# Commission Briefing Paper 3E-01

# 2006 C&P Findings: Impact of Alternative Assumptions on Future Highway and Transit Needs

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## Introduction

This paper is part of a series of briefing papers to be prepared for the National Surface Transportation Policy and Revenue Study Commission authorized in Section 1909 of SAFETEA-LU. The papers are intended to synthesize the state-of-the-practice consensus on the issues that are relevant to the Commission's charge outlined in Section 1909, and will serve as background material in developing the analyses to be presented in the final report of the Commission.

This paper builds on briefing papers 3C-01 and 3D-01, which summarized key findings of the 2006 Conditions and Performance (C&P) report on future highway and transit investment needs. It quantifies the impact that alternate assumptions about some of the key parameter values and future management strategies would have on the baseline C&P investment scenario estimates. This paper consolidates information previously provided to the Commission in other forms, plus additional supplementary information.

## Background and Key Findings

The findings presented in this paper are extracted from the 2006 *Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance* Report to Congress. The investment analyses are based on data from 2004. Key findings include:

- A 25 percent constant dollar increase in highway construction costs would lead to an increase in the Maximum Economic Investment level for highways and bridges of 11.2 percent, as some potential improvements would no longer be cost-beneficial. A comparable increase in transit capital costs increases the estimated amount required to improve transit conditions and performance by 15 percent.

- The C&P highway investment analysis assumes that the State-supplied baseline travel forecast for each highway section represents not what future travel *will* be, but what it *would* be if investment rose to the level required to keep highway user costs constant. The aggregate annual growth rate drawn from these section level forecasts is 1.92 percent. If instead, the 2.76 average annual VMT growth rate observed from 1984 to 2004 were a better predictor of future constant price VMT growth, then the estimated Maximum Economic Investment level would be 34 percent higher.

- The C&P transit investment analysis assumes an annual ridership growth rate of 1.57 percent. A 50 percent increase in the assumed level of future transit travel growth (to 2.36 percent) would increase the Cost to Improve transit by 14 percent.

- The baseline C&P investment scenarios reflect the effects of selected operations strategies and intelligent transportation systems (ITS), assuming existing deployment trends continue. However, if the deployment rates were to accelerate significantly, the amount of investment required to maintain current condition and performance levels. could decline by 2.4 percent. Assuming full immediate deployment in all applicable locations would bring down the Cost to Maintain highways and bridges by 6.6 percent.

- The baseline investment scenarios also assume the continuation of existing financing structures, with their inherent economic inefficiencies. In an ideal (from an economic point of view) world, users of congested facilities would be levied charges precisely corresponding to the economic cost of the delay they impose on one another, thereby reducing peak traffic volumes and increasing net benefits to all users combined. A preliminary analysis of universal congestion pricing using the Highway Economic Requirements System (HERS) suggests that such a strategy could significantly reduce the level of future highway investment that would be required to maintain or improve highway operational performance. The Maximum Economic Investment level would decrease by almost 16 percent, to $110.8 billion, while the Cost to Maintain Highways and Bridges would decline even more proportionally, by over 27 percent, to $57.2 billion.

## Sensitivity Analysis

The usefulness of any investment scenario analysis depends on the validity of the underlying assumptions used to develop the analysis. The investment scenario projections in the C&P report are developed using models that evaluate current system condition and operational performance and analyze investment and performance over a 20-year time horizon. As in any modeling process, simplifying assumptions are made to make analysis practical and to meet the limitations of available data.

Since there may be a range of appropriate values for several of the model parameters used in these analyses, the report includes an analysis of the sensitivity of the baseline analyses to changes in these assumptions, examining the impact that alternative parameter values or assumptions have on the investment and performance projections produced by the models. Sensitivity analysis also allows us to illustrate the impact that alternative strategies or approaches could have on investment requirements. Such analyses were added to the C&P report in order to make the modeling process more transparent and to make the report more useful for supplementary analysis efforts.

This briefing paper explores the impact that such alternative assumptions would have on the investment scenario projections presented in Commission Briefing Papers 3C-01 and 3D-01. The issues addressed here include the unit cost of different investments; future travel growth rates; the value of time assumed in evaluating improvements that reduce travel times; assumptions about future deployments of ITS and operations strategies; the theoretical impact that efficient congestion pricing could have on the analysis of highway investment; and the type of transit performance-enhancing investments assumed in the model.

## Construction Costs

One of the most important inputs into the C&P analytical models is the unit cost of improvements. These costs can affect both the projected cost of different investments and the extent to which such investments may be cost-beneficial. Though these costs are routinely updated to the base year used in each C&P analysis, they may themselves be subject to uncertainty. For example, currently unforeseen circumstances may cause highway construction costs to increase faster than the general rate of inflation in the future. It is therefore prudent to consider the impact of higher-than-expected capital improvement costs on the estimated investment levels under the C&P scenarios. While this particular sensitivity analysis has been routinely included in each of the previous three editions of the C&P report, it has taken on even more meaning in light of recent trends in construction costs, which rose sharply between 2004 (the base year of the analyses in the 2006 C&P report) and 2005.

### Highways and Bridges

The C&P report analyzes the **impact that inflating all the improvement costs used by HERS and the National Bridge Investment Analysis System (NBIAS) by 25 percent has on the Maximum Economic Investment level**. The increase in investment requirements due to higher unit values for the improvement costs is partially offset by the elimination of some projects that would no longer be considered cost-beneficial by HERS or NBIAS. The **net result is an increase of 11.2 percent in the estimated investment requirements**. The impact is greater on the NBIAS results (increasing scenario costs by 18.8 percent) than in HERS (increasing scenario costs by 10.1 percent). The benefit-cost tests applied in HERS are more robust than those in NBIAS, which results in relatively more potential investments being “screened out” at the higher construction cost levels.

Increasing the unit improvement costs by a given percentage has a straightforward (if less conceptually meaningful) impact on other scenarios based on achieving a given level of performance, such as the “Cost to Maintain Highways and Bridges” scenario. Since the investments included in the “Maintain User Cost” scenario in HERS all have BCRs well above 1.0, raising the improvement cost estimates does not cause HERS to forego any improvements on benefit-cost grounds. Similar effects would result in the “Maintain Economic Backlog” scenario in NBIAS. The increase in the Cost to Maintain Highways and Bridges will thus be roughly proportional to the change in improvement costs.

### Transit

The capital costs used in the Transit Economic Requirements Model (TERM) are based on actual prices paid by agencies for asset purchases as reported to FTA in the Transit Electronic Award and Management System (TEAM) and in special surveys. Given the uncertain nature of capital costs, a sensitivity analysis has been performed to examine the effect that higher capital costs would have on the dollar value of projected transit investment requirements.

A **25 percent increase in capital costs increases the cost to maintain conditions and performance by 18 percent and the costs to improve conditions and performance by 15 percent.** With this increase in costs, fewer investments are economically viable under the

Improve Conditions and Performance scenario than under the Maintain Conditions and Performance scenario.

While this particular sensitivity analysis has been included in each of the previous three editions of the C&P report, it has taken on even more meaning in light of recent trends in highway and transit construction costs, which have risen sharply in recent years. Between 2004 and 2005, the FHWA Bid Price Index increased by nearly 19 percent. As a result, this analysis may be viewed in some ways as reflecting actual recent trends, rather than simply serving as an analysis of the sensitivity of the investment estimates to assumptions about improvement costs.

## Future Travel Growth

One of the strongest determinants of the condition and performance of the surface transportation system, and of the need for investment to address condition and performance deficiencies, is the total volume of system usage. While estimates of current traffic volumes and transit use are available in the existing data sources used in the models, projections of future travel growth are also needed in order to model the evolution of the system and the need for future investment. While such projections can be obtained from either the same data sources used for current travel levels or from other sources, these forecasts will naturally be subject to considerable uncertainty, particularly to the extent that they diverge from past long-term trends in travel growth.

### Highway Travel

States provide forecasts of future vehicle miles traveled (VMT) for each individual Highway Performance Monitoring System (HPMS) sample highway section. HERS assumes that the forecast for each sample highway segment represents the level of travel that will occur if a constant level of service is maintained on that facility. This implies that VMT will occur at this level only if pavement and capacity improvements made on the segment over the 20-year analysis period are sufficient to maintain highway user costs (exclusive of taxes and tolls) at 2004 levels. If HERS predicts that highway-user costs will deviate from baseline 2004 levels on a given highway segment, the model's travel demand simulation features will modify the baseline VMT growth projections from HPMS.

The HERS model utilizes VMT growth projections to predict future conditions and performance of individual highway segments and to calculate future investment requirements. If the HPMS VMT forecasts *as modified by the HERS travel demand procedures* are overstated, the investment requirement projections may be too high. If travel growth is underestimated, the investment requirement projections may be too low.

The State-supplied VMT growth projections in HPMS for 2004 to 2024 average 1.92 percent per year, well below the 2.76 percent average annual VMT growth rate observed from 1984 to 2004. The HERS model assumes that the 1.92 percent composite VMT growth projection in HPMS represents the growth that will occur at a constant level of service. However, the level of service on highways in the United States has generally been declining over the past two decades. If States expect this trend to continue and have factored this into their projections, then the HPMS forecasts might represent a declining level of service as well, and would thus understate future *constant price* growth, causing HERS to likewise underestimate the level of investment that would be needed to achieve a given level of performance. It is thus prudent to consider the impact of such a circumstance on the C&P highway investment projections, and the historic growth rate provides a useful benchmark for comparison.

The C&P report models the **impact on investment requirements of assuming that the 20-year future growth in VMT that would occur at a constant level of service matches the growth over the previous 20 years,** rather than using the baseline assumption that the constant-price growth would be in line with the HPMS forecasts. Modifying the travel growth projections in this fashion would increase the Cost to Maintain Highway and Bridges by 56.6 percent. Increased VMT would increase the rate of pavement deterioration, as well as increase the share of resources that HERS would recommend using for capacity expansion, to nearly 50 percent of total highway investment under this scenario. Both of these factors would tend to increase the investment required to maintain user costs at 2004 levels.

The **Maximum Economic Investment level for Highways and Bridges would increase by 33.9 percent based on this change in assumptions.** The increased travel would increase the number of pavement and capacity projects that HERS would find cost-beneficial.

### Transit Passenger Travel

TERM relies heavily on forecasts of passenger-miles traveled (PMT) in large urbanized areas. These forecasts are the primary driver behind TERM's estimates of the amount of investment that would be required in the Nation's transit systems to maintain performance (measured by current levels of passenger travel speeds and vehicle utilization rates) as ridership increases. PMT forecasts are generally made by metropolitan planning organizations (MPOs), in conjunction with projections of vehicle miles traveled, as a part of the regional transportation planning process. These projections incorporate assumptions about the relative growth of travel on transit and in private vehicles in a metropolitan area.

The average annual growth rate in transit PMT assumed in the 2006 C&P investment analyses was 1.57 percent. This represents a weighted average of the most recent MPO forecasts available from 92 of the Nation's largest metropolitan areas. This rate is lower than the average annually PMT growth between 1995 and 2004 (2.23 percent), but higher than the average annual rate between 2002 and 2004 (0.65 percent).

The report also shows the impact that alternative assumptions about transit travel growth would have on the future transit investment requirements estimated by TERM. **Increasing the assumed PMT growth rate by 50 percent to 2.36 percent would increase the Cost to Maintain Conditions and Performance on Transit by 18.8 percent, and would increase the Cost to Improve Conditions and Performance on Transit by 13.7 percent.** Decreasing the assumed growth rate by the same percentage would decrease the estimates for the two scenarios by 17.8 percent and 12.9 percent, respectively. PMT growth rates primarily affect asset expansion costs, which account for a larger share of total estimated Maintain Conditions and Performance needs than estimated Improve Conditions and Performance needs, resulting in a proportionally larger effect on the maintain scenario estimate.

The C&P investment/performance analyses are thus quite sensitive to the future travel growth projections, one of the most important input parameters into the models. The data sources used for these projections generally cover a 20-25 year time horizon. Extending the analyses beyond the time frames included in the C&P analysis would require additional assumptions about travel growth in the years beyond these projections.

## Value of Time

The value of time is a key input parameter in the C&P analytical models. It is used in the benefit-cost analysis performed by the models to quantify the benefits that accrue from reducing travel times, which is one of the most significant impacts that capital improvements have on users of the transportation system. The more that users value such reductions, the greater will be the benefits that they derive from them.

The value of time parameter used in the HERS, NBIAS, and TERM models was developed using a standard methodology adopted by DOT. This methodology provides consistency among different analyses performed within the Department. However, some debate remains about the appropriate way to value time, and no single methodology has been uniformly accepted either by the transportation community or within the Federal government.

### Highways

**Increasing the value of ordinary travel time in HERS by 25 percent would increase the Maximum Economic Investment level by 5.6 percent.** Increasing the value of time causes HERS to consider more widening projects (which reduce travel time costs) to be cost-beneficial. The share of investment devoted to capacity expansion would thus increase slightly, to over 46 percent of total improvement costs (versus 44.6 percent in the baseline). Reducing the value of time by 25 percent would have the opposite effect, resulting in a 7.4 percent reduction in the Maximum Economic Investment level.

### Transit

Variations in the value of time have a limited effect on transit investment requirements. **Doubling the assumed value of time would increase the estimated Cost to Improve Transit Conditions and Performance by 3.9 percent.** Increases in the value of time make the travel time savings associated with faster modes of transportation relatively more beneficial to users. As a result, an increase in the value of time reduces projected investment requirements in modes with relatively slower transit services (as some travel shifts from transit to automobiles) and increases projected investment requirements in modes with relatively faster transit services (as some travel shifts from automobiles to transit). The opposite would occur in response to a decrease in the value of time.

## Operations/ITS Deployment

The HERS model also takes into account the impact that new investments in certain types of intelligent transportation systems (ITS) and the continued deployment of various operations strategies can have on highway system performance, as well as the amount of capital investment required to reach given performance benchmarks. The baseline scenario used for this report assumes the continuation of existing deployment trends. The C&P report analyzes the impact of two alternative operations and ITS deployment scenarios: one with more aggressive assumptions about future deployments, and a hypothetical scenario that assumes full, immediate deployment of selected operations/ITS strategies in all urban areas.

The **aggressive operations/ITS deployment scenario** assumes that existing trends in the adoption of ITS infrastructure and strategies would accelerate in the future. The impact of increasing the rate at which such technologies are adopted in the future would be to **decrease the estimated infrastructure investment necessary to maintain conditions and performance at current levels by approximately $1.9 billion per year** under this particular scenario. While this reduction is small in overall percentage terms (2.4 percent of total investment requirements), it should be considered that the impacts are concentrated on capacity investments in urbanized areas. In 2004, such investments accounted for just one-fifth of total highway capital outlay.

The aggressive scenario does not have as significant an impact on the Maximum Economic Investment relative to that based on existing trends, reducing that level by less than 1 percent. While ITS deployments would in some cases reduce the benefit-cost ratio (BCR) of certain potential widening projects below the 1.0 threshold imposed by this scenario, in other cases, both an ITS deployment and a widening project would be cost-beneficial. Consequently, the level of performance that HERS finds cost-beneficial to achieve would be significantly better under the aggressive scenario than under the baseline trends scenario. Average highway user costs would be lower than under the existing trends scenario, representing additional annual savings of $10 billion by 2024 ($126 billion in annual savings relative to 2004, compared with $116 billion under the existing trends scenario). Incident delay costs on urban arterials and collectors would be reduced by another 2.9 percent (and by 5.4 percent on urban Interstates) relative to the baseline scenario, even though the overall level of investment is lower.

The "full deployment" scenario illustrates the maximum impact that the types of strategies and technologies modeled in HERS could have on the estimates of future investment requirements. **Deploying ITS to the fullest extent would have a strong impact on the Cost to Maintain Highways and Bridges, reducing it by $5.2 billion (6.6 percent).** While the Maximum Economic Investment level with full deployment is essentially the same as for the baseline scenario, the impact on highway conditions and performance is even greater than under the aggressive deployment scenario. Annual highway user cost savings in 2024 would be $27 billion more than under the baseline scenario ($144 billion in annual savings compared with 2004), and incident delay costs on all arterials and collectors in urban areas would be reduced by 4.1 percent (6.9 percent on urban Interstates).

The impacts that these alternative scenarios have on the investment analysis estimates are based solely on the increasing the rate and extent of deployment of current operations technology and strategies. They do not account for the potential development of new technologies or strategies, or of improvements to existing technologies that would improve their efficacy. Such technological changes, particularly those that might arise in the distant future, would obviously be expected to result in further improvements in highway performance.

## Congestion Pricing

One of the key assumptions implicit in the baseline C&P investment scenarios is the continuation of existing financing structures, under which user fees are typically assessed on a per-mile (or per-gallon) basis. As a result, highway users are typically charged the same amount, regardless of where or at what time of day they travel. This can contribute to overuse of the transportation system, since users of congested roads are paying the same rate as those on uncongested routes.

The efficiency of the system could be improved by imposing congestion-based tolls, which could be set at a level at which users of congested facilities would pay a cost equivalent to the negative impact that their use has on other drivers.

For the 2006 edition of the C&P report, the HERS model was modified to simulate the imposition of optimal congestion pricing on congested roadways, and preliminary results from these new procedures were reported. There are numerous caveats that should be understood when interpreting these results. The scenario should be considered to show the impact that optimal, universal congestion pricing could have on the investment requirements estimates. This theoretical scenario does not constitute a comprehensive policy proposal. **The analysis does not account for the substantial startup and administrative costs that could be associated with deploying congestion pricing on a universal basis, which could vary widely depending on the type of technology adopted to collect them.** The congestion tolls applied in the analysis would be in addition to any current user taxes and fees; they do not substitute for existing fees. This analysis represents an initial attempt at quantifying some of the impacts of congestion pricing; future research is planned to refine this analysis to more explicitly consider time of day demand shifts and to better account for some of the network effects among parallel or intersecting routes. However, there will always be limits on how well a model such as HERS, which analyzes investment on individual sample segments, can model these effects.

The results of this illustrative analysis indicate that **universal congestion pricing could have a very significant impact on the investment requirements estimates. The Maximum Economic Investment level would decrease by almost 16 percent, to $110.8 billion.** The estimated "gap" between this scenario and 2004 highway capital outlay would be reduced to 57.7 percent. The Cost to Maintain Highways and Bridges would decline even more proportionally, by over 27 percent, to $57.2 billion. This level of investment is well below 2004 capital spending.

The average congestion toll calculated by HERS on sections where such tolls are applied is 20.5 cents per mile for the Maintain scenario and 17.4 cents per mile for the Maximum Economic Investment scenario. On some extremely congested sections, the optimal congestion tolls can be considerably higher. The larger average tolls and revenues under the Maintain scenario reflect the fact that higher tolls are required at lower levels of highway investment to suppress travel to the point that user costs would be maintained. Congestion would be higher under this scenario, so that drivers have larger negative impact on each other. For the Maximum Economic Investment scenario, the additional capacity expansion at the higher investment levels result in reduced congestion, so that drivers' impact on each other is not as severe, and thus the efficient congestion toll rates are lower.

This analysis suggests an important dichotomy between the revenues that would be produced under congestion pricing and revenues that would be generated from user fees to fund increased investment levels; in fact, the two are in some sense counter to one another. Lower levels of investment would require smaller user fee charges, but would result in more congestion and thus higher efficient congestion tolls and revenues. Higher levels of investment would require larger user fee charges, but congestion levels, toll rates, and revenues would be lower. While revenues from congestion pricing would be available to finance capital investment, they are not explicitly intended for that purpose under this scenario, and this is reflected in the efficient toll rates that would be applied in this analysis.

While this analysis uses a theoretical, idealized construct (universal pricing at economically efficient levels) and may thus potentially overstate the impact to some degree, it nevertheless indicates that pricing, in conjunction with operations strategies and other highway investment, has a very important and potentially substantial role to play in addressing highway congestion. Future refinements planned for this line of analysis could result in either higher or lower estimates of the impacts shown in this initial attempt at modeling congestion pricing in the C&P report.

### Transit Performance-Enhancing Investments

TERM assumes that investment to improve performance by increasing the speed of passenger travel in urbanized areas with populations of less than 1 million and no existing rail system are made in Bus Rapid Transit (BRT). Earlier editions of the C&P report assumed that these performance improving investments would made in new light rail systems. The investment required to improve conditions and performance would be 1.4 percent higher if performance-improving investments in these areas were assumed to be made in light rail instead of BRT.

## CONSOLIDATED COMMENTS FROM MEMBERS OF THE BLUE RIBBON PANEL OF TRANSPORTATION EXPERTS - PAPER 3E-01

One reviewer commented as follows:

The paper does an excellent job of looking at the sensitivity on C&P investment from changes in construction costs, travel demand, value of time, ITS deployment, and congestion pricing. It seems that one could also look at the impact of behavioral changes, one of which is the trend towards carpooling, or the use of HOVs, in highly congested metropolitan areas. Since HOVs allow for the transport of a given number of users with fewer vehicles, their usage certainly affects the level of congestion and, presumably, C&P investment. Also, the optimal congestion pricing policies, as outlined on pages 8-9, though preliminary, did not factor in how possible congestion pricing discounts for HOV usage could affect investment requirements.