Commission Briefing Paper 6A-01
Base Case Needs Assessment: Highways

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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.

Section 1909 requires the final report of the Commission to include an assessment of future needs over 15-, 30-, and 50-year time horizons. This paper describes the critical assumptions that were utilized in the development of the new Base Case analyses of future needs, as well as the results of those analyses. These baseline projections of future transportation system conditions and performance assume a general continuation of current trends and general policies. These analyses are to serve as a point of comparison for a number of alternative scenarios that will make different assumptions about future transportation system emphasis, program structures, and funding sources.

Background

Commission staff have previously provided an extensive amount of information to the Commission concerning future highway and transit needs via staff presentations on the findings of the 2004 C&P report, presented at the June 2006 Commission meeting; staff presentations on the findings of the 2006 C&P report (though not labeled as such) at the July 2006 Commission meeting; staff-written papers summarizing the 2006 C&P report, completed in December 2006; and staff-written papers summarizing an initial set of “baseline” analyses of 50-year needs, completed in January 2007 and discussed at the March 2007 Commission meeting. The Commission has also benefited from testimony at field hearings from various individuals commenting on these documents, and providing alternative views on the future needs of particular system components, or of the system as a whole.

One clear theme resonating through all of this information is the necessity of settling on a set of fundamental assumptions on which such analyses can be built. Since the charge of the Commission differs from that of the USDOT’s C&P report or the types of reports produced by other entities (both in terms of time period and breadth of coverage), it is natural that the assumptions utilized in the Commission’s analyses will differ from those utilized in other documents. This paper lays out the assumptions used in the Base Case analyses, building on information gathered by staff as part of the Commission process.

Approach and Key Assumptions

Scope

The revised baseline analysis described in this paper focuses on highways and bridges; analyses of transit, rail and other modes are being developed on a separate track and will be folded into the base case and the future scenarios as they are developed.

Based on feedback received from the Commissioners at the March meeting, the estimates of future investment requirements utilized in the base case and the scenarios will focus on capital investment needs only, consistent with the approach taken in the C&P report and AASHTO *Bottom Line* reports. This deviates from the approach used in the preliminary baseline analyses presented in March 2006 (described in Papers 3G-01 and 3G-02), which proportionally increased the investment requirement estimates to reflect non-modeled non-capital spending types (e.g., routine maintenance). Instead, relevant non-capital spending will be referenced in the scenario analyses in a descriptive way.

The Commissioners also indicated an interest in focusing on the higher-order highway functional classes that are currently eligible for Federal aid (all roads except rural minor collectors and local functional class roads, plus all highway bridges). Investment in system rehabilitation and expansion on these systems is directly modeled in HERS and NBIAS. The analysis also includes an adjustment for non-modeled capital improvement types (those classified as system enhancement), following the assumption that the share of future investment requirements represented by these improvements is consistent with their current share of highway capital spending (9%).

Institutional and Financing Considerations

The Base Case analyses are intended to be neutral in terms of institutional and financing considerations; therefore, they assume a continuation of current program structures and financing mechanisms. For the purposes of analyzing a level of investment higher than that which is currently sustainable, these analyses will effectively assume that revenues from all sources would be proportionally increased to cover the difference and that the current percentage of total spending funded by system users would remain the same. Note that this deviates from the assumption in the 2006 C&P report (which assumed that users would pay the full cost of any increase in spending) and in Papers 3G-01 and 3G-02 (which assumed that users would not pay any of the cost of increases in spending).

It is important to note that the Base Case does build in a fundamental assumption from the models on which it relies—that future capital investments in surface transportation will be made in an economically rational manner in order of the incremental benefit-cost ratios (from highest to lowest, until funding is exhausted). While such an assumption is necessary to facilitate national-level analysis (as it is neither feasible nor desirable to model political and other considerations that may influence project selection), it does effectively represent a departure from the current way of doing business. Thus, certain potential programmatic changes (e.g., increased use of economic analysis) designed to improve project selection methodology, and which might be considered as part of a scenario, would not be expected to have any discernable impacts, since they effectively have been built into the Base Case.

Future Inflation

While the analytical tools utilized in the estimation of future investment requirements operate on a constant dollar basis, it is clearly necessary to make assumptions about future inflation rates in order to link such estimates to alternative future potential revenue streams.

The recent run-up in highway construction costs complicates these types of decisions as well as the development of investment requirement analyses in general. In light of the 18.3% increase in the Federal-aid Highway Bid Price Index from 2004 to 2005, a decision was made to denominate the Commission estimates in 2005 dollars, as was done in the initial baseline estimates presented in papers 3G-01, 3G-02, and 3H-01. However, newly available data shows that the Bid Price Index jumped a further 20.5% from 2005 to 2006, suggesting that it would be more appropriate to use 2006 dollars as the starting point for the Commission estimates, so that they will appear more relevant in the near term. Therefore, the Base Case estimates below use costs in 2006 dollars.

It should be noted, however, that the Bid Price Index (which tracks actual bids) has been observed to lag indices more directly tied to the actual prices of various construction components. These other indices have recently shown signs of moderating. While papers 3G-01 and 3H-01 showed the potential impacts of three alternative assumptions about future inflation (2%, 2.5%, and 3%), other figures, as high as 6% have been recommended to the Commission as part of field hearing testimony. While the prevalent rate of inflation experienced in individual sectors of the economy can diverge wildly from the general inflation rate in the short term, such divergence is likely to balance out over a long period of time such as the 50 years covered by this study. Inflation projections produced by Global Insight suggest that highway and street construction costs would begin to grow more slowly that the general inflation rate beginning in 2009. Based on this analysis, the staff recommendation is that Global Insight general inflation forecasts be used in the Base Case analyses, which would translate into an initial inflation rate of 3.1% per year, gradually declining to a rate of 1.9% per year.

Future Passenger Travel Volumes

One of the key inputs into the analysis of future infrastructure investment needs is projected future travel volumes. Papers 3G-01, 3G-02 and 3H-01 had estimated 50-year highway and transit travel volumes by extrapolating from the 20-year forecasts used in the 2006 C&P report. The origin of these 20-year forecasts were State DOT projections of future highway travel volumes on the more than 100,000 sample sections in the Highway Performance Monitoring System (HPMS), and Metropolitan Planning Organization (MPO) projections of future transit travel volumes on an area-wide basis.

As part of the work completed in Module IV, Task Area A, a series of seven briefing papers were developed, which explored the potential impact of various factors on future personal travel demand. While these papers include valuable discussions of these topics in a qualitative manner, they did not include quantitative projections of travel. To supplement this work, Commission staff contracted with the Center for Urban Transportation Research (CUTR) at the University of

South Florida to develop a travel forecast model that takes as many of these factors into account as possible. The model was designed to produce vehicle miles traveled (VMT) and person miles traveled (PMT) forecasts for both the long term (30 years) and the very long term (50 years).

As embodied in the long-range CUTR forecasts, annual VMT can be viewed as the product of four terms: resident population, daily person trips per capita, average length of each person trip, and vehicle miles of travel per person mile of travel. The first term is simply the number of residents; the second term reflects the frequency with which people make trips, the third term captures the length of those trips, and the fourth term captures the mode share of auto usage—providing an indication of the share of those trips to create roadway travel demand versus those that occur on another mode or as passengers in an auto. (Without the fourth term, this equation can be used to estimate PMT rather than VMT.) This basic equation was built into a model that uses the National Household Travel Survey (NHTS 2001) to provide measures of trip rates, trip length and mode share for 2035 and 2055. The model is sensitive to the following characteristics:

- Age profile of the population (six age categories). The three senior population age groupings are further disaggregated by gender.
    - Travel behaviors for each population age/gender sub-segment are developed from NHTS data.
    - Forecast year age profiles are developed from Census or Census extrapolations
- Land development pattern of the population as captured by the shares of State population located within various ranges of population density in census tracts (5 density ranges).
    - Travel behaviors for each range of land development pattern are developed from NHTS data.
    - Forecast year land development patterns are estimated via regression equations developed from development pattern trends in the 1990 and 2000 censuses.
    - The model includes an option for user-specified development intensification scenarios.
- Residency tenure (years residing in the U.S.) for foreign-born population.
    - Travel behaviors for each residency tenure sub-segment of the foreign-born population are developed from NHTS data.
    - Forecast year estimates of foreign-born population by residency tenure are estimated based on census and Social Security Administration scenarios of net international immigration.
- Future travel behaviors are modified from the base year to reflect expected changes in response to per capita real income growth, including changes in trip rates, length, and vehicle use.
    - Travel behavior changes as a result of real income changes are estimated based on travel behavior differences across income groups in 2001, validated by a review similar data from the 1977 NPTS.
    - Future per capita real income growth estimates are input by the user based on the long range economic forecasts produced by Global Insight. The same rate is applied uniformly across all States.

Census Bureau forecasts (middle series) from 2000 and Census Bureau Interim projections from 2004 were the basis for future demographic assumptions; however, the lack of State level population forecasts beyond 2030 required extrapolations to create State-level population profiles for the forecast years.

Applying this model using a base set of assumptions results in a set of State-by-State highway VMT forecasts that averages out to approximately 1.82% growth per year (for 30 years); this is slightly lower than the values extrapolated from the 20-year HPMS sample section forecasts used in Papers 3G-01 and 3G-02, but is consistent with a concept of a gradual decline in VMT growth over time. This forecast is intended to reflect the growth that would occur in a future economy that is not more constrained by congestion than is currently the case. The effects of increased congestion on travel demand (and other components of highway user costs such as rising fuel prices) on travel demand are not reflected in this forecast and would instead be adjusted for automatically in the travel demand elasticity procedures built into HERS. The staff recommendation is that the CUTR-derived highway VMT forecasts be utilized as the input to the Base Case analysis.

It should be noted that the passenger travel growth projections are intended to serve as unconstrained baselines for further analysis. They may be altered externally as part of the programmatic assumptions made within individual scenarios (such as policies intended to shift travel from one mode to another), and internally within the analytical models in response to any significant changes in the direct and indirect costs of using the transportation system that might occur under different scenarios or different funding levels within the Base Case family.

Future Freight Volumes

Another key input into the analysis of future infrastructure investment needs is projections of future freight volumes. Papers 3G-01 and 3G-02 had effectively assumed that passenger and freight travel volumes would grow at the same rates.

The work reflected in the Module IV, Task Area B papers relied heavily on projections of future economic growth and freight volume growth estimated by models developed by Global Insight. The DOT's Freight Analysis Framework (FAF) also utilizes Global Insight projections to assign anticipated future freight flows to the network of available freight transportation facilities. The FAF forecasts are mode neutral within commodity types, assuming that the shares of a particular commodity transported between the same origins and destinations by truck, rail and other modes will remain constant over time. Hence, the only modal shifts in the FAF estimates occur as a result of variations in Global Insight's projections for growth in different commodity types or different origin-destination patterns. Based on conversations with the American Association of Railroads, it appears that the FAF figures for rail volumes are generally in line with projections that Global Insight has been providing to the railroad industry directly.

These FAF growth forecasts for freight travel on highways have been utilized in the Base Case analyses, reflecting an extension of the status quo in terms of current mode shares. As was noted above, these projections may be changed externally as part of the programmatic assumptions made within individual scenarios, to the extent that such scenarios assume changes in modal shares.

Energy Issues
Papers 3G-01 and 3G-02 effectively assumed the real price of fuel would remain constant over time (i.e., would increase in line with general inflation). The work reflected in the Module IV, Task Area C papers had relied on analyses developed by Oak Ridge National Laboratories (ORNL) and the Energy Information Administration (EIA), which described potential changes in fuel prices over time.

EIA's "Annual Energy Outlook 2007" includes three sets of projected alternative fuel prices out to 2030. The "Reference" and "Low Price" scenarios both project that the world oil prices experienced in 2006 represent a peak in constant dollar terms, so that oil prices in constant dollar terms would be lower (much lower in the case of the "Low Price" scenario) than today. In contrast, the "High Price" scenario projects that oil prices will continue to rise more quickly than general inflation over the next 25 years.

For purposes of the Commission analyses, it is necessary to extend these projections out to 50 years, a point in time at which petroleum scarcity will become a more pressing issue than in the time period considered by EIA. While the "Reference" case reflects EIA's best prediction through 2030, it assumes the entry into the market of significant amounts of certain alternative energy sources during that time period. While this may be an accurate prediction of what will occur, it may not be the most appropriate assumption for a Base Case, which is intended to show what is expected to happen in the absence of significant changes to current policies. Based on discussions of this issue with ORNL staff, the Commission staff recommendation is to utilize the more pessimistic "High Price" values from EIA (and the associated projections of future fuel efficiency) as part of the Base Case, recognizing that values from the "Reference" scenario might be utilized in any potential scenario that assumes significant changes in future national energy policy aimed at increasing supply. Conversely, alternatives assuming even higher energy prices than those reflected in the "High Price" EIA in response to government policies aimed at reducing consumption (such as a carbon tax) could also be analyzed.

Traffic Operations Strategies and ITS
Based on feedback received from the Commissioners at the March meeting, the Base Case assumption concerning operations strategies and ITS will be that current deployment trends will continue in the future, consistent with the approach taken in the C&P report and AASHTO *Bottom Line* reports. This deviates from the approach used in the preliminary baseline analyses described in Papers 3G-01 and 3G-02, which had assumed a more aggressive rate of deployment (with no additional deployments after 20 years).

While an acceleration of operations strategies and ITS deployment is likely in the future, it may require certain institutional actions to overcome obstacles that have impeded these types of deployment in the past, and thus may need to be addressed as part of the Commission's recommendations. Hence, potential accelerations in the rate of deployment of such strategies and technologies will be addressed as part of the scenarios, rather than the Base Case.

Technological Advances

Based on feedback received from the Commissioners at the March meeting, the Base Case analysis will assume only modest improvements in technologies. This is consistent with the approach used in the preliminary baseline analyses described in Papers 3G-01 and 3G-02. While technological advances may make significant contributions in our ability to accommodate anticipated future travel demand, such advances may require changes in research funding levels and institutional arrangements, and thus may need to be addressed as part of the Commission's recommendations. Hence, technological advances will be addressed primarily as part of the scenarios, rather than the Base Case.

Aging Infrastructure

The pavement and bridge deterioration algorithms built into the HERS and NBIAS models are based primarily on current infrastructure conditions, rather than on age. Age data are not currently collected in the HPMS for pavements; these data are available in the NBI, but are not presently utilized.

The Commission has received presentations suggesting that a purely condition-based modeling approach may understate future infrastructure investment needs by allowing multiple pavement resurfacings and bridge rehabilitations at a point beyond which these would likely be viable options in the real world. AASHTO is particularly concerned about the potential impact of age-related deterioration on long term reconstruction needs, particularly for the Interstate highway system. An NCHRP study currently underway is focusing on developing an approach to addressing this issue analytically.

A long-term approach for dealing with this issue would be to conduct research on specific relevant engineering relationships (such as the impact of pavement age on the life expectancy of a resurfacing project, the impact of age on routine maintenance costs) and to collect data on pavement ages. However, the NCHRP effort rightly suggests that this would require a multi-year effort. A short-term fix would be to limit the models' ability to indefinitely resurface or rehabilitate pavements and structures, leaving reconstruction (or doing nothing) as the only option after a certain point in time within the 50-year analysis period.

Accordingly, the HERS and NBIAS models have been modified to put a cap on the number of resurfacing/rehabilitation actions as described above. This may result in system rehabilitation needs being overstated in some cases, but avoids the risk that a significant component of needs over the very long term could be overlooked entirely. No such modifications would be required for the TERM model, as its deterioration algorithms are already heavily influenced by the age of transit assets.

Interstate Connectivity

The C&P report and the preliminary baseline needs analysis presented in Papers 3G-01 and 3G-02 focus primarily on accommodating travel demand in existing corridors, either via operations strategies, expansion of existing routes or (implicitly) building new parallel facilities. These analyses do not deal directly with connectivity issues.

An ongoing NCHRP study on the future of the Interstate system identifies areas in which the Interstate system could be expanded and areas in which NHS routes could be updated to

Interstate standards. Such expansions are a viable alternative to addressing future system needs, though it should be noted that they are not strictly additive to other estimates of investment requirements, as the traffic carried by such new routes would tend to draw traffic from other routes in the system, thus reducing capacity expansion needs in other locations.

These connectivity expansions have not been included in the Base Case analyses. While such changes may occur in certain locations given a continuation of existing programs, a systematic nationwide expansion of the Interstate system would require programmatic and institutional changes and thus may need to be addressed as part of the Commission's recommendations. Hence, Interstate connectivity will be addressed primarily as part of the scenarios, rather than the base case.

Time Horizons and Discounting

The benefit-cost analysis procedures employed in the HERS and NBIAS models require a discount factor to be applied in order to compare the future benefit streams produced by a highway improvement with the initial cost of that improvement.[1] For the C&P investment analyses, a 7 percent real discount rate is used, in accordance with the guidelines for Federal infrastructure investment analyses under OMB Circular A-94. Papers 3G-01, 3G-02, and 3H-01 instead utilized a 4 percent discount rate. The 4 percent rate is both more consistent with typical practice in analyses performed by State and local governments (including the HOT Networks study cited in Commissioner Heminger's *Metro Mobility* presentation), and is in line with the real interest rates experienced in the U.S. (which reflect the opportunity cost of making additional capital investments at the margin).

The benefit-cost analysis procedures employed in the HERS and NBIAS models also require a value of travel time. Time is one of the major components in total user costs (along with vehicle operating costs and crash costs), and the value of time has a significant impact on the estimated benefits of infrastructure improvements that would reduce congestion and delay. For the 20-year C&P investment analysis the value of time is computed based on a set of procedures developed by the U.S. Department of Transportation (USDOT), and is assumed to remain constant over time in inflation-adjusted terms. However, the USDOT's value of time estimates are based in part on real incomes and over the lengthy periods to be addressed in the Commission's analyses, increasing labor productivity is likely to cause incomes to increase significantly faster than general inflation, and society to thus become more affluent. Global Insight has projected annual increases in real income of 2.6 percent in the short term, declining to 1.6 percent in the longer term. The impact of these projected increases in real income have been taken into account in the travel demand forecasts described above, but could also be utilized in setting the value of time at rising levels within the analysis period.

Accordingly, the Base Case scenarios utilize a 4 percent discount rate, and assume gradual increases in the value of time in constant dollar terms as noted above. It should be noted that both of these assumptions tend to increase the level of investment that the analytical models would find to be cost-beneficial.

[1] The discount factor (often stated as a discount rate) reflects the fact that income or benefits received in the future are worth relatively less today, due to the time value of resources.

Analytical Results

The HERS and NBIAS models are designed to analyze the relationship between future investment levels and performance. Highway investment can thus be analyzed either in terms of the amount of investment required to achieve a given level of performance, or as the level of performance resulting from a given level of investment. The Base Case analysis addresses three such investment levels: the **Current Sustainable** level of investment in constant dollar terms; the level of investment required to at least **Maintain the Current System**; and the **Maximum Economic Investment** level. If desired by the Commission, these Base Case funding levels could potentially be supplemented by an additional investment level intended to improve indicators of condition and performance to a specified level, perhaps in between the performance levels achieved by the Maintain the System and Maximum Economic Investment levels.

Current Sustainable Funding

Commission staff has assumed that the current sustainable funding level is limited by the future revenue streams of existing taxes and fees flowing into the Federal Highway Trust Fund, which would determine Federal funding for highways and transit. State and local funding is assumed to match current investment levels in constant dollar terms, growing only with inflation.

Based on projections of Federal Highway Trust Fund revenues, an average annual capital investment level of $68.8 billion (in constant 2006 dollars) from Federal, State, and local sources could be sustained into the future.[2] If funding were to be sustained at this level in constant dollars into the future, growing only with inflation, the models project that the condition and performance of the Nation's highway system would become significantly degraded over time. Average traveler delay on urban principal arterials would be projected to increase by 13 percent through 2020 (relative to base year 2005 levels) and by 37 percent by 2035. Pavement condition would also worsen, with the percentage of travel on all Federal aid highways on roads with acceptable ride quality declining from 85.5 percent in 2005 to 74 percent in 2020 and to just 64 percent in 2035.

Maintaining the System

For highways, this investment level is set at a level high enough to maintain or improve all major performance indicators, including average delay per traveler on urban principal arterials and the percent of travel in rural and urban areas occurring on roads with acceptable ride quality. For bridges, investment is set at a level high enough to maintain (i.e., prevent from increasing) the current backlog of bridge deficiencies in constant dollar terms.

The projected level of capital investment that would be required to maintain or improve highway conditions and performance (relative to 2005 levels) over 15 years is $2.1 trillion ($143 billion on average annually) in constant 2006 dollars. Achieving this level of performance over 30 years would require $5.1 trillion ($170 billion annually) in constant-dollar capital investment.

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[2] This figure includes only capital outlays on Federal aid highways, and is slightly higher than the 2005 highway capital outlay levels. The near-term solvency issues associated with the Highway Trust Fund reflect the increasing size of the Federal-aid Highway Program authorized under SAFETEA-LU, rather than earlier authorized funding levels reflected in actual 2005 capital outlays.

Adjusting for projected inflation over these time periods would yield estimates of $2.5 trillion through 2020 and $7.0 trillion through 2035, respectively.

At these investment levels, pavement condition would be maintained at current levels, while highway operational performance would improve slightly. Average delay on urban principal arterials would be projected to decline by 16 percent through 2020, and by 9 percent through 2035.

Maximum Economic Investment

This represents the maximum level of investment for which potentially cost-beneficial uses can be identified. This level of investment would achieve the maximum potential improvements in condition and performance achievable with cost-beneficial investments.

The projected Maximum Economic Investment level for highways and bridges is $3.4 trillion ($225 billion on average annually) through 2020 and $6.6 trillion ($221 billion annually) through 2035, stated in constant 2006 dollars. Adjusting for projected inflation in highway construction costs over this period would yield estimates of $3.8 trillion over 15 years and $8.8 trillion over 30 years.

Both conditions and performance on Federal aid highways would be improved at these investment levels. By 2020, the percentage of VMT on roads with acceptable ride quality would be projected to increase to 93.4 percent; by 2035, it would be projected to reach 92.9 percent. Average delay on urban principal arterials would be projected to decrease by 31 percent through 2020 and by 22 percent through 2035.

The Very Long Term: 50-Year Analysis

The 50-year highway investment performance analyses produced for the Base Case are more illustrative than analytical in nature, for several reasons. The models used to produce these estimates of future highway and bridge investment and performance were originally developed to produce 20-to-30 year projections. While the models have been adapted to extend these analyses out to 50 years, the stability of the estimates becomes problematic beyond 30 years. The sources of much of the information used in the passenger and freight travel forecasts also provide projections for only 30 years, requiring less detailed assumptions about the impacts of demographic and economic factors beyond this time. The analyses being developed for other modes, which will be paired with the highway analyses as part of the scenario analyses, are also being developed for a 30-year time horizon. Finally, the degree of uncertainty associated with future transportation technologies and travel behavior become magnified when looking at the very long term, resulting in a greatly reduced level of confidence in any particular quantitative estimate.

With these caveats in mind, the 50-year investment analyses performed for the Base Case indicate that:

- At the current sustainable funding level, average delay would be projected to increase by 64 percent by 2055, while the percentage of travel on roads with acceptable ride quality would decline to just over 50 percent.

- The constant dollar Maximum Economic Level of investment would be $11.2 trillion through 2055 ($18.6 trillion in inflation-adjusted terms). If this level of investment were to be achieved, average delay in 2055 would be slightly less (roughly 2 percent) than in 2005, and 90 percent of travel would be on roads with acceptable ride quality.
- The average annual cost to Maintain the System would increase significantly beyond 2035 (to $230 billion annually from 2035-2055), assuming that the levels of investment described above through 2020 and 2035 were to be achieved. Maitaining this level of performance would require an estimated total 50-year investment of $9.7 trillion in constant 2006 dollars ($16.7 trillion when adjusted for projected inflation).

Implications of the Analysis

It is important to emphasize that this Base Case analysis assumes the continuation of existing financing mechanisms, policies, and other factors. The results indicate that, absent any other changes in the Nation's surface transportation system, continuing to fund highway capital investment at currently sustainable funding levels would result in both conditions and performance worsening significantly over time. Dramatically increasing funding levels could lead to improvements in conditions and performance over the medium or long term, but even the Maximum Economic Investment level would be unable to achieve significant improvement in the very long term, absent other changes in technology or policies. The impact of such alternatives will be explored through the Scenario analyses.