vehicles).

For all measures, the primary implementation mechanisms are new parking regulations and enforcement. While there is a transfer cost for those paying the taxes, permits and/or fees to a public or private entity, there is insufficient information to determine from which socioeconomic groups these transfer revenues would be collected and how these transfer revenues would be used. The public costs of implementing these measures are minimal and comparatively less than transfer revenues. The CBD/Activity Center on-street parking pricing measure includes some implementation cost for purchasing new meters or updating existing meters to reflect new prices as well as administrative costs to monitor and set appropriate fee levels. For consistency among measures and the recognition that any implementation and enforcement costs would presumably be deducted from the revenues raised by these strategies, the implementation costs are assumed to be zero.

1.2 Cordon Pricing

Cordon pricing was applied for all vehicle travel to central business districts. An estimate was made of the proportion of urban VMT (3 percent) which would be subject to cordon pricing. Thus, the cost estimate for cordon pricing is assumed to be proportional to the cost estimate for congestion pricing, which utilizes similar technology for implementation. Congestion pricing applies to 29 percent of urban VMT.

1.3 Congestion Pricing

Congestion pricing is applied for all highways and roads which are congested based on volume/capacity (V/C) ratio thresholds (maintain level of service (LOS) D for roads currently LOS F). An estimate was made of the proportion of all urban and rural roads and VMT, which would be subject to congestion pricing under each level of implementation. The proportions were derived from the Highway Performance Monitoring System (HPMS)[73] and HERS runs performed by FHWA for recent system pricing analyses. A value of 29 percent of congested VMT was utilized for urban areas and 7 percent for rural areas based on the FHWA information.

Initial capital costs include the on-board units (OBU) and installation, enforcement requirements and central system development. According to a 2008 study by the Puget Sound Regional Council (PSRC),[74] the total capital startup cost for the Seattle region is $748.5 million. The same PSRC study estimated annual system costs, which include OBU repair, enforcement and data communications needs at $287.7 million annually in 2008 dollars. These costs are expanded on a per capita basis (based on 2006 census population of the Seattle region, 3.3 million) to cover deployment to all urban areas within each of the six urban area classes. Deployment starts in 2015 in large areas (>1 million population), 2020 in medium areas and 2025 in small areas and rural.

As VMT grows at a forecasted rate of 1.4 percent annually (see Appendix B), annual operations costs will increase proportionally.

Table 1.1 Total Implementation Costs – Congestion Pricing
2010-2050

	Total Cost (Billions (2008 Dollars)	
Deployment Level	**2010-2030**	**2010-2050**
Level A	$133.00	$233.90
Level B	$179.24	$348.99
Level C	$206.62	$380.31

---

73 The Highway Performance Monitoring System (HPMS) is a national level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the nation's highways. http://www.fhwa.dot.gov/policy/ohpi/hpms/abouthpms.cfm.

74 Puget Sound Regional Council. 2008. Traffic Choices Study. http://psrc.org/projects/trafficchoices.

■ 1.4 Intercity Tolls

The same assumptions used for congestion pricing in terms of implementation and annual costs are applied for intercity tolls. This strategy tolls all intercity interstates at varying per mile rates in Levels A, B, and C. The rural system needs as estimated through the congestion pricing analysis (7 percent congested VMT) is applied at an expanded scale (all currently non-tolled rural interstates) to determine total cost for this strategy.

Table 1.2 Total Implementation Costs – Intercity Tolls
2010-2050

	Total Cost (Billions (2008 Dollars)	
Deployment Level	**2010-2030**	**2010-2050**
Level A	$15.96	$33.56
Level B	$25.82	$44.69
Level C	$38.28	$58.51

■ 1.5 Pay-As-You-Drive Insurance and VMT Fees

The costs for these measures are assumed identical because they both measure vehicle miles traveled. Thus if both pay-as-you-drive insurance (PAYD) and VMT fees are being implemented the total costs are split evenly across measures to reflect this implementation overlap. It is assumed that pay-as-you-drive insurance at the scale considered here would be implemented as a government supported program, thus there are associated public costs. Currently most costs of pay-as-you-drive insurance are borne by the insurance provider or the vehicle owner.

The basis of cost assumptions for these strategies in *Moving Cooler* come from a 2008 Cambridge Systematics white paper completed for FHWA on Estimating the Cost of Systemwide Road Pricing.

The PAYD and/or VMT fee system uses an on-board radio frequency (RF) transmitter connected either to existing vehicle odometers or to electronic hub odometers. Most discussions of vehicle infrastructure integration (VII) deployment assume a price closer to $100 per unit for on-board communications units. A recent paper on Toll Collection

Technology Considerations estimated the price of GPS OBUs at $200 to $400.[75] *Moving Cooler* uses a cost of $400 per unit, including start up costs and installation.

Transceivers would be located at gas stations to record mileage information between fill-ups. The estimate for roadside units from the VII Benefit Cost Analysis is used as a proxy for this type of unit.[76] Roadside equipment designed for installation in locations with access to communications is estimated to cost about $1,000, with an additional $4,800 for installation. For number of gas stations, the number of nationwide establishments from the 2002 Economic Census[77] (130,515) was used.

Assuming that the system is deployed as described above, costs for electronic hub odometers, on-board units, and gas station RF receivers are presented in Table 1.3. Additional operating costs are approximated at 10 percent of the field equipment cost. Annual administrative costs are estimated at 5 percent of revenue.

Costs are identical across deployment levels through 2050, however revenue will vary as per mile rates for VMT fees increase from Level A through Level C. Annual operating costs increase by 1.4 percent per year, consistent with *Moving Cooler* forecasts for annual VMT growth. Total implementation costs through 2050 in 2008 dollars are $166.48 billion.

Table 1.3 PAYD and VMT Fee Implementation Costs

Item	Units	Cost per Unit	Cost Extended
Hub Odometers (Electronic) and Start Up	275 million	$400	$110 billion
OBU RF Transmitters	250 million	$100	$25 billion
RF Receivers at Gas Stations	130,515	$5,800	$0.75 billion
Total Deployment Cost			$135.75 billion
Annual Operating and Administrative Costs			$1.715 billion

75 *Toll Collection Technology Considerations, Opportunities, and Risks*, Background Paper No. 8, Washington State Comprehensive Tolling Study, September 20, 2006 (IBI Group with Cambridge Systematics, Inc.).

76 *VII Initiative Benefit/Cost Analysis: Pre-Testing Estimates*, Draft Report, Sean Peirce and Ronald Mauri, John A. Volpe National Transportation Systems Center, Cambridge, Massachusetts, March 30, 2007.

77 Economic Census 2002 Reports. http://www.census.gov/econ/census02/.

1.6 Gas Tax/Carbon Price

It is assumed for *Moving Cooler* that a carbon price related to transportation would be assessed through the same or parallel procedures as are now used for motor fuel taxes. Existing motor fuel taxes are extremely cost-effective, because their costs of administration and compliance are very low. Increases in motor fuel taxes could be accomplished without incurring additional costs for administration or compliance. It also is assumed that a carbon price would be collected much like a motor fuel tax, primarily from the large energy producers at the top of the chain. Thus, a carbon price would have low administrative and compliance costs and high cost-effectiveness.

2.0 Land Use and Smart Growth Strategies

Administrative Costs

These are defined as the program costs of developing and implementing "smart growth"[78] land use planning and coordination mechanisms at the state, regional, and local levels. Costs include public agency staff time as well as external expenses for data acquisition, analysis, public involvement, etc.

Administrative cost estimates are based on experience from recent regional visioning efforts, as well as program requirements for states that already have implemented comprehensive planning requirements (Florida, New Jersey, Oregon, and Washington). The following are examples of regional visioning efforts for which costs have been documented:

- **California Blueprint Program –** Provided $5 million each in 2005-2006 and 2006-2007 for "seed money" for regional blueprint programs. In the first year, 11 applications were submitted, requesting $7 million. First-year grant amounts were $1.2 million (Los Angeles/Southern California Association of Governments), $500,000 (Metropolitan Transportation Commission/Association of Bay Area Governments), and $200,000 to $400,000 for other metropolitan planning organizations (MPO).[79] Second-year applications were of similar magnitude.

- **Envision Utah –** This was about $6 million in the first five to six years, now up to $9-10+ million since 1996.[80]

- **Myregion (Orlando, Florida) –** Cost: (Total in "low millions," public/private mix) Over $1 million dollars was spent by myregion.org in research and development, including private sources.[81]

---

[78] Smart Growth America defines smart growth according to its outcomes: neighborhood livability; better access, less traffic; thriving cities, suburbs and towns; shared benefits; lower costs and taxes; and keeping open space open.

[79] California Regional Blueprint Planning Program: Report to Joint Legislative Budget Committee, December 2006, http://calblueprint.dot.ca.gov/index_files/BP_Report_final.pdf.

[80] The History of Envision Utah. http://www.envisionutah.org/historyenvisonutahv5p1.pdf.

- **Lansing, Michigan** – Approximately $1.5 million for regional growth concept development. Additional ongoing funding for implementation activities.[82]

- **Charlottesville, Virginia –** Jefferson Area Eastern Planning Initiative 2050 – $500,000 grant from FHWA TCSP program to develop plan, plus additional local and in-kind. Ongoing implementation activities.[83]

- **Sacramento, California Blueprint –** Cost: "in the low millions," Public/Private, Federal dollars through Sacramento Area Council of Governments, state agencies, and private donors.[84]

- **Austin, Envision Central Texas –** Cost: Public/Private, wide variety of private contributors, with substantial support from the Capital Metropolitan Transportation Authority and participating cities and counties. Phase 1 cost upwards of $2 million.[85]

Based on experience, the following cost estimates are applied for regional-level planning/visioning, and applied to all metro areas:

- **Large Metro Areas –** $1 million a year for 10 years (5 years planning, and 5 years implementation), then continuing at $300,000 a year for three full-time equivalents (FTE) indefinitely for ongoing outreach, technical assistance, local plan review, plan updates, etc.

- **Medium Metro Areas –** $500,000 a year for 10 years, then continuing at $200,000 a year (two FTEs) indefinitely.

- **Small Metro Areas –** $200,000 a year for 10 years, then continuing at $100,000 a year (one FTE) indefinitely.

For state growth management programs, the average level of effort per state is estimated at $500,000 annually for Level A (5 FTEs), $1 million annually for Level B (10 FTEs), and $1.5 million annually for Level C (15 FTEs). This includes policy development and analysis in the first few years, then ongoing implementation work, including local outreach, technical assistance, local plan review, state plan updates, etc. It does not include grants for local planning, which are covered under municipal planning costs

---

[81] How Shall We Grow? A Shared Vision for Central Florida. 2007. http://www.myregion.org/Portals/0/HSWG/HSWG_final.pdf.

[82] Regional Growth: Choices for our Future. Tri-County Regional Planning Commission. http://www.mitcrpc.org/tricounty_website/1_overview.htm.

[83] Jefferson Area Eastern Planning Initiative. http://www.tjpdc.org/community/epi.asp.

[84] http://www.sacregionblueprint.org/sacregionblueprint/home.cfm.

[85] http://envisioncentraltexas.org.

(below) without the source of these costs being specified. The increasing costs correspond to increasing levels of state involvement in planning oversight, technical assistance, etc.

For local plan and code updates, an average cost of $100,000 per municipality is estimated for Levels A and B ($150,000 for Level C), with approximately 21,000 municipalities (counties, cities, and towns – based on Census data) in the United States updating their plans to comply with regional and state planning objectives. The cost may be considerably greater than this for larger jurisdictions; however, many jurisdictions probably would have performed updates anyway during the course of the implementation period and so this may not necessarily represent a significant additional cost. Many rural jurisdictions that currently do not have comprehensive plans and/or zoning also may need to expend additional resources.

Costs and Cost Savings Not Included in the Analysis

These include cost savings for roadways and water/sewer lines resulting from more compact development patterns.

The primary data source for infrastructure cost savings is the work of Robert Burchell and colleagues, as documented in TCRP Report 74, The Costs of Sprawl – 2000 (2002)[86] and Sprawl Costs: Economic Impacts of Unchecked Development (2005).[87]

Roadway Infrastructure – Burchell et al. (2002) developed a statistical model of the relationship between road density and population density at the county level in the United States, and then applied typical costs per mile for "developed" and "undeveloped" rural, suburban, and urban areas (Table 8.2, page 248).

Municipal Services – Burchell et al. (2002) estimate savings in municipal services based on population density, based on aggregate analysis of municipal revenues and expenditures, but the magnitude of these savings ($64 per residential unit and $3 per job) is quite small compared to the magnitude of the infrastructure cost savings shown above. In addition, there is some disagreement in the literature about whether higher-density development results in lower services costs when examined across all services. Lacking any strong evidence or data showing a larger impact to municipal services, this category of costs was therefore ignored. (Municipal service cost savings from Kentucky and Rhode

[86] Burchell, R., et al. (2002). TCRP Report 74, Costs of Sprawl – 2000. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_74-a.pdf.

[87] Burchell, R., et al. (2005). Sprawl Costs: Economic Impacts of Unchecked Development. Island Press.

Island studies referenced in Brookings (2004) could be reviewed to see if there is any further relevant information on this topic.)[88]

Real Estate Development – Burchell et al. (2002) also estimate real estate development cost savings from compact versus sprawl development, with the cost savings based primarily on smaller lot sizes (reduced land costs) and smaller building sizes in multifamily development. They estimate a reduction of $13,000 per unit (8 percent) for residential development and $865 per unit (1 percent) for commercial development. These cost savings were not accounted for in this study for two primary reasons. First, the savings resulting from smaller unit sizes may represent a welfare loss to consumers (although Burchell justifies ignoring this by stating that market trends are favoring smaller units anyway). Second, it is possible that more urban-style development requires additional public amenity costs (such as sidewalks, public space, etc.) that are not accounted for elsewhere in this analysis. Such cost differences, however, have not been well-documented. Finally, there is evidence that some types of growth policies (such as growth boundaries) may increase land prices (in fact, this is an important mechanism for achieving higher densities), meaning that land costs may not be lower taken together.

Transit Infrastructure and Services – One might argue that the additional cost of transit infrastructure and services should be considered, if reduced road costs are considered. Transit costs are considered separately, under the transit strategy category, and therefore it would be double-counting to also consider them here.

Utilities (Water, Sewer, Gas, Electric) – It is likely that compact development would realize savings from utilities due to shorter infrastructure connection requirements. Burchell et al. (2005) provide estimates of water and sewer costs per residential unit for different types of development. Gas and electric cost savings were estimated in an analysis of regional growth alternatives for northern Utah by Envision Utah.

Demonstration Grants and Catalyst Funding – A number of state and metropolitan area planning initiatives have include a significant program of demonstration grants, catalyst project funding, etc. in the implementation phase. Such costs are not included in this analysis for three reasons. First, it is assumed that these are largely infrastructure and development funds that are redirected from other uses – e.g., funds for pedestrian improvements in transit villages are reallocated from pedestrian (or other) infrastructure improvements that might have been implemented in other locations not identified as target growth areas. Second, "smart growth" practices are by now well-established so there is less need to learn how to do something particularly new or innovative. Finally, it is very difficult to say how much (if any) catalyst or demonstration funding might be required to achieve an ultimate desired plan outcome; if sufficient requirements and other policy levers (e.g., strings attached to Federal transportation funding) are part of the

---

[88] Muro, M. and R. Puentes. 2004. Investing In a Better Future: A Review of the Fiscal and Competitive Advantages of Smarter Growth Development Patterns. The Brookings Institution Center on Urban and Metropolitan Policy.

policy package, additional implementation funds (as incentives for local communities or developers) may not be necessary at all.

Land Preservation – While land preservation programs play a role in regional planning and land use, targeted land preservation is primarily a conservation strategy, not a compact growth/growth management strategy. While land protection can be accomplished through acquisition of development rights, it also may be accomplished through regulations at no cost. Therefore, it is difficult to make blanket assumptions about the magnitude of investment needed for land preservation to support regional growth strategies.

Overall Affordability – Some researchers have suggested that overall regional housing costs may increase because of growth boundaries or other regulations that restrict the location and form of development. The evidence on this point is limited, however, and there is dispute over the extent to which housing costs in (say) the Portland, Oregon region are a result of growth controls versus market factors. As noted above, there also are potential cost savings in the form of reduced real estate costs (from smaller-footprint buildings) that are not taken into account in this analysis.

Brownfields Cleanup – Some level of additional funding for brownfields cleanup may be required in order achieve greater levels of infill development than would otherwise occur. A 2006 survey by the U.S. Conference of Mayors, cited in a recent paper by Paull,[89] found that 82 respondent cities identified a capacity for new housing for a total of 2.8 million people on brownfields sites in these cities. A 1999 CUED study (also cited in Paull) found that the median remediation cost per acre of Brownfields was $57,000.

■ Results

Table 2.1 presents total administrative costs in 2008 dollars, which are the same for each implementation level. Much of the initial administrative costs take place in the early years but the benefits are compounded over time.

Table 2.1 Summary of Land Use Costs
Billions 2008 Dollars

	Level A/B/C	
	2010-2030	**2010-2050**
Total Costs	**$1.27**	**$1.51**

[89] Evans Paull, The Environmental and Economic Impacts of Brownfields Redevelopment. Northeast-Midwest Institute, July 2008.

3.0 Nonmotorized Transportation Strategies

3.1 Pedestrian Strategies

Costs of the pedestrian strategies are calculated using a bottom-up approach that takes unit costs of various types of pedestrian facilities (sidewalks, marked/signalized crossings, etc.) multiplied by assumptions about the quantity that will be required for each Deployment Level. Pedestrian improvements are assumed to be made in three types of areas – schools (K-12), transit station areas (fixed-guideway), and business districts.

The following assumptions are made about the **nature and quantity of new pedestrian facilities** in each type of area:

- **Sidewalks –** New sidewalk within 0.25 (Level A) or 0.5 (Levels B and C) mile radius along arterial or major collector, both sides of street; one-quarter of all areas currently are missing sidewalks. This yields 0.5 mile new sidewalk for 0.25-mile radius, or 1.0 mile for 0.5-mile radius. Applied to all six urban area types.

- **Pedestrian Crossings/Traffic Calming –** Four new painted/signed crosswalks for one-quarter-mile radius (Level A) of schools and transit stations (one per major directional approach); doubled for business districts since these are a larger area, not a point destination. Two of these locations are retrofitted with bulb-outs or median refuge islands. One location is retrofitted with a two-corner pedestrian signal. Quantities are doubled for one-half-mile radius (Level B). Quantities are doubled again for Level C implementation to reflect greater implementation of traffic calming measures.

The following assumptions are made about unit costs:

- **Sidewalks –** A literature review for NCHRP 20-24(63)[90] suggested a range of costs of $200,000 to $800,000 per mile for new sidewalks. A number close to the low end of this range ($250,000) was selected, assuming that in most cases where sidewalks already do not exist, a four- or five-foot sidewalk would be installed, and applications that are more expensive avoided.

---

[90] Porter, C., et al. (2008). NCHRP 20-24 (63). Partnership Approaches to Identify, Promote, and Implement Congestion Management Strategies. http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/20-24(63)_FR.pdf.

- **Pedestrian Crossings/Traffic Calming –** A literature review for NCHRP 20-24(63) found that marked and signed crossings cost less than $1,000. The Bicycle Transportation Alliance (2008) reports that bulb-outs cost $10,000 to $19,000 each, and refuge islands $8,000 to $15,000.[91]

The analysis was supported by a "top-down" review of various cities' pedestrian plans, to compare proposed expenditures on pedestrian facilities with what is contained in the plans. Three cities were located with pedestrian plans and cost estimates, as shown in Table 3.1. As can be seen, costs varied widely. However, the range of $100 to $200 per person for Oakland and Portland is fairly consistent with the Level B and C costs of $133 and $185 per person, respectively, in this analysis. These cities' plans included improvements that extended beyond just the pedestrian areas (schools, transit stations, and business districts) analyzed in this analysis, and therefore costs would be expected to be higher.

Table 3.1 Pedestrian Master Plans and Cost Estimates

City	Population	Cost/Person	Comments
Sacramento	475,000	$ 1,684	Estimated cost of all sidewalk and crosswalk improvements – not fully funded
Oakland	501,000	$100	Twenty-year priorities for streetscape projects (median improvements, street restriping, sidewalk/curb repair, traffic signal improvements, etc.)
Portland	568,000	$211	Twenty-year project list; includes $26 million for "Pedestrian District" and "Main Street Pedestrian Design" projects (includes widened sidewalks, curb extensions, street lighting and signing) and $24 million for sidewalk improvements
Average (Three Cities)		**$504**	

It was assumed that these capital investment costs would be spread over a 15-year timeframe, starting in 2010. It was further assumed that after this initial 15-year period, maintenance costs would continue at the level of 10 percent of initial annual capital costs. The results of the pedestrian cost analysis are shown in Table 3.2.

[91] Bicycle Transportation Alliance. Bicycle Boulevard Toolkit. http://www.bta4bikes.org/at_work/bikeboulevards.php.

Table 3.2 Pedestrian Strategy Costs

		Cost per Area			Total Cost, All UZAs (Millions Dollars)		
Area Type	**Total Number**	**A – One-Quarter Mile**	**B – One-Half Mile**	**C – One-Half Mile with More Traffic Calming**	**A – One-Quarter Mile**	**B – One-Half Mile**	**C – One-Half Mile with More Traffic Calming**
Schools	75,000	$191,000	$382,000	$514,000	$14,325	$28,650	$38,550
Transit Stations	1,500	$191,000	$382,000	$514,000	$287	$573	$771
Business Districts	20,000	$257,000	$514,000	$778,000	$5,140	$10,280	$15,560
			Total 15-Year Capital (Millions Dollars)		**$19,752**	**$39,503**	**$54,881**
			Cost per UZA (Millions Dollars)		$54.4	$108.8	$151.2
			Cost per Person (Dollars)		$67	$133	$185
			Cost per Year, 2010-2024		$1,317	$2,634	$3,659
			Cost per Year, 2025+		$132	$263	$366

3.2 Bicycle Strategies

Costs of the bicycle strategies were calculated using a bottom-up approach that applied unit costs of various types of bicycle facilities (lanes, paths, racks, etc.) multiplied by assumptions about the quantity that will be required for each metro area size category and Deployment Level. These costs estimates were validated and refined based on a top-down review of various North American cities' bicycle plans. The review focused on plans that are directed at achieving an extensive bicycle infrastructure as described in the scenarios for this strategy.

For bicycle facilities (lanes, shared-use paths, and bicycle boulevards), assumptions were made about the network spacing at each level of implementation, which was then expressed in terms of miles of facility per square mile. The network density was then multiplied by the total land area within census tracts of population density of at least 2,000 persons per square mile (as obtained from the Land Use strategy analysis). This corresponds to moderate-density suburban areas and higher-density urban neighborhoods. It was assumed that these areas would have the most significant potential for bicycling, and therefore would represent the most cost-effective extension of the bicycle network. Simple bicycle improvements lanes and signage could be implemented in many lower-density areas at relatively low cost, but would be expected to have only a minor impact on mode shares.

Cost data for bicycle facilities and parking were taken from a number of sources, including the NCHRP-developed *Benefit/Cost Analysis of Bicycle Facilities* tool (http://www.bicyclinginfo.org/bikecost/); the Bicycle Transportation Alliance web site (http://www.bta4bikes.org/at_work/bikeboulevards.php); and various cities' bicycle master plans. In some cases, professional judgment was used to reconcile estimates that varied significantly among different sources.

Table 3.3 shows the various assumptions that were made in determining the overall costs of the bicycle strategies. The bottom of this table also shows some summary statistics such as miles of bikeway per capita, cost per person, and cost per mile, that are compared with findings from North American bicycle plans. Overall, the cost per person for Level C of $198 compares with $211 for five cities with aggressive bicycle plans, and the miles of facility per person of 727 compares with the average of 681 from three of these cities' plans.

Table 3.3 Bicycle Facility Assumptions

Item	Unit Cost/ Quantity	Level A	Level B	Level C	Comments
Signed Bicycle Routes					
Cost per Mile	$1,000				
Miles per Square Mile		2	0		
Total Miles		54,000	-	-	
Cost (Millions Dollars)		$54	-	-	
Bicycle Lanes					
Cost per Mile	$25,000				NCHRP reports $5K/mile for signing/striping; assume some roads require reconfiguration of all lanes, more expensive (Columbus $12-93K; Toronto $40K)
Miles per Square Mile		2	2	4	Two miles/square mile = 1 mile spacing; 4 miles/square mile = one-half-mile spacing
Total Miles		54,000	54,000	108,000	
Cost (Millions Dollars)		$1,350	$1,350	$2,700	
Shared Use or Off-Street Path					
Cost per Mile	$750,000				Columbus – $707,000; Toronto; $675,000 CDN. Includes bridges
Miles per Square Mile		0	1	2	One mile/square mile = 2-mile spacing; 2 miles/square mile = 1-mile spacing
Total Miles		-	27,000	54,000	
Cost (Millions Dollars)		-	$20,250	$40,500	~$1-1.5 trillion/year; compare to $1 trillion total from 1991-1997 in the United States

Item	Unit Cost/ Quantity	Level A	Level B	Level C	Comments
Bicycle Boulevard Conversions					
Cost per Mile	$200,000				Splits the cost of Columbus ($50K/mile), Bicycle Trans Alliance ($250-500K), and Berkeley ($375K); includes bicycle signals, 1/mile
Miles per Square Mile		0	1	2	1 mile/square mile = 2-mile spacing; 2 mile/square mile = 1-mile spacing
Total Miles		-	27,000	54,000	
Cost (Millions Dollars)		-	$5,400	$10,800	
Bicycle Racks					
Cost per Unit (Inverted U)	$200				NCHRP Guidebook
Quantity per 1,000 Residents	50				Portland: 15 short-term and 41 long-term per 1,000 population in Bike Plan
Total Racks (Millions)		7.5	7.8	8.0	
Cost (Millions Dollars)		$1,500	$1,550	$1,600	
Bus Bicycle Racks					
Cost per Unit	$600				NCHRP Guidebook
Number of Buses	106,700				
Total Racks (Millions)		106,700	106,700	106,700	
Cost (Millions Dollars)		$64	$64	$64	
Bicycle Station					
Cost per Unit	$200,000				NCHRP Guidebook
Number per UZA		1	1	2	
Cost (Millions Dollars)		$59	$59	$118	
Cycling Skills Course (K-12)					
Cost per Class	$1,000				
Students per Class	25				
Total Number of Students (Millions/Year)	4.58				53.8 million K-12 students in 2006
Number of Years	15				
Cost (Millions Dollars)		$2,750	$2,750	$2,750	
Total Cost, First 15 Years (Millions)		**$5,723**	**$31,423**	**$58,710**	
Cost per Metro (Millions)		$19.3	$106.2	$198.3	
Cost per Person		$19	$106	$198	Compare with $211 average from five cities
Cost per Mile of Facility		$105,986	$290,956	$271,806	Compare with $217,000 average from three cities
Miles/Million Persons		182	364	727	Compare with 681 average from three cities
Annual Costs (Billions)					
Infrastructure, 2015-2029		$0.20	$1.91	$3.73	
Infrastructure, 2015-2030+		$0.02	$0.19	$0.37	
Skills Course		$0.18	$0.18	$0.18	

To annualize costs (also shown in Table 3.3), it was assumed that initial capital investment costs would be spread over a 15-year timeframe (2015-2029). Beyond this point, it was assumed that maintenance costs would be incurred at 10 percent of the annual capital investment cost. The skills course is assumed to continue into the future.

The costs estimates are most heavily driven by the assumptions regarding the quantity and cost of major investments, including shared-use/off-road paths and bicycle boulevards. Bicycle lanes and the cycling skills course also represent significant expenses. The overall costs and costs per facility-mile will depend upon the assumed mix of facilities, and this analysis is somewhat simplified in the sense that it does not consider strategies such as widening existing pavement to create bicycle lanes or shoulders.

4.0 Public Transportation Improvement Strategies

4.1 Fare Measures

This strategy is defined as offering lower fares or discount passes. In Level A, the average fare decrease is 25 percent, in Level B 33 percent and in Level C 50 percent. It is assumed that minimal administrative costs are required to manage these reductions and zero capital costs. If fare reductions are combined with smart card systems, there are costs associated with the purchase of new or upgraded equipment as well as lifetime operations and maintenance costs of the system. *Moving Cooler* assumes zero cost for this strategy.

There are significant transfer costs associated with this strategy. While lower fares would result in a cost savings to existing transit users and for new transit users who switch modes as a result of travel cost savings, the revenue lost by transit agencies would need to be offset by new revenue from other sources (increased local taxes, impact fees, etc.). These issues are addressed in the multi-attribute table in the final report.

4.2 Increased Level of Service and Speed Strategies

For the purposes of *Moving Cooler* cost-effectiveness analysis, the three individual strategies within this category are grouped together to determine total costs and cost-effectiveness. This includes increased frequency, improved operations and speed and expanded urban/rural fixed route bus service.

Moving Cooler uses costs estimated for the Bottom Line transit analysis[92] to obtain capital and operations/maintenance costs through 2050. The total costs are the marginal additional investments required above needed costs for an annual 2.4 percent ridership growth rate.

---

[92] American Association of State Highway and Transportation Officials (AASHTO). 2009. Transportation: Are We There Yet?: Bottom Line Report. Washington, D.C.

Capital Costs

The Bottom Line cost model is extended from 2026 through 2050, using the 20-year trend for urban transit systems. Total capital costs for the headway and level of service strategies use Bottom Line costs for the difference in annual costs between "maintain" transit service performance and "improve" transit service performance scenarios from Bottom Line. For the bus expansion strategy, the vehicle replacement model developed for Bottom Line is utilized to determine total vehicles required to support transit ridership increases resulting from system expansion.

The "improve" service performance scenario assumes that added investments are made to improve the speed of systems where the average speed falls below the national average. For the baseline ridership growth scenario, Bottom Line estimates that on average an additional investment of $7.3 billion annually (a 21 percent increase from "maintain") is required to improve performance. This difference from the base plus rural capital investment forecasts for the 3 percent, 3.5 percent, and 4.6 percent ridership growth rates are the total capital costs for Level A, B, and C.

For the extent measure, the strategy definition for Level A, B, and C identifies annual growth rates for bus revenue miles of 50 percent, 100 percent and 200 percent above baseline growth from 1997 to 2006. This results in annual ridership growth of 2.7 percent, 3.7 percent, and 6.0 percent. These growth rates are applied to the Bottom Line vehicle replacement model to determine annual costs for fleet expansion and replacement/rehabilitation to support ridership growth.

The total capital costs are decreased based on forecasts used in *Moving Cooler* for increases in transit load factors. Based on results from the Federal Transit Administration's Transit Economic Requirements Model (TERM)[93] run (see Appendix B), the trip weighted load factor increase in 2050 for Level A is 15.9 percent, Level B 9.4 percent, Level C 8.9 percent. The trip weighted load factor adjustment is calculated by multiplying the forecasted 2050 mode shares among transit modes by the forecasted load factor increase from TERM. The load factor increase and related reduction in costs is phased in incrementally over the first 20 years (2010-2030). Refer to Table 4.1 for details.

[93] FTA TERM Model, http://wwwcf.fhwa.dot.gov/policy/2006cpr/appc.htm.

Table 4.1 Transit Load Factor Adjustment

Mode	Trip Share		2050 Load Factor Increase		
	2010	2050	Level A	Level B	Level C
CR	5%	7%	8%	9%	8%
HRT	24%	39%	15%	15%	16%
LRT	5%	10%	17%	15%	15%
Bus	54%	44%	18%	16%	15%
Other	2%	<1%	6%	7%	7%
Trip Weighted Load Factor Increase			**15.9%**	**9.4%**	**8.9%**

Operating Costs

Using data from the American Public Transportation Association's (APTA) 2007 Public Transportation Factbook,[94] the estimate for operating costs per unlinked transit trip in 2006 is $2.50 (excluding paratransit services and nonvehicle facility maintenance costs). From 1995 to 2006, this number has increased from $1.84 per trip, a 36 percent increase or 2.6 percent increase annually. This growth rate is in line with Consumer Price Index (CPI) increases from 1996 to 2006 (32.3 percent increase) and is not indicative of any decrease in the operating efficiency of transit. For reference, Table 4.2 presents general transit operating cost trends from the 2007 Public Transportation Factbook.

Table 4.2 Operating Cost per Transit Trip
Excluding Paratransit

Year	Bus	Rail (CR, HR, LR)	All Modes
1995	$2.13	$2.33	$2.20
2000	$2.28	$2.15	$2.25
2006	$3.02	$2.68	$2.93

[94] American Public Transportation Association. 2007. Public Transportation Fact Book. http://www.apta.com/resources/statistics/Documents/FactBook/APTA_2007_Fact_Book.pdf.

In *Moving Cooler*, the 2006 operating cost per trip is multiplied by the total annual marginal trip increase (i.e., Level A trips – Base trips) to obtain total annual operating costs. Total annual operating costs are then decreased by the trip weighted load factor increase (see Table 9).

Results

Average annual implementation costs and total costs for Level A, B, and C are presented in Tables 4.3 and 4.4.

Table 4.3 Annual Implementation Costs (2010-2050)
Billions Increase over Baseline

	Average Annual Cost (Billions 2008 Dollars)		
Deployment Level	**Capital**	**Operations**	**Total**
Level A	$0.42	$0.94	$1.36
Level B	$0.83	$1.82	$2.65
Level C	$1.95	$4.38	$6.32

Table 4.4 Total Implementation Costs
Billions Increase over Baseline

	Total Cost (Billions (2008 Dollars)	
Deployment Level	**2010-2030**	**2010-2050**
Level A	$19.48	$52.48
Level B	$37.55	$102.61
Level C	$83.55	$243.77

4.3 Urban Transit Expansion

This measure focuses on expansion of all transit modes in urbanized areas to meet annual ridership growth rates as identified in the Bottom Line report.

Moving Cooler uses costs estimated for the Bottom Line to obtain capital and operations/maintenance costs through 2050. The total costs are the marginal additional investments required above needed costs for an annual 2.4 percent ridership growth rate.

Capital Costs

The Bottom Line cost model is extended from 2026 through 2050, using the 20-year trend for urban transit systems. Total capital costs for this strategy use Bottom Line difference in annual costs for the “maintain/maintain” scenario between the base, Level A, Level B, and Level C ridership growth rates.

The total capital costs are decreased based on forecasts used in *Moving Cooler* for increases in transit load factors. Based on results from the TERM model run (see Appendix B), the trip weighted load factor increase in 2050 for Level A is 15.9 percent, Level B 15.2 percent, Level C 14.9 percent. Using the Bottom Line assumption that approximately 64 percent of expansion costs go to fixed guideway transit (i.e., New Starts projects), this allows calculation of a cost weighted load factor increase. This results in a 14 percent reduction in total capital costs per year (assume this reduction is phased in linearly over the first 20 years). The cost weighted load factor is used for this strategy to reflect the proportionally higher expense for expanding rail-based transit.

Table 4.5 Transit Load Factor Adjustment

	Trip Share		2050 Load Factor Increase		
Mode	**2010**	**2050**	**Level A**	**Level B**	**Level C**
CR	5%	7%	8%	9%	8%
HRT	24%	39%	15%	15%	16%
LRT	5%	10%	17%	15%	15%
Bus	54%	44%	18%	16%	15%
Other	2%	<1%	6%	7%	7%
Cost Weighted Load Factor Increase			14.6%	14.2%	14.0%

Operating Costs

Using data from APTA’s 2007 Public Transportation Factbook, the estimate for operating costs per unlinked transit trip in 2006 is $2.80 (excluding paratransit services only). From 1995 to 2006, this number has increased from $2.07 per trip, a 35 percent increase or 2.5 percent increase annually. This growth rate is in line with Consumer Price Index increases from 1996 to 2006 (32.3 percent increase) and is not indicative of any decrease in the operating efficiency of transit.

In *Moving Cooler*, the 2006 operating cost per trip is multiplied by the total annual marginal trip increase (i.e., Level A trips – Base trips) to obtain total annual operating costs. Total annual operating costs are then decreased by the trip weighted load factor increase.

Results

Average annual implementation costs and total costs for Level A, B, and C are presented in Tables 4.6 and 4.7. All costs are presented in constant 2008 dollars.

Table 4.6 Annual Implementation Costs (2010-2050)
Billions Increase over Baseline

	Average Annual Cost (Billions 2008 Dollars)		
Deployment Level	**Capital**	**Operations**	**Total**
Level A	$3.84	$2.91	$6.75
Level B	$7.57	$5.76	$13.33
Level C	$17.73	$14.12	$31.85

Table 4.7 Total Implementation Costs
Billions Increase over Baseline

	Total Cost (Billions (2008 Dollars)	
Deployment Level	**2010-2030**	**2010-2050**
Level A	$111.55	$255.03
Level B	$218.34	$502.97
Level C	$489.39	$1,197.29

4.4 Intercity Rail

Capital Costs

The total capital cost estimate for maintaining and expanding the national intercity passenger rail network between 2008 and 2050 is $357.2 billion in 2007 dollars, an annualized cost of $8.1 billion.[95] Total capital costs above the National Surface Transportation Policy and Revenue Study Commission (NSTPRSC) recommended investment are based on an average cost per diverted vehicle mile. This is obtained from estimates of Federal capital assistance and diverted vehicle miles in the National Passenger Rail Working Group report for NSTPRSC in 2008. The results are:

- Level A (additional 5 percent passenger mile growth) – $13.6 billion above base;
- Level B (additional 10 percent passenger mile growth) – $27.1 billion above base; and
- Level C (additional 20 percent passenger mile growth) – $49.9 billion above base.

The added capital costs plus baseline NSTPRSC annual costs are averaged over 25 years for Level A, 20 years for Level B and 15 years for Level C. No additional capital costs are assumed beyond these timeframes (such as replacement vehicle purchases or rehabilitation).

Operating Costs

According to Amtrak financial reporting[96] for January to September 31, 2008, there were 6.159 billion passenger miles with total operating costs of $914.1 million (operations, fuel, utilities, facilities, materials and communications). This results in an average operating cost of $0.15 per passenger mile. Average operating cost per passenger mile is applied to total new passenger mile forecasts compared to the base for each level through 2050.

---

[95] National Surface Transportation Policy and Revenue Study Commission, *U.S Intercity Passenger Rail Network Through 2050*, December 2007.

[96] Amtrak. Annual Reports & Consolidated Financial Statements. http://www.amtrak.com/pdf/AmtrakAnnualReport_2008.pdf.

Results

Table 4.8 Annual Implementation Costs (2010-2050)
Billions Increase over Baseline

	Average Annual Cost (Billions 2008 Dollars)		
Deployment Level	**Capital**	**Operations**	**Total**
Level A	$0.433	$0.038	$0.471
Level B	$0.799	$0.072	$0.870
Level C	$1.698	$0.163	$1.861

Table 4.9 Total Implementation Costs
Billions Increase over Baseline

	Total Cost (Billions (2008 Dollars)	
Deployment Level	**2010-2030**	**2010-2050**
Level A	$17.04	$19.26
Level B	$31.13	$35.58
Level C	$64.94	$76.05

4.5 High-Speed Rail

Capital Costs

Total costs are from a variety of sources, including Federal Railroad Administration (FRA) studies, project-level environmental impact study (EIS) documents and project web sites. These are used to determine an average capital cost per passenger mile. The strategy considers up to 10 corridors as identified by FRA. When looking at available cost data for these corridors, capital costs range from $4.75 per passenger mile for corridors 1-5 to $4.08 per passenger mile for all 12 corridors. Using these ranges, the resulting total costs are: Level A $80.26 billion, Level B $83.01 billion, Level C $103.91 billion. For Level A, the total costs are split evenly over 25 years, 20 years for Level B, 15 years for Level C and then discounted to 2008 dollars. Costs in Level A, B, and C do not represent marginal costs over a forecasted baseline investment for this strategy.

Operating Costs

Annual operating costs are assumed to be 2.5 percent of total capital costs. This represents a total capital cost weighted average of available information from three high-speed rail corridors: California (2 percent), Midwest (6 percent) and Southeast (2.9 percent). Annual operating costs reach maximum when system construction is complete (assumes 10-year linear increase during implementation).

Results

Table 4.10 Annual Implementation Costs
2010-2050

	Average Annual Cost (Billions (2008 Dollars)		
Deployment Level	**Capital**	**Operations**	**Total**
Level A	$1.958	$0.571	$2.529
Level B	$2.025	$0.743	$2.768
Level C	$2.534	$1.189	$3.724

Table 4.11 Total Implementation Costs

	Total Cost (Billions (2008 Dollars)	
Deployment Level	**2010-2030**	**2010-2050**
Level A	$69.74	$99.55
Level B	$90.64	$108.15
Level C	$117.53	$144.20

5.0 High-Occupancy Vehicle (HOV) Lanes, Regional Car-Sharing and Commuting Strategies

5.1 HOV Strategies

A distinction is made between new HOV facilities and increased hours of operation of existing HOV facilities. It is assumed that the new HOV lanes are Quickchange Moveable Barriers™ (QMB) which would create an HOV lane from the off-peak direction of existing urban expressways. The costs were based on information on a study of a "Zipper Lane" in Honolulu.[97] From that study, a capital cost of $1,000,000 and $100,000 annual operating costs, in year 2000 dollars, per lane mile was obtained. The projects implemented in *Moving Cooler* are assumed to be a single additional lane in each direction. The center line miles of new HOV lanes was assumed to be the percent of the urban expressways to be implemented by deployment level multiplied by the miles of urban expressway in each *Moving Cooler* urban group (estimated as equal to a percent of the VMT in that group as determined from the parameter table estimated from Highway Statistics table HM-71 applied to the CLM of 224,348 miles of urban expressways from that same table). Based on the level of implementation it is estimated that:

- For Level A: 51,648 miles of QMB HOV lanes are created;
- For Level B: 66,150 miles of QMB HOV lanes are created; and
- For Level C: 145,015 miles of QMB HOV lanes are created.

[97] Papacostas, C S, Honolulu's Zipper Lane: A Moveable Barrier HOV Application, Compendium of Papers, Institute of Transportation Engineers 2000, District 6 Annual Meeting.

Table 5.1 New HOV Lane Annual Costs

Strategy	HOV CLM	Capital Cost	Life (Years)	Annualized Capital Cost	Annual Operating Cost	Total Annual Cost
Level A	51,648	$103.3 billion	20	$7.6 billion	$5.2 billion	$12.8 billion
Level B	66,150	$132.3 billion	20	$9.7 billion	$ 6.6 billion	$16.3 billion
Level C	145,015	$290.0 billion	20	$21.3 billion	$ 14.5 billion	$35.8 billion

Capital costs are only expended through 2030, defined as the completion date of the system for each level.

The HOV capital costs used in the final iteration of *Moving Cooler* results have not been changed per input from the Moving Cooler stakeholder committee. HOV costs and implementation schedule vary significantly depending on the infrastructure approach chosen.

Many stakeholder comments noted that "Zipper Lanes" represent an outdated HOV strategy. While the intent to illustrate how "Quickchange Moveable Barriers" (QMB) could utilize existing infrastructure to obtain more HOV lanes is a more cost-effective approach, recent experience indicates that state DOTs are moving away from this approach and investing in at-grade or grade separated HOV facilities since there are fewer distinct directional flows during the peak periods (congestion is seen in both directions during peak flows).

The study team notes that it is probably unrealistic to assume that HOV lanes could be implemented in the magnitude and with the deployment dates outlined in *Moving Cooler* without QMB. The costs for the barriers were not specific for the Hawaiian system but were taken from a review of such systems which was published in support of the Hawaii deployment (this included the Boston moveable barrier system). If QMB are not used and new lanes and ramps are constructed, the costs go up by several orders of magnitudes and the regulatory requirements for implementation become inconsistent with the schedules outlined in *Moving Cooler*. For these reasons, the study team decided to stick with the cost estimates for the QMB type HOV deployment.

Annual operations costs continue through 2050. For the 24/7 operation of existing HOV lanes, it is assumed that there are minimal regulatory and enforcement costs, therefore costs are assumed at zero.

5.2 Car-Sharing Strategies

The implementation costs of car-sharing strategies are equal to the cost of the number of cars acquired; assumed to be at a cost of $15,000 per car. The method for determining the number of cars acquired is detailed in Section 5.0, Table 5.12 of Appendix B. Level A represents current practice and expanded start-up of car-sharing organizations through 2020, while Level B and C set targets of number of residents per car through 2015.

It is assumed that members would be responsible for the fuel and operating maintenance costs and those costs are not included in this estimate. It also is likely that the subsidy would cover only some of the depreciation costs of the vehicles with the remaining depreciation costs assigned to the members. Since the percentage of the depreciation costs that would be assigned to the members was not established, the entire annualized capital costs are included below.

The description of the strategy suggests that only a start-up subsidy would be provided. It is therefore assumed that the capital costs of replacing the vehicles would be borne by the members and no costs would incur beyond the start up period. From an accounting perspective, it may be appropriate to assign the total capital costs as a one time cost in the first year of implementation rather than annualizing the costs over the life of the cars. Finally, there is no basis on which to determine the socioeconomic groups that would become members due to this strategy and therefore no basis to assign this subsidy to any socioeconomic group.

Table 5.2 Car-Sharing Costs

Strategy	Cars	Capital Cost	Years	Annualized Capital Cost	Annual Operating Cost	Total Annual Cost
Level A	49,000	$735 million	10	$91 million	$ 0	$91 million
Level B	98,000	$1.47 billion	5	$330 million	$ 0	$330 million
Level C	196,000	$2.94 billion	5	$660 million	$ 0	$660 million

5.3 Employer-Based Commute Strategies

Cost estimates were built up from general assumptions about the major inputs to commuter programs. Fare subsidies or other financial incentives to commuters are not included because these represent a transfer, rather than a net social cost. Therefore, the cost to the public sector and/or businesses of these programs is likely to be greater than the estimates shown here – offset by cost savings to the commuting public.

Costs were built up for the following five types of program expenses:

- Regional vanpool;
- Regional rideshare (including guaranteed ride home);
- Employer outreach;
- Administration and enforcement of transportation demand management (TDM) requirements; and
- Telework.

Annual costs were determined per metro area for large, medium, and small metro areas, and then aggregated across all areas. Capital costs were annualized based on an assumed average lifetime of the equipment. Key assumptions are discussed below.

- **General Parameters –** Administrative staff costs (salaries and overhead) of $100,000 per full-time equivalent (FTE).

- **Regional Vanpool –** Administrative staff varying from 0.5 to 2 FTEs by metro area size; $25,000 cost per van; 12-year lifetime; total number of vans corresponding to a roughly 0.5 percent vanpool mode share (1,000 in large metro areas).[98]

- **Regional Rideshare** – Administrative staff varying from 0.5 to 2 FTEs by metro area size; $100,000 software/setup cost lasting five years; guaranteed ride home (GRH) program costing $2/year per participant at 10 percent workforce participation.[99]

- **Employer Outreach –** Two hundred and fifty employers covered by each program staff (one day of outreach time per employer per year); total establishments vary by whether employers with >50 or >100 employees are covered by the program.

- **TDM Requirement Administration and Enforcement –** Two hundred and fifty employers covered by each program staff (same as for employer outreach only – essentially, a doubling of effort if requirements are added).

- **Telework –** Cost per new teleworker of $1,000/year to cover additional hardware and software, communications equipment, etc. This cost is assumed the same for both home-teleworkers and remote-office/telework center teleworkers.[100]

---

[98] For comparison, the San Diego Association of Governments' Ridelink program had 572 participating vanpools as of late 2007.

[99] http://www.vtpi.org/tdm/tdm18.htm.

Costs that are not included include:

- **Compressed Work Week (CWW) –** No costs are assumed to be associated with this strategy, aside from administrative costs of outreach/promotion programs as already described.
- **Vanpool Operating Costs –** In all likelihood, vanpool users will experience a net cost savings because of reduced automobile operating costs.
- **Additional Transit Operating Costs –** For large-scale travel shifts to transit, it may be necessary to account for additional transit service operating costs. This will be revisited in coordination with the Transit strategy cost estimates.

Discussion of Telework Costs

Telework cost estimates vary widely, depending upon assumptions such as what equipment the worker already has versus what is provided at additional cost, as well as the specific types of equipment provided. Furthermore, telework costs are likely to continue to decline in the future as technologies such as high-speed Internet access become ubiquitous and costs continue to decline. Therefore, the telework cost estimates should be viewed as highly uncertain. This is a particular problem since, as is shown below, the telework cost estimates are quite high.

Some studies have found business cost savings as a result of increased productivity. However, productivity impacts vary widely by worker and may be negative for some workers. Since it is likely that workers with the greatest interest in telework already are doing so, no further productivity benefits were assumed for programs that lead to additional telework penetration. In addition, it was assumed that most workers will still work in the office most of the week and retain their own office or desk space, and therefore there are no significant savings in office space from teleworking.

Results

Table 22 shows the resulting annual costs across all metro areas, by program category. This provides an indication of which parameters are most important in determining the overall cost estimates, and which are essentially negligible. Overall, telework costs are the highest (see discussion below). Employer outreach and TDM requirements are next-

[100] A 2006 GSA survey found an estimated total annual telework cost per employee ranging from $310 to $5,420 across 18 organizations interviewed, with a mean of $1,920 and a median of $1,088. See: http://www.teleworkexchange.com/ppts/Current-Telework-Costs-2.ppt#0. A Federal telework program run from 1999-2001 found an annual user cost per teleworker of $1,000 to $2,000 for remote teleworkers; see http://www.telework.gov/Reports_and_Studies/tw_rpt01/Dec01con.aspx.

highest, because of the significant labor involved in implementing meaningful outreach and enforcement programs. Capital costs for vanpools also are significant. Administrative costs for the regional rideshare and vanpool programs, as well as the GRH program, are small.

Table 5.3 Commuter Program Costs

Program	Element	Total Annual Cost, All Metro Areas (Millions)
Regional Vanpool	Administration	$27.7
	Capital (Vans)	$179.8
Regional Rideshare	Administration	$27.7
	Capital	$5.9
	Guaranteed Ride Home	$29.7
Employer Outreach	Admin – Employers >100 Workers	$215.7
	Admin – Employers >50 Workers	$367.7
TDM Requirements	Admin – Employers >50 Workers	$367.7
Telework	Additional 4% Telework	$5,940.0
	Additional 4% Public Sector Telework	$831.6

Table 5.4 shows the resulting cost for each strategy, in annual terms as well as over the analysis period. Some key assumptions in Table 23 need to be noted:

- Because they are both so large and yet so uncertain, telework costs are not included in the costs of Strategies 6.2.1, 6.2.4, and 6.2.7. It is likely that these strategies, which are general strategies to encourage alternative mode/commute patterns, will result in some shifting to telework. However, it also might be assumed that if these strategies are so expensive, that less costly strategies would be employed instead. Of course, telework may actually end up being a lower-cost and more attractive strategy for some workers compared to the time and other welfare costs of shifting to other modes of travel. Since such costs are not being included in this analysis, however, this comparison cannot be made.

- Strategy 6.1.5 is a four-day workweek for all government employees. It is likely that this will result in some cost savings to public agencies in building energy costs. On the other hand, energy costs at home may increase on the day off. The net effect is assumed to be zero. Administrative costs also are assumed to be zero.

- Strategy 6.2.7 includes a required parking fee on commercial parking. The costs in administering this fee will likely not be insignificant. However, because substantial mode shifts may be induced, the required effort for TDM requirements and outreach will probably be considerably lower. Therefore, the cost for this strategy is assumed to be the same as for Strategy 6.2.4.

Table 5.4 Commuter Strategy Costs
Millions

Strategy	Brief Description	Annual	2015-2030	2031-2050
6.1.1	Telecommuting and CWW goals and incentives	$5,940	$89,100	$118,800
6.1.2	Government agencies provide telecommuting and CWW option	$832	$12,474	$16,632
6.1.5	Required four-day workweek for government employees	$0	$0	$0
6.2.1	Outreach to employers >100, regional ridesharing and vanpooling	$486	$7,296	$9,728
6.2.4	TDM requirements for employers >100; outreach expanded to employers >50	$1,006	$15,094	$20,125
6.2.7	Tax on all commercial parking spaces, plus continuation of TDM requirements and outreach programs	$1,006	$15,094	$20,125

6.0 Regulatory Strategies

6.1 Nonmotorized Zones

This strategy is defined as converting a share of CBD and Activity Center streets to transit malls, linear parks or other nonmotorized zones. For all deployment levels, the timing of implementation is over 10 years, starting in 2010 in high-density regions and 2015 or 2020 in lower density regions.

The 16th Street Mall in Denver, Colorado is selected as the example on which cost estimates are based. This mall was opened in 1982 over 16 blocks for a total cost of $29.5 million. In 2008 dollars, this would equate to $4.88 million per block converted.

The average length of a nonmotorized zone is five blocks according to data from a 1992 survey of pedestrian malls completed in the United States in the 1970s.[101] Using this as a guidance, Level A assumes 25 percent of urbanized areas build at least one, five block nonmotorized zone. Level B assumes 75 percent of urbanized areas build at least one, five block nonmotorized zone. Level C assumes 100 percent of urbanized areas build at least two, five5 block nonmotorized zones. Implementation costs include capital construction costs only. Operations costs for transit using these zones are not included.

Table 6.1 Total Implementation Costs

	Total Cost (Billions (2008 Dollars)	
Deployment Level	**2010-2030**	**2010-2050**
Level A	$1.05	$1.39
Level B	$4.23	$4.23
Level C	$8.47	$8.47

[101] Rubenstein, H. (1992). *Pedestrian Malls, Streetscapes and Urban Spaces*. John Wiley & Sons, Inc.

6.2 Urban Parking Restrictions

Urban parking freezes, similar to those implemented in Boston and San Francisco, set caps for the total number of commuter parking spaces in central business districts and employment centers. For *Moving Cooler*, it is assumed that there is zero cost for implementing this strategy. As part of a discussion of co-benefits of this strategy, it is recognized that urban parking restrictions lead to employers developing more expansive travel demand management programs for their employees to offset the impact of fewer parking spaces. While there may be some cost to the private sector in this case, it also is likely that there are significant savings resulting from leasing fewer parking spaces.

6.3 Reduced Speed Limits

Reduced speed limit measures result in comprehensive reductions to 65 mph overall by 2020 for Level A, 60 mph overall by 2020 for Level B and 55 mph overall by 2015 for Level C. Using information on maximum posted speed limits for interstates by urban and rural areas from the Insurance Institute for Highway Safety[102] combined with data from the 2006 Highway Statistics publication,[103] total centerline miles by state at different maximum posted speed limits is determined.

To decrease all posted speed limits to a maximum of 65 mph would affect 25,317 centerline miles of interstates (61.4 percent of the national system). To decrease all posted speed limits to a maximum of 60 mph would affect 40,476 centerline miles of interstates (98.1 percent of the national system). The mileage estimates are multiplied by capital, maintenance, and administrative costs associated with enforcement.

Estimates from Saving Oil in a Hurry analysis of the potential of speed limit reductions, indicate an average cost of $26,000 per camera and estimates the need of one camera per direction every 6.2 miles.[104] Camera maintenance costs per site are estimated at $3,000 per year.[105] Annual operating and administration costs are obtained from a 2003 study of

---

[102] Insurance Institute for Highway Safety. Maximum posted speed limits; see http://www.iihs.org/laws/speedlimits.aspx.

[103] Office of Highway Policy Information. Federal Highway Administration. 2006 Highway Statistics; see http://www.fhwa.dot.gov/policy/ohim/hs06/index.htm.

[104] International Energy Agency. *Saving Oil in a Hurry*. 2005.

[105] http://www.itscosts.its.dot.gov/its/benecost.nsf/.

speed enforcement systems in the United Kingdom.[106] The results of this study indicate a 2008 cost of approximately $25,000 per camerar per year.

Table 6.2 Total Implementation Costs

	Total Cost (Billions 2008 Dollars)	
Deployment Level	2010-2030	2010-2050
Level A	$2.51	$4.06
Level B	$4.01	$6.50
Level C	$4.90	$7.46

[106] http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/07D81D8AB57059AE85256F430051A633?OpenDocument&Query=CApp

7.0 Operational and Intelligent Transportation System (ITS) Strategies

7.1 Eco-Driving

The strategy assumes no public sector costs for this analysis. It is recognized that implementation of eco-driving education programs will incur a public cost. Eco-driving programs could be included as part of drivers-education programs.

Sources for the costs for direct eco-driver training programs include details on a similar program in the Netherlands, which required an investment of 2 million Euros to train 6,500 driving instructors(Wilbers et al., 2006).[107]

7.2 Operations Strategies

The deployment of operations strategies mirrors the procedures used in FHWA's HERS Operations Preprocessor. The analysis starts by merging intelligent transportation systems (ITS) Deployment Tracking data from the Research and Innovative Technology Administration (RITA) with HPMS data (2006 in this case) so that current levels of deployment are known for each HPMS segment. Congestion levels (as determined by the V/C ratio) are calculated, the data are sorted, and the worst segments that do not have the strategy already present are selected for deployment.

As a starting point, the thresholds in Table 7.1 from Appendix B were used to determine the scope of each deployment level.

[107] http://www.iapsc.org.uk/presentations/0606_Kroon_combined.pdf.

The analysis makes use of the following assumptions and methodology:

- Deployment of strategies, except for Vehicle Infrastructure Integration (VII), is assumed to occur continuously throughout the analysis period.

- VII deployment and costs are based on the deployment curve in Volpe VII Benefit/Cost Analysis Report[108] (Chart 3.1: Projected Phase-In of VII Equipped Vehicles in the U.S. Fleet). Deployment Level B uses these forecasts, and they are adjusted appropriately for Levels A and C. Costs are the same for all scenarios because it is assumed that the public investment is the same; only penetration rate of vehicles varies.

- Cost per centerline mile for the strategies are based on those used in the HERS Operations Preprocessor.

Table 7.1 Operations Strategies Implementation Costs per Mile

Strategy	Capital Cost per Mile	Annual Operations and Maintenance Cost per Mile
Traveler Information	$100,000	$10,000
Ramp Metering	$51,000	$1,000
VMS	$50,000	$2,000
Signal Management	$25,000	$15,000
Automated Traffic Management	$100,000	$50,000
Integrated Corridor Management	$100,000	$50,000
Weather Management	$100,000	$10,000
Incident Management	$65,000	$18,000

[108] Volpe National Transportation Systems Center. 2008. Vehicle-Infrastructure Integration (VII) Initiative Benefit/Cost Analysis Version 2.3.

8.0 Bottleneck Relief and Capacity Expansion Strategies

8.1 Bottleneck Relief Strategies

The bottleneck analysis is based on previous work done for the American Highway Users Alliance (AHUA)[109] and FHWA.[110] These studies compiled a list of national bottlenecks, almost exclusively freeway-to-freeway interchanges, where the majority of delay occurs in urban areas. The following deployment levels were used in the analysis:

- **Deployment Level A) –** Improve 100 of top 200 bottlenecks to Level of Service "E" by 2030;
- **Deployment Level B) –** Improve all top 200 bottlenecks to Level of Service "E" by 2030; and
- **Deployment Level C) –** Improve all top 200 bottlenecks to Level of Service "D" by 2020 using pricing, system management, enhanced alternatives and capacity expansion in the mix best supported by cost/benefit analysis that accounts for indirection, secondary and cumulative impacts.

The analysis makes use of the following assumptions and methodology:

- Potential bottlenecks compiled from a list of 388 locations used in previous studies conducted for American Highway Users Alliance (AHUA) and FHWA.
- Updated data for locations using 2006 HPMS data.
- Estimated total delay at the locations using the methodology used in the AHUA and FHWA studies; this is based on the delay equations in FHWA's HERS model.

---

[109] AHUA, Unclogging America's Arteries: Effective Relief for Highway Bottlenecks, 2004, http://www.highways.org.

[110] Battelle Memorial Institute and Cambridge Systematics, Inc., *An Initial Assessment of Freight Bottlenecks on Highways*, prepared for Federal Highway Administration, Office of Transportation Policy Studies, October 2005.

- Ranked locations by total delay; select top bottlenecks for improvement in each year – the number improved depends on the scenario used.
- Deployment of strategies is assumed to occur continuously throughout the analysis period.
- Average cost per bottleneck to achieve LOS D conditions assumed at 750 million.

■ 8.2 Capacity Expansion Strategies

Capacity expansion strategies were estimated using the difference in results of HERS runs for maximum economic investment and constrained current funding. The two runs give a picture of highway system performance over time with maximum justified investment compared to current funding levels.

9.0 Freight Strategies

9.1 Rail Bottleneck Strategies

This measure addresses choke points in the rail system for carload and double-stack service so expected 2025 capacity restrictions are reduced by 20 percent, 30 percent, and 60 percent for Deployment Levels A, B, and C, respectively.

The cost savings analysis used the following assumptions:

- Assume 25 percent diverted to truck due to choke points:
  - Billion ton miles (B TM) diverted to truck in 2030 if no rail investment = 675.4;
  - B TM diverted back to rail under Level A (20 percent) = 135.1;
  - B TM diverted back to rail under Level B (30 percent) = 202.5;
  - B TM diverted back to rail under Level C (60 percent) = 337.5;
  - RR TM/gallon = 413, rail cost per ton-mile = $0.063; and
  - Truck TM/gallon = 155, truck cost per ton-mile = $0.097.

Corresponding capital investment levels are derived from National Surface Transportation Policy and Revenue Study Commission, Transportation for Tomorrow, December 2007, Volume 2, Exhibit 4-16).

9.2 Marine Strategies

Vehicle Costs: The Level B analysis estimated benefits that would result from investment in the waterway system that would allow water traffic to grow by 50 percent between 2006 and 2025,[111] rather than the reduced annual rate of 0.42 percent[112] that has resulted from underfunding of waterway improvements in recent years. The Level A and C

[111] Based on a forecast from Cambridge Systematics, Inc., *Waterborne Freight Transportation Bottom Line,* prepared for AASHTO, April 2006, page 4-6.

[112] Derived from U.S. Army Corps of Engineers, *Waterborne Commerce of the United States,* Calendar Year 2006, Part 5, Table 1-11, data for 1987 and 2006.

analyses assumed growth of 33.3 percent and 75 percent, respectively. These assumptions, combined with 2006 data for lakewise and internal movements,[113] produced estimates of increased waterway freight movements of 92.6, 138.9, and 208.3 billion ton-miles for the three analyses.

Reduced use of rail was estimating by dividing the above values by a relative circuity factor of 1.2,[114] and truck access hauls to/from ports were assumed to average 10 miles per movement. Changes in fuel consumption were then estimated by using fuel efficiency factors (in ton-miles per gallon) of 576 for water transport, 413 for rail, and 155 for truck.[115]

Implementation Costs: The total construction backlog for Corps of Engineers navigation projects was estimated to be $10 billion in 2003.[116] Based on this information, capital costs in 2008 dollars for the Level A, B, and C analyses were assumed to be $3, $6, and $12 billion. Annual maintenance costs were assumed to be five percent of the capital costs.

9.3 Truck Size and Weight Permits

Natural Resources

Vehicle Costs: Under this strategy, the 80,000 pound cap on gross vehicle weights (GVW) would be replaced by higher caps for longer combination vehicles (LCV) carrying natural resources for distances of up to 250 miles and operating under permit. Eligible commodities would include grain, fertilizer, coal, crushed stone, sand and other nonmetallic minerals. The new limits would be: 105,500 pounds for Level A; 129,000 pounds for Level B; and, for Level C, 138,000 pounds for eight-axle B Trains (and 129,000 pounds for other LCVs). These higher caps would apply on an appropriate set of truck roads that would include the Interstate System. The minimum distance of 250 miles is assumed as part of the strategy in order to minimize any reduction in the use of rail transport of these commodities, since rail is more fuel efficient than truck.

The VMT of trucks carrying the above commodities was 6.21 billion in 2002.[117] Applying our assumed growth rate of 1.4 percent annually produces an estimate of 6.57 billion VMT

---

[113] *Ibid.,* Table 1-4.

[114] Derived from Congressional Budget Office, *Energy Use in Freight Transportation,* 1982, Table A-16.

[115] Texas Transportation Institute, *A Modal Comparison of Domestic Freight Transportation Effects on the General Public,* prepared for the U.S. Department of Transportation, Maritime Administration, and the National Waterways Foundation, November 2007, Table 12.

[116] Robert F. Vining, *The U.S. Army Corps Budget: The Challenge to Meet Navigation Needs,* presentation to the National Waterways Conference, Waterways Rally and Budget Summit, March 6, 2003.

[117] U.S. Census Bureau, *2002 Vehicle Inventory and Use Survey,* December 2004, Table 8.

for these trucks in 2006. It is assumed that, under this strategy, shipments accounting for 25 percent of this VMT would be diverted from 80,000 pound trucks to LCVs operating at the above weight limits.

Fuel consumption rates for transport in hopper-bottom trailers operating in these configurations in 1995 at loaded weights of 80,000, 105,500, 129,000, and 138,000 pounds and operating empty 50 percent of the time were forecast in 1991 to be 9.65, 8.24, 7.35, and 6.88 mpg, respectively.[118] There does not appear to have been an increase in mpg for combination trucks between 1995 and 2006,[119] so these fuel consumption rates were used without adjustment. This information indicates that the strategy would save between 26.0 (Level A) and 39.6 (Level C) million gallons of diesel fuel in 2006.

Implementation Costs: Estimates of increased pavement and bridge costs were developed from cost responsibility data for the various configurations and operating weights presented in the 1997 Federal Highway Cost Responsibility Study.[120] These costs were converted to 2006 dollars using the FHWA Comparative Price Index for Highway Construction, and then to 2008 dollars using the Bureau of Labor Statistics Producer Price Index (PPI) for Highway Construction. Estimates of reduced driver costs and vehicle operating costs were developed from The Effect of Size and Weight Limits on Truck Costs[121] and converted to 1992 dollars using the Consumer Price Index (CPI-U), to 2003 dollars using the PPI for Trucking except Local (PDU4213), and to 2008 dollars using the PPI for Truck Transportation (PCU484). In addition, savings in costs for overseas shipment of containers were estimated using an assumed average charge of $2,000 per container shipped (in 2008 dollars).

Containers

Vehicle Costs: The Vehicle Inventory and Use Survey (VIUS)[122] contains no information on the VMT of trucks carrying loaded shipping containers, but it does indicate that the VMT of trucks carrying empty shipping containers was 794 million in 2002. It has been estimated that the percentage of combination-truck-miles operated empty on the Interstate

---

[118] Derived from data in Jack Faucett Associates, *The Effect of Size and Weight Limits on Truck Costs,* prepared for FHWA, revised October 1991.

[119] Actually, data in FHWA, *Highway Statistics,* Tables VM-201A, 1995 and VM-1, 2006 show a decline in average mpg from 5.9 to 5.1, though this is dues, at least in part, to increases in truck weight.

[120] FHWA, *Federal Highway Cost Responsibility Study,* 1997, Tables V-6, V-10, V-15, V-20, and V-27.

[121] Jack Faucett Associates, *op,cit.*

[122] U.S. Census Bureau, *2002 Vehicle Inventory and Use Survey,* December 2004, Table 8.

System (IS) is about 20 percent.[123] Applying this percentage to the estimate of empty operation and applying our assumed growth rate of 1.4 percent annually produces an estimate of 3.36 billion loaded VMT for trucks carrying shipping containers in 2006. It was assumed that half of this VMT currently is carried by five-axle combinations under the 80,000-pound weight limit, and half is carried under permit in six-axle combinations at weights of 90,000 pounds.

Under this strategy, loaded shipping containers could be carried under permit on the IS and on most other roads by eight-axle combinations (4S4s) for distances of up to 250 miles at weights of up to 110,000 pounds. (The minimum distance of 250 miles is assumed as part of the strategy in order to minimize any reduction in the use of rail transport of containers, since rail is more fuel efficient than truck.) It is assumed that, under this strategy, 80 percent of the freight currently carried in containers that are transported by truck would be carried in more heavily loaded containers having an average weight of 100,000 pounds, with half of the affected traffic currently being subject to the 80,000 pound weight limit and half currently being subject to the 90,000 pound limit.

Fuel consumption rates for transport in these configurations in 1995 at loaded weights of 80,000, 90,000 and 100,000 pounds were forecast in 1991 to be 5.75, 5.48, and 5.23 mpg, respectively.[124] There does not appear to have been an increase in mpg for combination trucks between 1995 and 2006,[125] so these fuel consumption rates were used without adjustment. After allowing for the higher fuel consumption rates of empty eight-axle combinations (relative to empty five- and six-axle combinations), the above information indicates that the strategy would save 23.7 million gallons of diesel fuel in 2006.

Implementation Costs: Estimates of increased pavement and bridge costs were developed from cost responsibility data for the various configurations and operating weights presented in the 1997 Federal Highway Cost Responsibility Study.[126] These costs were converted to 2006 dollars using the FHWA Comparative Price Index for Highway Construction, and then to 2008 dollars using the Bureau of Labor Statistics Producer Price Index (PPI) for Highway Construction. Estimates of reduced driver costs and vehicle operating costs were developed from The Effect of Size and Weight Limits on Truck Costs[127] and converted to 1992 dollars using the Consumer Price Index (CPI-U), to 2003 dollars using the PPI for Trucking except Local (PDU4213), and to 2008 dollars using the

---

[123] Interstate Commerce Commission, Empty/Loaded Truck Miles on Interstate Highways During 1976, April 1977, Table 1.

[124] Derived from data in Jack Faucett Associates, *The Effect of Size and Weight Limits on Truck Costs,* prepared for FHWA, revised October 1991.

[125] Actually, data in FHWA, *Highway Statistics,* Tables VM-201A, 1995 and VM-1, 2006 show a decline in average mpg from 5.9 to 5.1, though this is due, at least in part, to increases in truck weight.

[126] FHWA, *Federal Highway Cost Responsibility Study,* 1997, Tables V-6, V-10, V-15, V-20, and V-27.

[127] Jack Faucett Associates, *op,cit.*

PPI for Truck Transportation (PCU484). In addition, savings in costs for overseas shipment of containers were estimated using an assumed average charge of $2,000 per container shipped (in 2008 dollars).

9.4 Weigh Station Bypasses and Weigh-in-Motion (WIM)

Vehicle Costs: There currently are two major weigh station bypass systems, PrePass and NorPass, plus the Green Light system used in Oregon. A major limitation on the benefits of these systems results from a restriction that PrePass transponders not be used to communicate with non-PrePass systems. To achieve the maximum benefits of weigh station bypass, a single system should be implemented throughout the country allowing all transponder-equipped trucks to communicate with all weigh stations.

It has been estimated that the interoperability restriction prevents 500,000 bypasses per year in Oregon alone.[128] Comparing truck VMT in Oregon to National VMT suggests that, a single national bypass system would allow the annual number of bypasses to increase by about 39.4 million. One evaluation of the benefits of bypass systems[129] summarizes the range of estimates of time and fuel saved per bypass. The midpoints of these two ranges are approximately three minutes saved and 0.1 gallon of diesel fuel saved.

High-speed WIM screening without checking of electronic credentials is primarily of value at weigh stations where safety inspections are not conducted. It was assumed that the number of such sites is half the number at which electronic credentialing is used, and that the benefits are half those for full weigh station bypass systems.

Implementation Costs: Currently, eight of the contiguous states do not have bypass systems, most of which are relatively small. Assuming that an average of 10 weigh stations per state would require installation of a new system, the number of new systems required would be 80. Implementation costs for new systems are estimated to be $150,000 per weigh station, with annual operating and administrative costs of $10,000 per weigh station plus $15,000 per state.[130] Costs for modifying existing bypass systems to eliminate interoperability restrictions were not considered.

---

[128] Oregon DOT, "Green Light" Emission Testing Project, August 2008, page 3.

[129] Carolyn J. Rodier, Susan A. Shaheen and Ellen Cavanaugh, *Virtual Commercial Vehicle Compliance Stations: A Review of Legal and Institutional Issues,* University of California Davis, Institute of Transportation Studies, 2005, page 8.

[130] Estimates were obtained from a review of U.S. data by Tri-Global Solutions Group and IBI Group, *Cost Benefit Study of Electronic Clearance and Roadside Inspection for Canada*, prepared for Transport Canada, June 2003, Chapter 3, page 9.

The value of time saved was estimated by multiplying total time saved by the current HERS estimate of the average value of time for combination trucks of $36.05.[131] The value of fuel saved was estimated by multiplying total fuel saved by the price of diesel fuel.

9.5 Truck Stop Electrification

Vehicle Costs: There are about 5,000 truck stops in the country. As of October 2008, 136 of these had been electrified.[132] For the Truck Stop Electrification strategy, it was assumed that varying numbers of the remaining truck stops would be electrified by 2025, 2020, or 2015.

The average number of spaces to be electrified per truck stop was taken to be 40 (based on data from a proposed electrification project for Oregon and Washington.[133]) On average, 30 percent of available electrified spaces are estimated to be used in any 24-hour period, with the average period of utilization being 8 hours, and with one gallon of diesel fuel saved per hour of use and 3.8 kW of electricity used during this time.[134]

Implementation Costs: Capital and operating and maintenance (O&M) costs were estimated using data for two truck stops in New York,[135] and converting from 2004 dollars to 2008 dollars by multiplying by 1.119, as indicated by the GDP deflator. In 2004 dollars, the source indicated that capital costs were $10,000 per space, and O&M costs per space were $100 for maintenance, $25 for insurance, and $1,314 for overhead labor. The capital-cost estimate of an average of $10,000 per space was assumed to apply to all spaces constructed under Level A assumptions. Level B and C implementations were assumed to include electrification of some truck stops where capital costs would be higher. Accordingly, average capital costs were assumed to be 10 percent higher for Level B and 20 percent higher for Level C.

---

[131] FHWA, *Highway Economic Requirements System.*

[132] U.S. Department of Energy, Alternative Fuels and Advanced Vehicles Data Center, http://www.afdc.energy.gov/afdc/vehicles/idle_reduction_stations.html, accessed October 9, 2008.

[133] The Climate Trust, Truck Stop Electrification, http://www.climatetrust.org/offset_truckstop.php, accessed October 9, 2008.

[134] Thomas L. Perrot, et al., "Truck Stop Electrification as a Long-Haul Tractor Idling Alternative", TRB 2004 Annual Meeting CD-ROM, December 2003.

[135] Antares Group, Inc., *Summary of Operations: Truck Stop Electrification Facilities on the New York State Freeway,* prepared for the New York State Energy Research and Development Authority, January 2005, Section 5.

Reduced costs of energy were derived from the above estimates of electricity requirements and diesel fuel saved and from estimated 2008 prices of $3.90 per gallon for diesel fuel and $0.202 per KWhr for electricity.

9.6 Truck APUs and HVAC Systems

Vehicle Costs: Sleeper cabs are estimated to idle 2,400 hours per year[136] and to use one gallon of diesel fuel per hour when idling.[137] Auxiliary power units (APU) are estimated to use 0.3 gallons of diesel fuel per hour,[138] and battery-operated heating and cooling systems are estimated to require between 0.03 and 0.06 gallons of diesel fuel for battery recharging per hour of battery operation.[139] In addition, the ratio of numbers of sleeper cabs to total VMT of all combination trucks is 5.95 per million VMT.[140]

Estimates of the benefits of APUs and battery-operated heating and cooling systems per million VMT of combinations trucks were developed using the above information and assuming that: 90 percent of sleeper cabs already do not have APUs or battery-operated heating and cooling systems; there will be a 50/50 split between the two technologies for future implementation; and the average fuel consumption of battery-operated heating and cooling systems is 0.05 gallons of diesel fuel per hour.

Implementation Costs: There were 666,300 sleeper cabs in 2002.[141] For purposes of analysis, the above assumptions indicate that 10 percent of these already are equipped with APUs or battery-operated heating and cooling systems, 45 percent will be equipped with APUs in the future, and 45 percent will be equipped with battery-operated heating and cooling systems in the future.

---

[136] *Bulk Transporter,* "Thermo-King Discusses Idle Reduction", http://bulktransporter.com/fleet/, October 1, 2007, accessed October 14, 2008.

[137] Thomas L. Perrot, et al., "Truck Stop Electrification as a Long-Haul Tractor Idling Alternative", TRB 2004 Annual Meeting CD-ROM, December 2003.

[138] Business Wire, "Navistar's Fleetrite Auxiliary Power Unit To Help Fleet Truck Fuel Consumption", July 31 2008.

[139] Business Wire, "Bergstrom, Firefly Energy Agree to Test, Co-Market NITE™ Sleeper Cab Cooling System Powered by Oasis™ Group 31 Battery", January 29, 2008.

[140] U.S. Census Bureau, *2002 Vehicle Inventory and Use Survey,* December 2004.

[141] *Ibid.*

APUs cost $9,000[142] and battery systems cost $3,500.[143] It is assumed that both types of system require replacement, on average, after 10 years, either because the system wears out or because the sleeper cab is scrapped. In addition, it is assumed that battery packs have to be replaced every two years, at a cost of $100. In addition, it is assumed that all states will provide appropriate weight allowances for APUs and battery packs, so that these devices have no effect on the maximum payload that can be carried. Finally, for simplicity, the small increase in fuel consumption due to increased vehicle weight is ignored.

9.7 Truck-Only Toll Lanes

Vehicle Costs: Annual fuel consumption savings for commercial vehicles using truck-only toll lanes is multiplied by forecast diesel fuel prices to obtain estimates of cost savings.

Implementation Costs: The Georgia Department of Transportation (GDOT) completed a Statewide Truck Lanes Needs Identification Study in April 2008.[144] Table 22 of this report presented total implementation cost estimates and annual operations and maintenance cost estimates. Phase I of the Atlanta system, which covered 25 percent of interstate VMT in the Atlanta region cost $7.479 billion. Phase II covered 44 percent of interstate VMT at a total cost of $13.209 billion. These figures were translated into implementation cost per vehicle mile traveled with all LH (large, high-density regions) implementing systems similar to Atlanta Phase II ($0.61/VMT) and all LL (large, low-density regions) implementing systems similar to Atlanta Phase I ($0.20/VMT).

9.8 Urban Consolidation Centers

Vehicle Costs: A small number of Urban Consolidation Centers (UCC) have been implemented in Europe and Asia, but none in the United States. The literature contains effectiveness information from six of these centers,[145],[146] including one that was

[142] *Bulk Transporter, op.cit.*

[143] California Air Resources Board, "Alternatives to Primary Engine Idling", undated.

[144] www.dot.state.ga.us/INFORMATIONCENTER/PROGRAMS/studies/trucklanestudy.

[145] Michael Brown, et al., *Urban Freight Consolidation Centres,* Final Report, University of Westminster, prepared for the (British) Department for Transport, November 2, 2005.

[146] Kristof Carlier, Developments in Urban Transport Since the 2001 White Paper, Annex XVI of *Assessment of the Contribution of the TEN and Other Transport Policy Measures to the Mid-Term*

(Footnote continued on next page...)

unsuccessful and has been closed, and one, at Heathrow Airport, that serves only the airport and not an entire urban area. Estimates of reductions in truck VMT and in fuel consumption are fairly limited; however, it has been estimated that the UCC in Bremen, Germany, results in monthly savings of about 6,000 truck-miles of travel and 250 gallons of diesel fuel.[147] Unfortunately, the source does not relate these figures to total truck VMT or truck fuel consumption.

In the United States, 8.6 percent of the VMT of combination trucks is operated by Less-Than-Truckload (LTL) carriers.[148] For purposes of analysis, it was conservatively assumed that, in large urbanized areas half of this VMT represents operations that could be served by a UCC, and that use of such centers would reduce the VMT of affected operations by 10 percent in large high-density areas and by eight percent in large low-density areas. Similarly, it was conservatively assumed that, in medium-sized high-density urbanized areas, 40 percent of LTL operations could be served by a UCC, resulting in a six percent reduction in the VMT of affected operations. It was assumed that only large high-density urbanized areas would be served by UCCs under a Level A implementation, but that all three of these area types would be served under a Level C implementation.

Implementation Costs: The literature contains no information on the cost of building UCCs. However, these costs are clearly related to the size (population) of the area that they are designed to serve. For purposes of analysis, development costs were assumed to be $5 million per million persons in the area.

Implementation of the White Paper on European Transport Policy for 2010, Final Report, DG TREN, European Commission, October 28, 2005.

[147] *Ibid.*, page 12.

[148] U.S. Census Bureau, *2002 Vehicle Inventory and Use Survey,* December 2004.