Appendix A

Highway Investment Analysis Methodology

Highway Investment Analysis Methodology

Investments in highway resurfacing and reconstruction and in highway and bridge capacity expansion are modeled by the Highway Economic Requirements System (HERS), which has been used since the 1995 C&P Report. This appendix describes the basic HERS methodology and approach in slightly more detail than is presented in Part II, including the treatment of intelligent transportation system (ITS) deployment and operations strategies, the allocation of investment across improvement types, the calculation of the highway backlog, and procedures that link investment levels to revenues and simulate the effect of universal congestion pricing. Also described are some of the changes that have been made to the model since the 2008 C&P Report. These include the refinement of the equations for predicting crash rates, updates to the capital improvement cost matrix and, the addition of a new procedure to quantify greenhouse gas (GHG) emissions and their associated costs.

Highway Economic Requirements System

The HERS model begins the investment analysis process by evaluating the current state of the highway system using information on pavements, geometry, traffic volumes, vehicle mix, and other characteristics from the Highway Performance Monitoring System (HPMS) sample dataset. Using section-specific traffic growth projections, HERS forecasts future conditions and performance across several funding periods. As used in this report, the future analysis covers four consecutive 5-year periods. At the end of each period, the model checks for deficiencies in eight highway section characteristics: pavement condition, surface type, volume/service flow (V/SF) ratio (a measure of congestion), lane width, right shoulder width, shoulder type, horizontal alignment (curves), and vertical alignment (grades).

Once HERS determines that a section's pavement or capacity is deficient, it identifies potential improvements to correct some or all of the section's deficient characteristics. The HERS model evaluates seven kinds of improvements: resurfacing, resurfacing with shoulder improvements, resurfacing with widened lanes (i.e., minor widening), resurfacing with added lanes (i.e., major widening), reconstruction, reconstruction with widened lanes, and reconstruction with added lanes. For reconstruction projects, the model allows for upgrades of low-grade surface types when warranted by sufficient traffic volumes. For improvements that add travel lanes, HERS further distinguishes between those that can be made at "normal cost" and those on sections with limited widening feasibility that could only be made at "high cost." HERS may also evaluate alignment improvements to improve curves, grades, or both.

Q&A

Where can I find more detailed technical information concerning the HERS model?

The Federal Highway Administration has previously developed a Technical Report for HERS. The most recent printed edition, dated December 2000, is based on HERS version 3.26, which was used in the development of the 1999 edition of the C&P report. An update to this document is currently underway, and should be completed in 2011.

The FHWA also has developed a modified version of HERS for use by States. This model, HERS-ST, builds on the primary HERS analytical engine with a number of customized features to facilitate analysis on a section-by-section basis. HERS-ST version 4.4 is largely based on HERS version 4.097, which was utilized in developing the 2004 edition of the C&P report. "The Highway Economic Requirements System – State Version: Technical Report" is available on request from the FHWA; see http://www.fhwa.dot.gov/infrastructure/asstmgmt/hersdoc.htm.

When evaluating which potential improvement, if any, should be implemented on a particular highway section, HERS employs incremental benefit-cost analysis. Such an analysis compares the benefits and costs of a candidate improvement relative to a less-aggressive alternative—for example, reconstructing and adding lanes to a section may be compared with reconstruction alone. The HERS model defines benefits as reductions in direct highway user costs, agency costs, and societal costs. Highway user benefits include reductions in travel time costs, crash costs, and vehicle operation costs (e.g., fuel, oil, and maintenance costs); agency benefits include reduced routine maintenance costs (plus the residual value of projects with longer expected service lives than the alternative); and societal benefits include reduced vehicle emissions. Increases in any of these costs resulting from a highway improvement (such as higher emissions rates at high speeds or the increased delay associated with a work zone) would be factored into the analysis as a negative benefit or "disbenefit."

Dividing these improvement benefits by the capital costs associated with implementing the improvement results in a benefit-cost ratio (BCR) that is used to rank potential projects on different highway sections. The HERS model implements improvements with the highest BCR first. Thus, as each additional project is implemented, the marginal BCR declines, resulting in a decline in the average BCR for all implemented projects. However, until the point where the marginal BCR falls below 1.0 (i.e., costs exceed benefits), total net benefits will continue to increase as additional projects are implemented. Investment beyond this point would not be economically justified because it would result in a decline in total net benefits.

Because the HERS model analyzes each highway section independently rather than the entire transportation system, it cannot fully evaluate the network effects of individual highway improvements. While efforts have been made to indirectly account for some network effects, HERS is fundamentally rooted to its primary data source, the national sample of independent highway sections contained in the HPMS. To fully recognize all network effects, it would be necessary to develop significant new data sources and analytical techniques.

Highway Investment Backlog

To determine which action items to include in the highway investment backlog, HERS evaluates the current state of each highway section before projecting the effects of future travel growth on congestion and pavement deterioration. Any potential improvement that would correct an existing pavement or capacity deficiency and that has a BCR greater than or equal to 1.0 is considered part of the current highway investment backlog.

As noted in Chapter 9, the backlog estimate produced by HERS does not include either rural minor collectors or rural and urban local roads and streets (since HPMS does not contain sample section data for these functional systems), nor does it contain any estimate for system enhancements. The backlog for the bridge portion of system rehabilitation is modeled separately through the National Bridge Investment Analysis System (NBIAS), which is discussed in Appendix B.

HERS Crash Rate Equations

The HERS model contains equations that predict for each highway section the vehicle crash rate per 100 million vehicle miles traveled (VMT) as a function of section characteristics (e.g. median width, shoulder width, number of intersections). The model also contains parameters for the average number of fatal, and nonfatal, injuries per crash by highway functional class. In preparation for this report, these parameters as well as the crash equations have been re-calibrated for consistency with data reported for 2007; previously, these parameters and equations had been benchmarked to data for 1995. The recalibration had the effect of reducing the overall estimate of crash costs by about 30 percent, which is partly attributable to the actual improvement in road safety that occurred between the original and updated calibration years. An indication of this improvement is the large decrease in the crash fatality rate in recent years identified in Chapter 5. Another reason why recalibration reduced the HERS estimated crash costs is that the 2007 data on crash incidence included only reported crashes. HERS used to include a factor to allow for unreported crashes, but omitting this factor made it easier to compare HERS estimates of crash incidence with other published estimates. For the recalibration, data on crash incidence was obtained from the Highway Safety Information System to which several States supply data from their crash records.

Greenhouse Gas Emissions

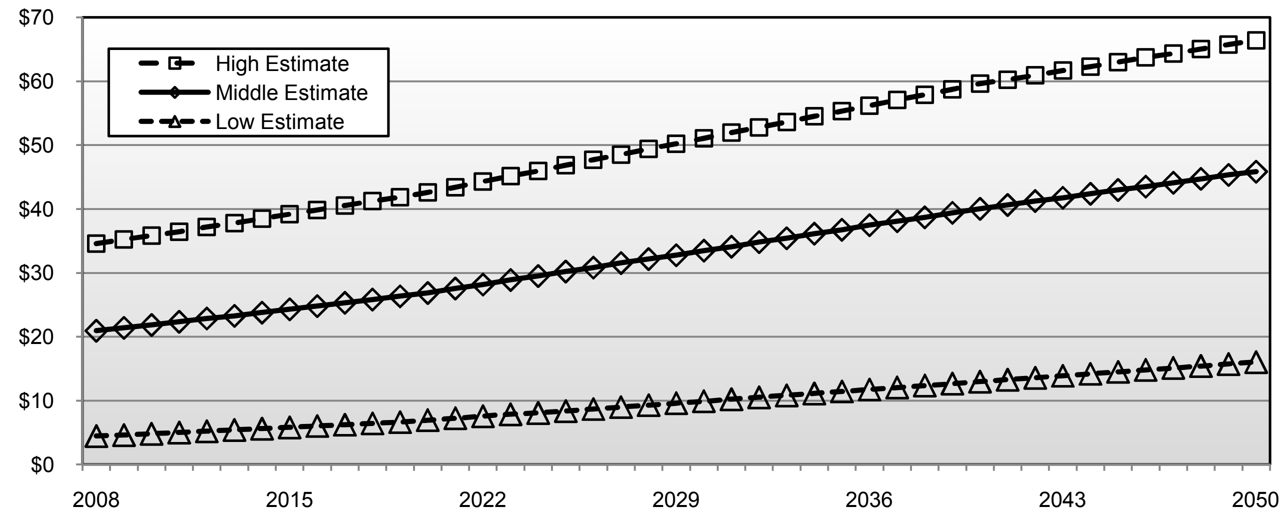
Road traffic generates an appreciable share of anthropogenic emissions of GHG. In the United States, passenger vehicles alone account for roughly 20 percent of emissions of carbon dioxide,[1] which account for about 95 percent of the global warming potential from passenger vehicle operation. In line with carbon dioxide emissions being the dominant concern, a capability for quantifying and costing these emissions has been added to the HERS model for the preparation of this report.

The quantification of CO_2 emissions from motor vehicle traffic is based on the amounts of gasoline and diesel fuel consumed (alternative fuels have yet to be incorporated into the model). Emissions directly from vehicles amount to 8,852 grams of CO_2 per gallon of gasoline consumed, and 10,239 grams per gallon of diesel fuel. These emissions may be termed "tailpipe emissions' since they result mainly from the combustion process, but they also result to some extent from evaporative release of vehicle fuel. In addition to these direct emissions, the production of fuel and the distribution processes for delivering fuel to vehicles produce emissions as well. HERS allows users of the model the option of adding these upstream emissions, about which there is greater quantitative uncertainty, to the direct emissions. The estimates of upstream emissions are 2,072 grams of CO_2 per gallon of gasoline consumed, and 2,105 grams CO_2 per gallon of diesel.

A recent study by a Federal interagency working group (Interagency Working Group on Social Cost of Carbon 2010) estimated the costs to society from incremental CO_2 emissions. The group's estimates of this social cost of carbon were intended to include, at a minimum, the monetized impacts of emissions-induced climate change on net agricultural productivity, on human health, on property damages from increased flood risk, and on the value of ecosystem services. Low, medium, and high estimates of the social cost per metric ton of carbon were formed for each year from 2010 through 2050 using alternative discount rates. For 2010, the medium estimate was about $21, meaning that an incremental ton of CO_2 released into the atmosphere in that year would have present and future discounted costs totaling $21. For the same year, the low and high estimates were $4.55 and $34.61. The estimates increase over the analysis period as shown in *Exhibit A-1*. All estimates were in 2007 dollars. For the baseline analyses presented in this report, the medium estimates were extrapolated back to 2008, re-expressed in 2008 dollars, and then averaged across the 5 years in each funding period.

Exhibit A-1

Social Marginal Cost per Metric Ton of CO_2 Emission Estimates, in Constant 2008 Dollars



Source: Interagency Working Group on Social Cost of Carbon, United States Government 2010, Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.

Highway Operational Strategies

One of the key modifications to HERS featured in previous reports was the ability to consider the impact of highway management and operational strategies, including ITS, on highway system performance. This feature is continued in this report with only minor modifications. Current and future investments in operations are modeled outside of HERS, but the impacts of these deployments were allowed to affect the model's internal calculations and, thus, to also affect the capital improvements considered and implemented in HERS.

Among the many operational strategies available to highway agencies, HERS considers only certain types based on the availability of suitable data and empirical impact relationships. Grouped by category— arterial management, freeway management, incident management, and travel information —these are:

- Arterial Management
  - Signal Control
  - Electronic Roadway Monitoring (considered to be a supporting deployment necessary to other operations strategies)
  - Variable Message Signs

- Freeway Management
  - Ramp Metering (preset and traffic-actuated)
  - Electronic Roadway Monitoring (considered to be a supporting deployment necessary to other operations strategies)
  - Variable Message Signs
  - Integrated Corridor Management (ICM), with and without comprehensive deployment of Vehicle Infrastructure Integration (VII) technologies
  - Active Traffic Management, which includes lane controls, queue warning systems, and Variable Speed Limits (VSL), also known as “speed harmonization”.
- Incident Management (freeways only)
  - Incident Detection (free cell phone call number and detection algorithms)
  - Incident Verification (surveillance cameras)
  - Incident Response (on-call service patrols)
- Traveler Information
  - 511 systems
  - Advanced in-vehicle navigation systems with real-time traveler information (enabled by Vehicle-Infrastructure Integration deployment)
  - Incident response (on-call service patrols).

Creating the operations improvements input files for use in HERS involved four steps: determining current operations deployment, determining future operations deployments, determining the cost of future operations investments, and determining the impacts of operations deployments. Different levels and types of deployments can be selected for an individual scenario.

Current Operations Deployments

To determine current operations deployments on the HPMS sample sections, data were used from three sources: HPMS universe data, HPMS sample data, and data from the ITS Deployment Tracking System. These section-level determinations took into account that operational deployments occur over corridors (or even over entire urban areas, as with traffic management centers).

Future Operations Deployments

For future ITS and operational deployments, three scenarios were developed. For the “Continuation of Existing Deployment Trends” scenario, existing deployments in urban areas were correlated with the congestion level and area population in order to predict on the basis of these factors where future deployments will occur. This scenario is reflected in the analyses presented in Chapters 7 and 8.

The other two scenarios were developed for the supplemental analysis presented in Chapter 9. The “Aggressive Deployment” scenario assumes that deployment accelerates above existing trends and expands to more advanced strategies. The “Full Immediate Deployment” scenario differs from the “Aggressive Deployment” scenario in assuming that all deployments will occur immediately rather than being phased in over 20 years. The "Full Immediate Deployment" scenario is intended to illustrate the maximum potential impact of the strategies and technologies modeled in HERS on highway operational performance. *Exhibit A-2* identifies the strategies employed in each scenario.

Exhibit A-2

Types of Operations Strategies Included in Each Scenario

Operations Strategy	Scenario: Continue Existing Trends	Scenario: Aggressive and Full Immediate Deployment
Arterial Management		
Signal Control	●	●
Emergency Vehicle Signal Preemption	●	●
Variable Message Signs		●
Advanced Traveler Information		●
Freeway Management		
Ramp Metering	●	●
Variable Message Signs	●	●
511 Traveler Information	●	
Advanced Traveler Information		●
Integrated Corridor Mgmt.		●
Active Traffic Mgmt.		●
Incident Management (Freeways Only)		
Detection	●	●
Verification	●	●
Response	●	●

Source: Highway Economic Requirements System.

Operations Investment Costs

The unit costs for each deployment item were taken from the U.S. Department of Transportation's (U.S. DOT's) *ITS Benefits Database* and *Unit Costs Database* and supplemented with costs based on the ITS Deployment Analysis System (IDAS) model. Costs were broken down into initial capital costs and annual operating and maintenance costs. Also, costs were determined for building the basic infrastructure to support the equipment, as well as for the incremental costs per piece of equipment that is deployed. A major addition to operations deployment costs in this report is the inclusion of traffic signal replacement costs, which were not previously considered in the estimated capital costs.

Impacts of Operations Deployments

Exhibit A-3 shows the estimated impacts of the different operations strategies considered in HERS. These effects include the following:

- Incident Management: Incident duration and the number of crash fatalities are reduced. Incident duration is used as a predictor variable in estimating incident delay in the HERS model.
- Signal Control: The effects of the different levels of signal control are directly considered in the HERS delay equations.
- Ramp Meters, Variable Message Signs, Variable Speed Limits (VSL), Integrated Corridor Management, and Traveler Information: Delay adjustments are applied to the basic delay equations in HERS. VSL is assumed to have a small impact on fatalities as well.

Based on the current and future deployments and the impact relationships, an operations improvements input file was created for each of the two deployment scenarios. The file contains section identifiers, plus current and future values (for each of the four funding periods in the HERS analysis) for the following five fields:

- Incident Duration Factor
- Delay Reduction Factor
- Fatality Reduction Factor
- Signal Type Override
- Ramp Metering.

Exhibit A-3

Impacts of Operations Strategies in HERS (Highway Economic Requirements System)

Operations Strategy	Impact Category	Impact
Arterial Management		
Signal Control	Congestion/Delay	Signal Density Factor = n(nx+2)/(n+2), where n = # of signals per mile x = 1 for fixed time control 2/3 for traffic actuated control 1/3 for closed loop control 0 for real-time adaptive control/SCOOT/SCATS Signal Density Factor is used to compute zero-volume delay due to traffic signals
Electronic Roadway Monitoring	Congestion/Delay	Supporting deployment for corridor signal control (2 highest levels) and traveler information
Emergency Vehicle Signal Preemption		
Variable Message Signs	Congestion/Delay	-0.5% incident delay
Freeway Management		
Ramp Metering		
Preset	Congestion/Delay	New delay = ((1 - 0.13)(original delay)) + 0.16 hrs per 1000 VMT
Traffic Actuated	Congestion/Delay	New delay = ((1 - 0.13)(original delay)) + 0.16 hrs per 1000 VMT
	Safety	-3% number of injuries and PDO accidents
Electronic Roadway Monitoring	Congestion/Delay	Supporting deployment for ramp metering and traveler information
Variable Message Signs	Congestion/Delay	-0.5% incident delay
Integrated Corridor Management	Congestion/Delay	-7.5% total delay without VII, 12.5% total delay with VII
Active Traffic Management	Congestion/Delay Safety	-7.5% total delay -5% fatalities
Incident Management (Freeways Only)		
Detection Algorithm/ Free Cell	Incident Characteristics Safety	-4.5% incident duration -5% fatalities
Surveillance Cameras	Incident Characteristics Safety	-4.5% incident duration -5% fatalities
On-Call Service Patrols		
Typical	Incident Characteristics Safety	-25% incident duration -10% fatalities
Aggressive	Incident Characteristics Safety	-35% incident duration -10% fatalities
All Combined	Incident Characteristics Safety	Multiplicative reduction -10% fatalities
Traveler Information		
511 Only	Congestion/Delay	-1.5% total delay, rural only
Advanced Traveler Information (VII-enabled)	Congestion/Delay	-3% total delay, all highways

HERS Improvement Costs

For the 2004 C&P Report, significant changes were made to the structure of the HERS improvement cost matrix, the assumed unit costs in that matrix, and the manner in which those values were applied. The improvement cost updates reflected in the 2004 C&P Report were based on highway project data from six States (see Appendix A of that report for more information). Though adequate in most respects, that dataset was relatively thin in certain key areas. The 2004 update disaggregated the improvement cost values in urban areas by functional class and by urbanized area size. Three population groupings were used: small urban (populations of 5,000 to 49,999), small urbanized (populations of 50,000 to 200,000), and large urbanized (populations of more than 200,000). However, the data used to create values for the large urbanized areas did not include a significant number of projects in very large urbanized areas, and concerns were raised about the degree of construction cost comparability within this category.

For the 2006 C&P Report, additional project cost data were collected for large urbanized areas, rural mountainous regions, and high-cost capacity improvements. These data were used to update the HERS improvement cost matrix, which was also modified to include a new category for major urbanized areas with populations of more than 1 million. The HERS improvement cost matrix was adjusted further for the 2008 C&P Report based on some additional analysis of the data previously collected. For this report, no changes were made to the cost matrix except to adjust it for the change in the National Highway Construction Cost Index between 2006 and 2008.

Exhibit A-4 identifies the costs per lane mile assumed by HERS for different types of capital improvements. For rural areas, separate cost values are applied by terrain type and functional class, while costs are broken down for urban areas by population area size and type of highway. These costs are intended to reflect the typical values for these types of projects in 2006, and thus do not reflect the large variation in cost among projects of the same type even in a given year. Such variation is evident in the project-level data on which these typical values are based, and are attributable to a number of location-specific factors. For example, the costs assumed for highway widening projects will be predicated on each section having a number of bridges typical for its length, but in reality some sections will have more bridges than other sections of equal length, which adds to costs. Among other factors that could make costs unusually high are complicated interchanges, major environmental issues, and/or other extreme engineering issues.

The values shown for adding a lane at "Normal Cost" reflect costs for projects where sufficient right-of-way is available or could be readily obtained to accommodate additional lanes. The values for adding lane equivalents at "High Cost" are intended to reflect situations in which conventional widening is not feasible and alternative approaches would be required in order to add capacity to a given corridor. Such alternatives would include the construction of parallel facilities, double-decking, tunneling, or the purchase of extremely expensive right-of-way. While HERS models these lane equivalents as though they are part of existing highways, some of this capacity could come in the form of new highways or investment in other modes of transportation.

Allocating HERS Results Among Improvement Types

Highway capital expenditures can be divided among three types of improvements: system rehabilitation, system expansion, and system enhancements (see Chapters 6 and 7 for definitions and discussion). All improvements selected by HERS that do not add lanes to a facility were classified as part of system rehabilitation. Highway projects that add lanes to a facility normally include resurfacing or reconstructing the existing lanes. HERS therefore splits the costs of such projects between system rehabilitation and system expansion.

Exhibit A-4

Typical Costs per Lane Mile Assumed in HERS, by Type of Improvements

(Thousands of 2008 Dollars per Lane Mile)

Category	Reconstruct and Widen Lane	Reconstruct Existing Lane	Resurface and Widen Lane	Resurface Existing Lane	Improve Shoulder	Add Lane Normal Cost	Add Lane Equivalent High Cost	New Alignment Normal	New Alignment High
Rural									
Interstate									
Flat	$1,730	$1,130	$979	$401	$75	$2,224	$3,083	$3,083	$3,083
Rolling	$1,940	$1,159	$1,127	$427	$123	$2,411	$3,902	$3,902	$3,902
Mountainous	$3,678	$2,539	$1,868	$632	$258	$7,507	$8,788	$8,788	$8,788
Other Principal Arterial									
Flat	$1,351	$905	$817	$322	$50	$1,782	$2,550	$2,550	$2,550
Rolling	$1,525	$930	$928	$359	$83	$1,908	$3,079	$3,079	$3,079
Mountainous	$2,963	$2,094	$1,799	$507	$110	$6,734	$7,755	$7,755	$7,755
Minor Arterial									
Flat	$1,236	$795	$761	$285	$47	$1,619	$2,274	$2,274	$2,274
Rolling	$1,492	$880	$947	$307	$86	$1,856	$2,928	$2,928	$2,928
Mountainous	$2,479	$1,625	$1,799	$422	$195	$5,685	$6,822	$6,822	$6,822
Major Collector									
Flat	$1,301	$842	$786	$291	$60	$1,682	$2,272	$2,272	$2,272
Rolling	$1,424	$855	$884	$309	$81	$1,719	$2,796	$2,796	$2,796
Mountainous	$2,159	$1,338	$1,287	$422	$124	$3,640	$4,754	$4,754	$4,754
Urban									
Freeway/Expressway/Interstate									
Small Urban	$2,822	$1,954	$2,224	$474	$87	$3,540	$11,589	$4,771	$16,287
Small Urbanized	$3,033	$1,971	$2,300	$561	$115	$3,894	$12,709	$6,431	$21,955
Large Urbanized	$4,838	$3,226	$3,563	$753	$435	$6,474	$21,713	$9,433	$32,203
Major Urbanized	$9,676	$6,452	$6,914	$1,247	$869	$12,948	$53,991	$18,866	$72,173
Other Principal Arterial									
Small Urban	$2,459	$1,660	$2,035	$398	$88	$3,009	$9,829	$3,762	$12,838
Small Urbanized	$2,631	$1,680	$2,127	$470	$118	$3,260	$10,690	$4,641	$15,840
Large Urbanized	$3,759	$2,462	$3,113	$591	$379	$4,771	$15,941	$6,370	$21,744
Major Urbanized	$7,517	$4,925	$6,225	$954	$758	$9,542	$36,990	$12,740	$55,150
Minor Arterial/Collector									
Small Urban	$1,812	$1,254	$1,539	$291	$64	$2,222	$7,198	$2,714	$9,264
Small Urbanized	$1,899	$1,268	$1,553	$331	$78	$2,342	$7,608	$3,330	$11,367
Large Urbanized	$2,556	$1,695	$2,124	$406	$213	$3,246	$10,778	$4,334	$14,792
Major Urbanized	$5,112	$3,391	$3,213	$676	$426	$6,492	$36,990	$8,668	$45,774

Source: Highway Economic Requirements System.

Growth in Value of Travel Time

Among the sensitivity tests in Chapter 10 was varying the value of travel time by 25 percent from the value standard in HERS. As that chapter explained, the standard values are based on wage and income levels prevailing in the base year for the analysis and are assumed to remain constant over the 20-year analysis period. More realistically, the value of travel time will increase over time due to growth in real wages and incomes. According to the U.S. National Income and Product Accounts (NIPA), average hourly labor compensation of employees increased by 68 percent from 1995 through 2008, while the price index for personal consumption expenditure increased by 33 percent. Real wages, which measure wage growth after adjusting for purchasing power being eroded by inflation, grew at an average annual rate of about 1.8 percent based on these statistics. If real wages were to grow at the same rate over the 20-year period analyzed in this report, 2009–2028, the average real wage at the end of the period would be 22 percent higher than in the base year. To increase the value of time by 25 percent above the base year value would be a reasonable allowance in HERS for future economic growth.

One could come up with possibly lower estimates of real wage growth over the 1995–2008 period using alternative measures of wage growth and consumer price inflation. For real wage growth from 1975 to 2005, Fitzgerald[2] found that some combinations of measures produced by the Bureau of Labor Statistics (BLS) yielded a picture of stagnation or even slight decline. The study also found, however, that the measures from NIPA—also used in the calculations above—are more adequate. In particular, the BLS measure of average hourly earnings excludes supplements to wages, which have become an increasingly important part of compensation over time (due in no small part to the growth of employer costs for employee health benefits).

HERS Revenue and Pricing Analysis

The 2006 edition introduced into the C&P report the modeling of (1)congestion pricing and (2) budgetary linkages between highway spending and highway user taxes. The baseline analyses presented in Chapters 7 and 8 of this edition use neither procedure, but a supplemental analysis in Chapter 9 applies them both separately and in conjunction.

HERS Congestion Pricing Analysis

The congestion pricing procedures in HERS simulate the impacts of imposing peak-period charges on all relatively congested (V/SF>0.80) sections of Federal-aid highways. The procedures are designed to accommodate the model's current lack of a capability to predict the impacts of such charges on the distribution of traffic between the peak and off-peak periods. The limitations of the HPMS database, exacerbated by the sparseness of related evidence from the research literature, would make adding this capability a major challenge. The current congestion pricing procedures utilize the existing equations in HERS in combination with auxiliary assumptions.

The existing equations are used to simulate the impacts of an all-day charge per VMT on each relatively congested section. The charge varies among sections, generally being higher where congestion is more severe; but being uniform across the day, it may also be thought of as a VMT tax imposed on congested sections. The HERS model estimates for each section the optimal charge based on the cost of delay created by an extra mile of peak-period travel (as discussed in the Introduction to Part II) and the impact of the charge on daily VMT. To derive from these results predictions for peak-period congestion charges, the model assumes in essence that (1) the optimal peak-period charge would be the same as the estimated all-day charge and (2) the impact of peak-period charges on daily VMT would equal the impact of all-day charges on VMT multiplied the peak-period share of VMT (before pricing). These auxiliary assumptions both have a strong influence on the computations, with potential to introduce significant error. Using a model that can realistically simulate peak-period charges including their impacts on travel time-of-day decisions would clearly be preferable. For future editions of the C&P report, the FHWA will be exploring possibilities for more realistically modeling peak-period within HERS and for obtaining supplementary evidence from other modeling frameworks, such as urban transportation planning models.

HERS Revenue Analysis

The HERS revenue analysis procedures provide the option of imposing a "balanced budget" constraint with the aim of funding any modeled change in highway investment from the base-year level through an assumed surcharge on highway users. The surcharge may be applied on a per-mile or per-gallon basis, and will be negative when HERS considers spending levels below the base-year level. A negative surcharge, or rebate, represents the equivalent of reductions in existing user charges such as tolls or fuel taxes.

The first step in the procedure is to determine the amount of revenue that must be raised to reach a target funding level. This calculation is based on the difference between the average annual funding level projected in the HERS model run and and the actual level of HERS-related expenditures in the base year (2008 in this edition of the C&P report). This difference is then multiplied by the ratio of the base-year ratio of total highway capital spending to HERS-related expenditures on the assumption that this ratio will be maintained in the future. Highway capital spending that is not HERS-related includes spending on bridge rehabilitation and replacement, on system enhancement, and on the functional systems not modeled in HERS (rural minor collector, rural local, and urban local). Of the change in total highway capital spending, the percentage that will be funded with highway user tax revenue is model user-determined.

The next step in the procedure is to solve iteratively for the surcharge rate that will generate the required change in highway user tax revenue. The solution process is iterative to allow that the level of surcharge would affect the size of the associated tax base (VMT or fuel consumption). The iterations start with calculation of the tax rate by dividing the required revenue change by the HERS projection for total VMT or fuel consumption. After re-running the computations to take account of the influence of the tax on VMT or fuel consumption, the surcharge rate is recalculated followed by another simulation to adjust for this revision to the surcharge, and so forth until an equilibrium is reached. (At the equilibrium surcharge, the total VMT that enters the calculation of the surcharge is the same as the amount of VMT that the model projects would result from this surcharge.)

The revenue and surcharge calculations are repeated sequentially for each funding period. However, in evaluating the potential implementation of a highway improvement in a given funding period, HERS assumes that the surcharge tax rate in that period is carried forward into future periods during which benefits from the improvement continue to accrue. Another limitation of the procedure is the omission of surcharge impacts on the bases of existing fuel taxes. HERS incorporates the influence of these taxes on the demand for highway travel (VMT), but does not calculate changes in total revenue from these taxes resulting from changes in VMT or future fuel economy. In this, as in previous editions of the C&P report, the analysis does not directly address the issue of the sustainability of current highway financing structures and does not attempt to identify changes in revenue mechanisms or tax rates that might be required to sustain highway capital spending at the base-year levels in constant dollar terms.

Linking Congestion Pricing With Revenue Analysis Procedures

For HERS analyses in which both the congestion pricing and the revenue analysis procedures are enabled, the model takes into account the total revenue that is required to achieve the target funding level specified as well as the revenue that would be generated from the variable congestion pricing charges. In cases where the congestion pricing revenue exceeds the amount of total revenue required, a negative fixed rate all day surcharge is imposed, which has the effect of shifting some costs from off-peak highway users to peak-period highway users.

Because the all-day surcharge and the peak-period congestion charge both impact travel volumes through the travel demand elasticity procedures described above, the process of developing a new equilibrium volume and price is significantly more complex for analyses that incorporate both the congestion pricing and the revenue analysis procedures.

(Endnotes)

[1] B. Yacobucci and R. Bamberger, *Automobile and Light Truck Fuel Economy: The CAFE Standards*, Congressional Research Service Report for Congress, Order Code RL33413, 2008.

[2] T.J. Fitzgerald, "Has Middle America Stagnated? A Closer Look at Hourly Wages," *The Region*, Federal Reserve Bank of Minneapolis, 2007.