Integrating National Data Sets with Asset Management, Traffic Forecasting, Performance and Economic Models to Show National Economic Implications of Transportation Funding and Performance Gaps Under Different Scenarios

Prepared by:
Chandler Duncan (corresponding author)
Economic Development Research Group, Inc.
2 Oliver Street, FL9, Boston, MA 02109 USA
Telephone: (617) 338-6775, x203
Fax: (617) 338-1174
Email: cduncan@edrgroup.com

Steven Landau
Economic Development Research Group, Inc.
2 Oliver Street, FL9 Boston, MA 02109 USA
Telephone: (617) 338-6775, x206
Fax: (617) 338-1174
Email: slandau@edrgroup.com

Derek Cutler
Economic Development Research Group, Inc.
2 Oliver Street, FL9 Boston, MA 02109 USA
Telephone: (617) 338-6775, x216
Fax: (617) 338-1174
Email: dcutler@edrgroup.com

Brian Alstadt
Economic Development Research Group, Inc.
2 Oliver Street, FL9 Boston, MA 02109 USA
Telephone: (617) 338-6775, x209
Fax: (617) 338-1174
Email: balstadt@edrgroup.com

Lisa Petraglia
Economic Development Research Group, Inc.
2 Oliver Street, FL9 Boston, MA 02109 USA
Telephone: (617) 338-6775, x204
Fax: (617) 338-1174
Email: lpetraglia@edrgroup.com

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ABSTRACT
This paper explores how different asset management, traffic forecasting, performance and economic models can be integrated to show the national economic implications of transportation funding and performance gaps under different scenarios.

Asset management models have often been utilized to assess and forecast the condition and performance of current infra-structure, travel demand models have been used to anticipate how traffic volumes are likely to develop over time, depending on capacity improvements, user cost models have been used for cost-benefit analysis and the management of trade-offs, and economic impact models have been used to characterize transportation choices in terms of earnings, output and employment.

INTRODUCTION
The objective of this paper is to explore how available data sources and models can be synthesized to offer a holistic macro-economic perspective on multi-modal investment needs and deficiencies at multi-state levels. This objective is especially pertinent, as there is a growing need in the fiscally constrained national policy environment for an understanding of how the 'national economic interest' or 'nationally significant projects' can be defined and compared in funding decisions. This paper offers a perspective, and a 'real-world' example at the national level of how this may be addressed by synthesizing the data and tools currently available.

This paper explores how national level research undertaken for the American Society of Civil Engineers (ASCE) in 2011 has integrated national asset management models, a national network traffic assignment model, a standard user-cost model and an international economic impact model to assess multi-modal ground transportation scenarios. It is also based on statewide analyses conducted for Kansas Department of Transportation and the Virginia Department of Transportation. Models used are generally available to practitioners, either because they are public products of the U.S. Department of Transportation or are commercially obtainable.

Multiple models and data sets needed to be joined to assess current conditions of transportation facilities, expectations of current and system performance; funding available today and assumed future funding; the economic consequences of meeting or not meeting funding levels to achieve desired conditions; and consequences it any the economy. The analytical framework joins models and data sets as noted in Table 1 and Figure 1.

TABLE 1 Combination of Models and Data Sets

<table>
<tr><th>Model</th><th>Data Set</th><th>Purpose</th></tr>
<tr><td>HERS-ST</td><td>Highway Performance Monitoring System</td><td rowspan="3">Determine recent state/national funding trends; determine transportation goals (e.g., free flow conditions; minimum tolerable conditions; state of good repair); set constrained future funding scenarios; determine how well transportation facilities are expected to function as different from goals set given current backlog and projected funding. These models and data sets do not include travel.</td></tr>
<tr><td>TERM</td><td>National Transit Database</td></tr>
<tr><td>NBIAS</td><td>National Bridge Inventory</td></tr>
<tr><td>CUBE/Voyager</td><td>Freight Analysis Framework (FAF3)</td><td>Projects travel conditions on a national highway network based on VMT/VHT analysis from HERS-ST, TERM & NBIAS. This model does not include conditions of transportation facilities.</td></tr>
<tr><td>TREDIS</td><td rowspan="2">BEA and other data sets from the US Department of Commerce and Bureau of the Census</td><td>User costs to industries and households (dynamic elasticities), and societal costs based on output from models listed above. Regional economic impact analysis can be rolled up to national analysis.</td></tr>
<tr><td>LIFT</td><td>Based on inputs from TREDIS, assesses international competitiveness and impacts of international trade on domestic economy on a national scale.</td></tr>
</table>

HERS-ST – Highway Economic Requirements System (U.S. Federal Highway Administration)
TERM – Transit Economic Requirements Model (U.S. Federal Transit Administration)
CUBE/Voyager – Citilabs; www.citilabs.com
TREDIS- Transportation Economic Impact System; Economic Development Research Group; www.tredis.com
LIFT- Long-term Interindustry Forecasting Tool; Inforum Group of the University of Maryland; www.**inforum**.umd.edu/services/models/**lift**.html

LITERATURE REVIEW

There are many widely used and circulated sources of analysis using models to quantify transportation investment needs, many of which use some economic measures to assess the costs to users in the US Economy. The Federal Highway Administration, "2008 Status of the Nation's Highways, Bridges and Transit: Conditions and Performance" Report is among the most widely known and documented (typically updated every two years) (*1*).

Economic Development Research Group, Inc. , "Failure to Act: The Economic Impact of Current Investment Trends in Surface Transportation Infrastructure" (for the American Society of Civil Engineers); July, 2011 is the vehicle that combined the models and data sets described in Figure 1 for an analysis at national and multi-state regional levels.

A Cambridge Systematics study (*2*) explored investment needed to meet future economic demand. The study did not consider investment needed to maintain the rail system, and was limited primarily to rail transport needs. Economic Development Research Group (*3*) estimated the impact of preservation funding on the Kansas economy using three funding scenarios. The Kansas study considered the differential costs of different levels of pavement and bridge sufficiency and their overall economic impact, but like other preservation studies, it did not consider network traffic effects. A 2010 New York Study (*4*) explored the user costs of unmet needs at the state level, but did not further analyze these in terms of national economic significance. Booz Allen Hamilton (*5*) attempted to answer a number of questions about how states are using Transportation Asset Management (TAM), including:

• Increasing traffic volumes and vehicle weights result in increasing rates of roadway deterioration.

• Trade-offs between preservation and capacity needs.

The Caltrans Business, Transportation and Housing Agency (*6*) explored needs, and compared the costs of improving vs. accommodating unmet improvement needs on the state system. The Institute of Labor and Industrial Relations – University of Michigan and Economic Development Research Group (*7*) analyzes the economic trade-off between road-bridge Rehabilitation and repair (R&R) and increased capacity/new roads (IC/NR). The study looks at both the construction period economic impacts and the long-term economic impacts. We are interested in the latter. The Urban Institute, Cambridge Systematics, and the Pennsylvania Economy League (*8*) evaluates four potential future funding scenarios for SEPTA, assessing relative impact of VMT, VHT and overall user cost. Tanner, T. and A. Jones (*9*), finds that if MARTA were to stop running, annual traffic delays would increase by 1.25 million hours at a cost of $245 million, including costs to operate a vehicle, time delays, and parking.

The above review finds that while there is extensive applied work on assessing the user costs of different types of transportation deficiencies, there is more limited work on modeling the complete sequence of analysis from assessing needs (including both preservation and expansion needs), to estimating network impacts of unmet needs, to assessing economic costs and impacts in a national or multi-state setting.

Consequently, this study seeks to explore how these different types of models may fit together within a national modeling context to provide a greater holistic economic understanding of the economic implications of unmet or unfunded transportation investment needs.

METHODOLOGY

We analyzed projected national surface transportatoin needs over two funding periods (from 2010 to 2020, and from 2020 to 2040), beginning with publicly available data sources and models. .The overall steps of the methodology include:

1. Quantify the overall investment needs from 2010 to 2040, and the performance implications of shortfalls using the performance measures and data of widely accepted models at the national level.

2. Assess the accruing **costs** to America's households and businesses based on the performance implications of these unmet needs and

3. Quantify how these costs work their way through the US economy over time; resulting in long-term changes in employment, earnings, and value-added.

Figure 1 illustrates the data sources, models and adjustments involved in the synthesis of the economic impacts included in the report and described in this report.

Needs Models

The methodology begins with needs models, which address overall investment need (the first point above). Needs models are the natural starting place, because they transform current empirical data and assumptions into both dollar amounts and quantified performance outcomes for a specified set of performance measures. These models are also publicly available, and used by the United States Department of Transportation (USDOT).

The needs models used in the report include:

• Highway Economic Requirements Model – HERS-ST (Federal Highway Administration (FHWA))

- C CUBE/Voyager software
- National Bridge Inventory Analysis System – NBIAS (FHWA)
- The Transit Economic Requirements Model – TERM (Federal Transit Administration (FTA)

Highway Economic Requirements Model – HERS-ST (FHWA)

For the purposes of this study, the HERS-ST "Full Engineering Needs" analysis was applied to develop the improvement costs needed to build and maintain the nation's infrastructure to the HERS-ST default "minimum tolerable conditions" from 2010 to 2040 (six five-year funding periods), given the HERS-ST unit improvement costs and financial assumptions. The "Full Engineering Needs" analysis relied on adjustments to the HERS-ST default parameters in the following regards:

The maximum number of lanes was set to 16 lanes (8 lanes in each direction). HERS-ST was programmed not to find an expansion need due to a capacity deficiency when 16 or more lanes were in place (including lanes assumed built to satisfy needs in previous period). HERS-ST was programmed not to find an expansion need if a roadway section in the data sample on which the HERS-ST model is based is coded as "widening infeasible" (hence 'high-cost-lanes' widening to overcome extreme geographic or environmental constraints on widening were not counted as needs).

Because of these two adjustments, the HERS-ST full engineering needs analysis (which serves as the fully funded base-case for the economic analysis) represents some level of congestion, and represents slightly less than 'minimum tolerable conditions,' much less free-flow traffic conditions in even a fully funded system.

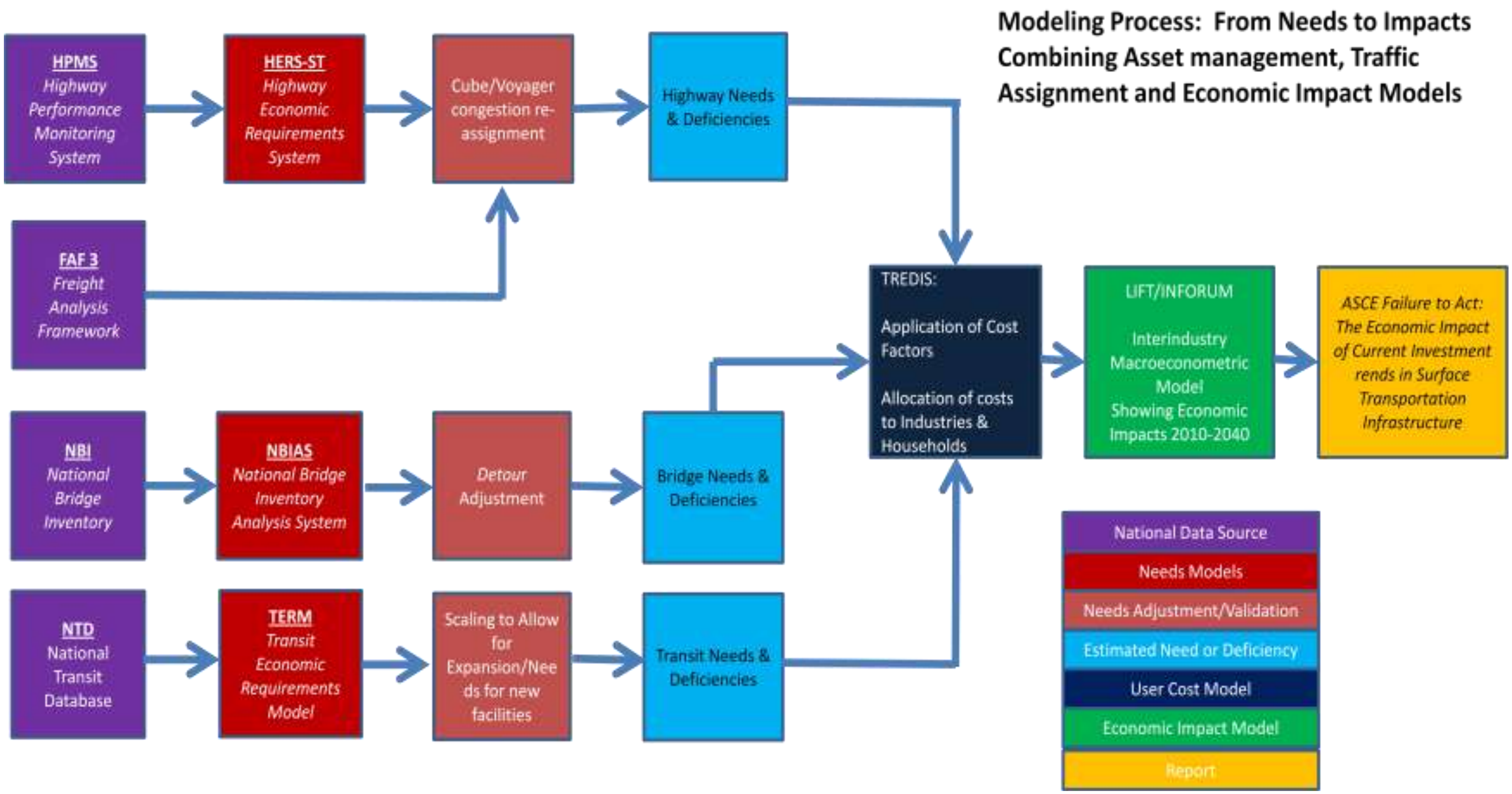

FIGURE 1 Modeling Process: From needs to impacts combining asset management, traffic assignment and economic impact models.

This analysis yields the highway system conditions and performance in terms of vehicle miles and vehicle hours of travel on capacity deficient facilities and pavement deficient facilities as a percentage of overall vehicle miles and hours, as well as average speeds and crash rates by state and by national functional classification. The highway system conditions and performance results of the HERS-ST "Full Engineering Needs Analysis" provide the baseline level of highway deficiencies; with any deficiencies exceeding those found in this analysis considered to be among the costs of deteriorating infrastructure.

The fiscally constrained analysis represents a funding level commensurate with current highway spending levels (on an average annual basis). Like the "Full Engineering Needs Analysis", this analysis gives the highway system conditions and performance in terms of vehicle miles and vehicle hours of travel on capacity deficient facilities and pavement deficient facilities as a percentage of overall vehicle miles and hours, as well as average speeds and crash rates by state and national functional classification.

Using the HERS-ST model, significant differences in speeds were found on each functional classification of roads between the fully funded and deficient scenarios as described in the report. It was assumed that these changes in speed may result in a re-assignment of traffic on the US highway network requiring a geographic (mapped) network assignment methodology to quantify how these speed changes may affect overall VMT and VHT levels by functional classification.

CUBE/Voyager software

We used CUBE/Voyager software to apply generalized origin-destination matrix estimation to U.S. counties based on 2010 estimated passenger car and truck volumes given in the USDOT Freight Analysis Framework (FAF3). This resulted in a county-to-county origin-destination matrix for all passenger car and truck trips in the US. This origin-destination matrix was then re-assigned to the national network provided by FAF3, to a new set of routings assuming minimum time paths are altered by the speed changes associated with the congestion found by HERS-ST. The result is the traffic reassignment map which appears in the report, and a set of post-processed vehicle miles traveled (VMT), vehicle hours traveled (VHT) and percent congested estimates for user costs and application of economic impact models described in the study.

National Bridge Inventory Analysis System – NBIAS (FHWA)

The bridge needs model in this study used NBIAS with the bridge element profile and parameters used in the 2008 Conditions and Performance report (this profile was obtained directly from FHWA) and applied to the 2010 National Bridge Inventory assuming a base-case (comparable to "Full Engineering Needs" in HERS-ST), average annual funding level of $17 Billion in comparison with a $10.5 Billion average annual fiscally constrained funding level.

The results of this analysis yielded the number of structurally deficient or functionally obsolete bridges expected to be on each national functional classification of the US highway system in each year of the 2010-2040 analysis. Based on 2010 compiled data from the national bridge inventory, we estimated the percent of structurally deficient or functionally obsolete bridges actually posted with load restrictions for cars or trucks. This percentage was then applied to the NBIAS estimates of future numbers of deficient bridges in each year, yielding an estimated number of bridge detours, by US highway functional classification for each year.

Finally, the NBIAS cost matrix has a built-in assumption regarding average detour lengths for bridge closures by national functional classification. These detour lengths (in terms of miles and hours) were then applied to the number of bridge closures or weight restrictions in each year of the analysis, resulting in an estimated number of vehicle miles and vehicle hours of travel occurring due to bridge closures or restrictions in any given year. The vehicle miles and vehicle hours of travel attributable to deficiencies was compared between the fully funded base case ($17 Billion average annual) and the fiscally constrained case ($10.5 Billion average annual) to arrive at the passenger car and truck vehicle miles and vehicle hours of travel that are caused by additional bridge deficiencies in the fiscally constrained case and not occurring in the fully funded case.

As bridge conditions have been historically improving, the funding levels suggested by the report card find a reduction in bridge deficiencies over time, fully resolving the backlog before in both the fully funded and fiscally constrained cases before 2040. Therefore the only difference between these cases is the number of years it takes to resolve the backlog – but by 2040, the user cost of deficient bridges is effectively zero.

The Transit Economic Requirements Model – TERM (FTA)
Unlike HERS-ST and NBIAS, the TERM model does not provide a specific percentage of trips, vehicle miles or vehicle hours subject to the deficiencies on the fiscally constrained system. Instead, TERM simply provides the differential improvement costs for each asset type between a fully funded system and a continuation of today's level, and a comparative percentage of assets left below the 'state of good repair' for each funding level. The percent of assets below the state of good repair for each asset type in each future year is then applied to TERM's forecast of the number of revenue miles by asset type in each future year of the analysis for each state. The result is a number of vehicle revenue miles, by asset type and state that are expected to be subject to a deficiency in each of the future years.

2010 compiled statistics from the national transit database were then used to derive a ratio of average service interruptions per revenue mile of deficient infrastructure, and an average time lost per service interruption. This loss of travel time is then allocated to trip purposes using the national household travel survey (NHTS) for integration into the user cost model.

Relationship of Deficient Case to Base Case
The basis of user costs of highway needs used in the study is the difference in performance between the "full engineering needs analysis" and the "fiscally constrained analysis." Figure 2 below illustrates how the magnitude of the effects of unmet highway investment needs was derived.

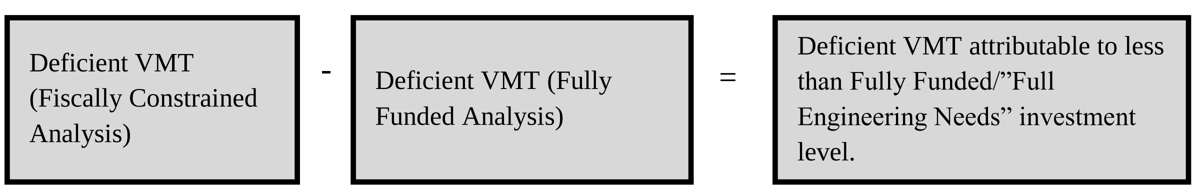

FIGURE 2 Arriving at deficient highway VMT.

The same basic relationship given above for VMT applies to passenger car and truck capacity and pavement deficient VMT, VHT and crash rates found by HERS-ST (and post processed using CUBE/Voyager).

Economic Models

The two economic models used in this methodology were:

1. Transportation Economic Development Impact System (TREDIS); and
2. Long-term Inter-industry Forecasting Tool (LIFT).

First, the TREDIS travel cost module was used to translate travel characteristics into cost changes for households and industries, and were passed to the LIFT model (see section on LIFT below).

Travel costs were analyzed by mode and trip purpose. This is important for two reasons. First, unit cost factors used to monetize each cost type vary with mode and trip purpose. As a simple example, time spend making a personal trip typically has a lower opportunity cost than on the-clock travel. Second, in order to estimate economic impacts, transportation cost savings are allocated to households and industries. This allocation is made based on which modes and trip purposes are affected. For this study "personal time" was not included as part of the travel cost and subsequent economic calculations.

Travel costs were approached the following ways:

- Passenger Time Cost
- Crew Time Cost
- Freight Time Cost
- Reliability Costs
- Vehicle Operation Costs

Differences in user cost between the fully funded and fiscally constrained scenarios include not only differences in assumed vehicle miles and hours of travel, but also different per-mile costs and crash rates depending on whether miles and hours are traveled on sufficient or deficient services (as found by the needs models).

Secondly, the TREDIS economic adjustment module was used to validate/calibrate the LIFT results. In TREDIS, the economic adjustment module incorporates dynamic elasticities that translate transportation cost changes into additional output at the regional level (without double-counting). This is essentially an industry investment module that recognizes that, for a specific industry, transportation cost savings may be passed on to customers or retained as profit, where the latter may be used for business investment. Business investment yields future economic growth through increased productivity. This basic logic is also incorporated in the INFORUM model. However, LIFT also has feedback effects from international trade due to changes in domestic commodity prices. This overlap gave common-ground for validation purposes, and allowed national LIFT results to be accurately allocated to TREDIS regions (BEA). The relationship of TREDIS to LIFT is illustrated by Figure 3

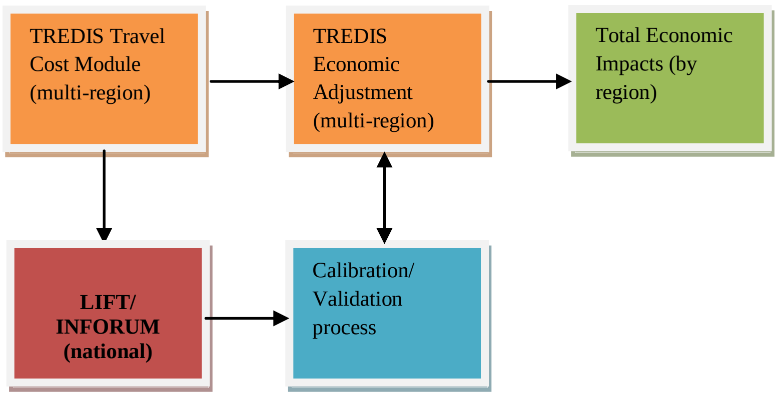

FIGURE 3 Interaction between TREDIS and LIFT.

The user costs accruing to households and industries are used as inputs to LIFT, an inter-industry macroeconomic model which follows those costs through the economy through buyer and supplier transactions over time from 2010 to 2040, yielding an estimate of the overall change in earnings, output, employment and value-added over the life of the analysis (FIGURE 4).

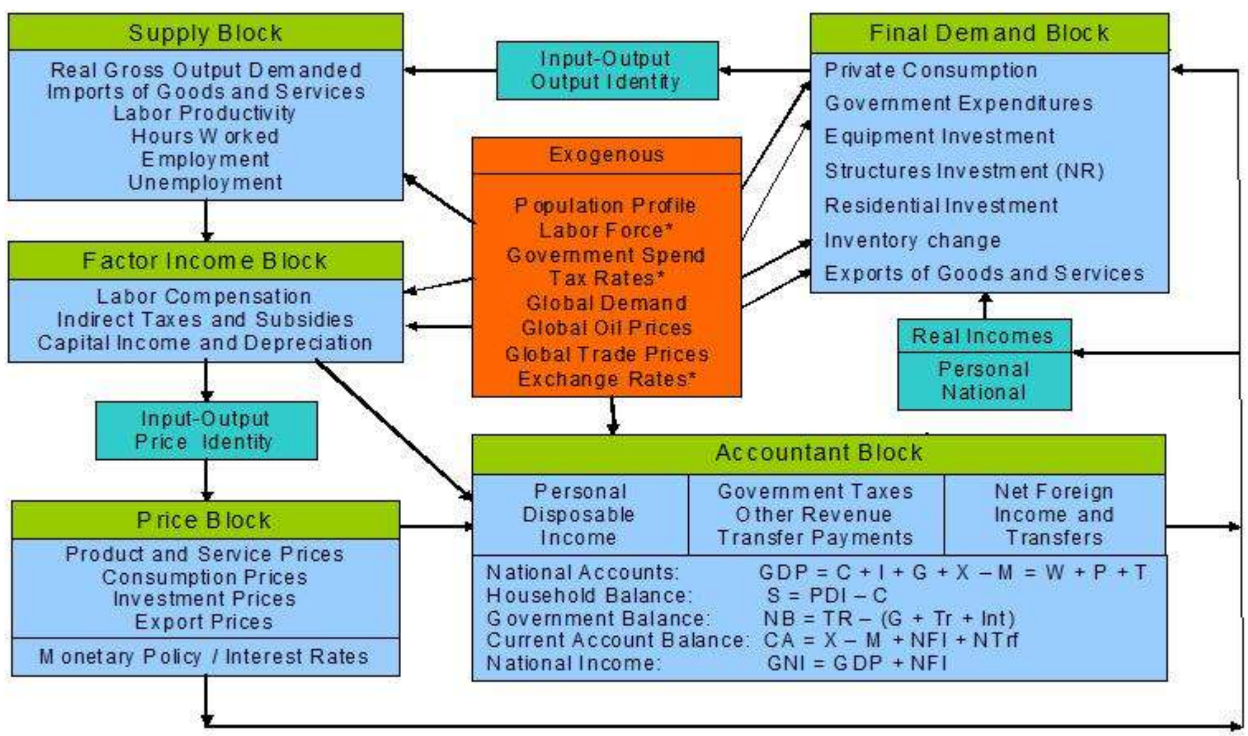

FIGURE 4 LIFT model schematic diagram.

LIFT calculates all of the major nominal economic balances for an economy: personal income and expenditure, the government fiscal balance (at both the federal and state and local government levels), and the current account balance. It also contains a full accounting for population, the labor force, and employment.

RESULTS

The results show that the typical needs, and conditions and performance implications of un-funded needs lend themselves to further analysis of national transportation network effects, the dispersion of user-costs across state lines and across different facility types, and these effects are quantifiable in terms of both user costs accruing on the US economy, as well as impact on overall international economic competitiveness of US industries.

Because this paper focuses primarily on how different models and paradigms can be integrated into a national (or international) understanding of economic significance, the reporting of results is focused primarily on those findings which specifically depend on linkages between the asset management (HERS-ST, NBIAS and TERM), travel demand (CUBE Voyager Re-assignment of Traffic Across the FAF network based on speed changes found by HERS-ST) and economic (User Cost and Economic Impact) models, as opposed to the more conventional findings of any given model in the sequence. For example the findings of an up-to-date analysis among the 50 states in HERS-ST and NBIAS with the latest HPMS and NBI data, or a current transit needs picture from TERM may be of some interest, but such findings are not emphasized in the paper. Instead, the results here focus on how those results represented by subsequent, downstream analysis lending to a holistic understanding of the economic significance of transportation funding. The results emphasize the particular insights that may be gleaned from combining these different types of models at the national (or multi-state) level with a focus on the economic significance of transportation funding.

Transportation Performance & Needs Findings

Based on the synthesis of models and data sources described above with, minimum tolerable conditions, and data sources consistent with current application of federal highway, bridge, and transit investment models, roughly $220 billion annually (2010 dollars) is needed from 2010 to 2040. This breaks down to an average investment of approximately $196 billion per year in highway pavements and bridges, including $161 billion congestion mitigation7 and $35 billion in preservation of existing facilities. In addition, $25 billion per year in transit capital infrastructure investment (including rolling stock as well as trackage, terminals, and roadways for access) is needed.

Approximately 37% of this highway and bridge investment and 25% of this transit investment will be needed simply to resolve existing deficiencies of almost $74 billion that are already affecting the U.S. economy. The remainder is needed to prevent deficiencies from recurring or getting worse over time. The HERS-ST modeling aspect of the methodology revealed that urban interstate capacities have not kept pace with demand in urban areas, and speeds on U.S. interstates in urban areas in 2010 were 10 miles per hour less than they would be if the system were built to minimum tolerable engineering standards for projected traffic levels. In 2020 this ‘speed deficit’ will grow to 13 miles per hour and 16 miles per hour in 2040.

By including a national county-to-county re-assignment of a national O-D matrix (based on the FAF network), it is possible to consider in general terms, the network effects of urban interstate bottlenecks on national routings. The HERS-ST analysis finds that congestion is increasingly concentrated on urban interstates (based on anticipated future AADT levels and capacities).

This is an example of a result from a HERS-ST model that may lend itself to further interpretation through integration with other models. Because of the significantly deteriorating average interstate speeds through America’s major cities, a national re-assignment of traffic can be performed on the FAF network showing the potential re-assignment effects of urban interstate deficiencies on other facilities (both within and beyond urban areas). The urban and rural arterial routes absorbing the majority of the traffic from a deficient urban interstate system typically (by definition as arterials vs. interstates) have lower design speeds and standards than the interstates, and are subject to higher crash rates and other costs. In 2010, it is estimated (from a stochastic re-assignment of traffic on the FAF network based on HERS-ST congested speed by functional classification) that 18% of urban interstate traffic was diverted to lower classified systems, and 6% of rural interstate traffic was diverted.

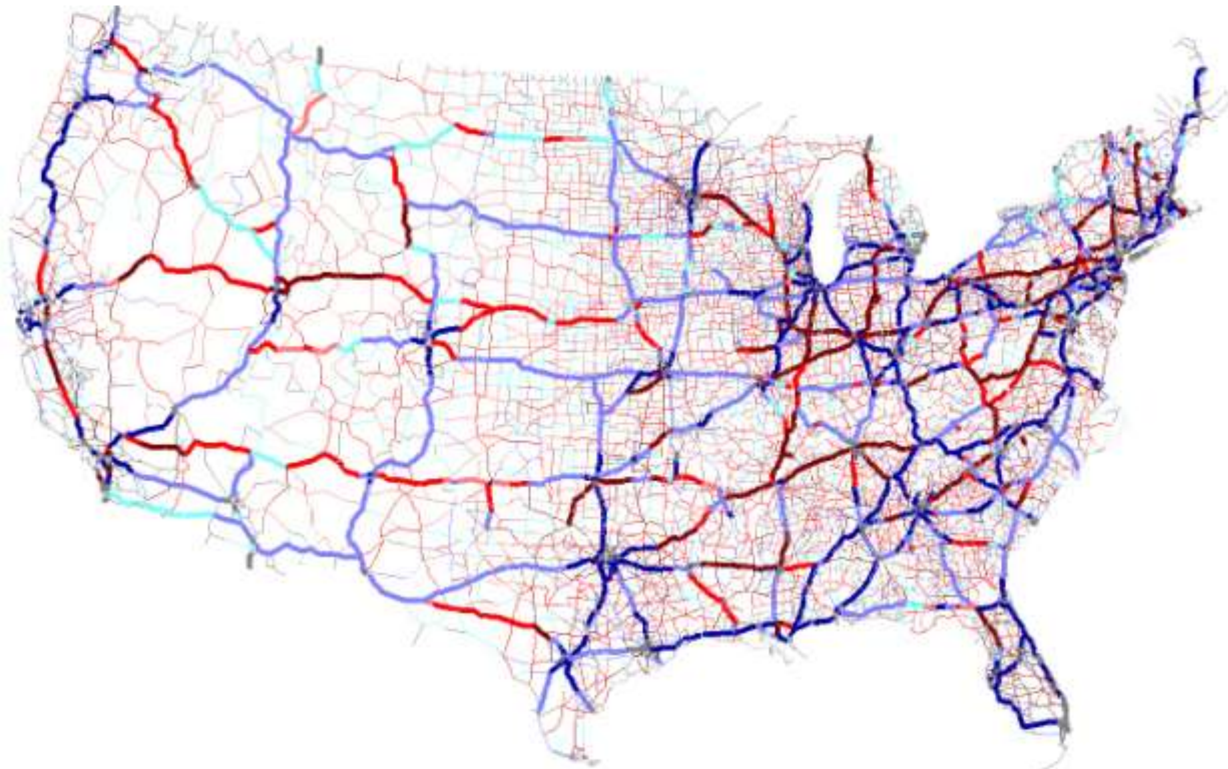

FIGURE 5 Urban congestion affects the national routing of traffic.

Figure 5 shows that while congestion and VMT growth are increasingly concentrated in urban areas—the costs and performance implications of these deficiencies are affecting rural and outlying areas as well, and often result in significantly higher VMT and vehicle hours of travel (VHT), especially for trucks and transcontinental moves than would otherwise be the case. These projected changes draw attention to the sufficiency and performance of arterials, and even nonurban arterials (shown as smaller lines in the background in FIGURE 5), most of which are absorbing some share of the intercity traffic that is shown to be diverted when urban interstate and freeway speeds are affected by congestion. Thus, the routing effect s of deficiencies in the interstate system cannot be isolated to only urban areas where deficiencies occur but also affect all the different regions of the U.S., both urban and rural.

Figure 5 is an illustration of the change in routing that occurs due to urban bottlenecks on the interstate system. At current funding levels, the reassignment of interstate traffic to lower classified systems creates an additional 360 million urban VHT and 104 million rural VHT in 2010, and will increase to 22 billion urban VHT and 6 billion rural VHT in 2020, and 34 billion urban VHT and 6 billion rural VHT by 2040. Most of the routes gaining traffic are state arterial routes with lower capacities, design speeds, and design standards than the routes losing traffic.

Economic Findings

The user costs associated with VMT and VHT changes can readily be translated into user costs (by trip purpose for passenger cars, and by commodity for heavy trucks) using traditional IMPLAN data embedded in the TREDIS system as described in the methodology section. When these costs are incorporated into the LIFT model, further implications of unmet needs, consistent with both the HERS-ST/NBIAS/TERM results, and a national network effect can be quantified.

The analysis finds that by 2040, the cost of America's deteriorating surface transportation infrastructure is expected to cost the nation's economy more than 400,000 jobs. Although infrastructure deficiency creates jobs in sectors such as auto and bus repair, retail sales of gasoline, services and parts purchased due to the deficiencies and decreased productivity per worker, critical job opportunities are lost in highly skilled and well-compensated non-transportation sectors throughout the economy. The sectors losing the most employment include high-value professional, business and medical sectors, as well as sectors such as restaurants, entertainment and other amenities, which must be forgone by households when a larger share of the household budget must go to transportation. Figure 6 shows those industries in which jobs will be gained, and ultimately lost to the U.S. economy in 2040, due to deficient infrastructure compared with 2040 conditions if the surface transportation system was maintained to minimum tolerable conditions/state of good repair.

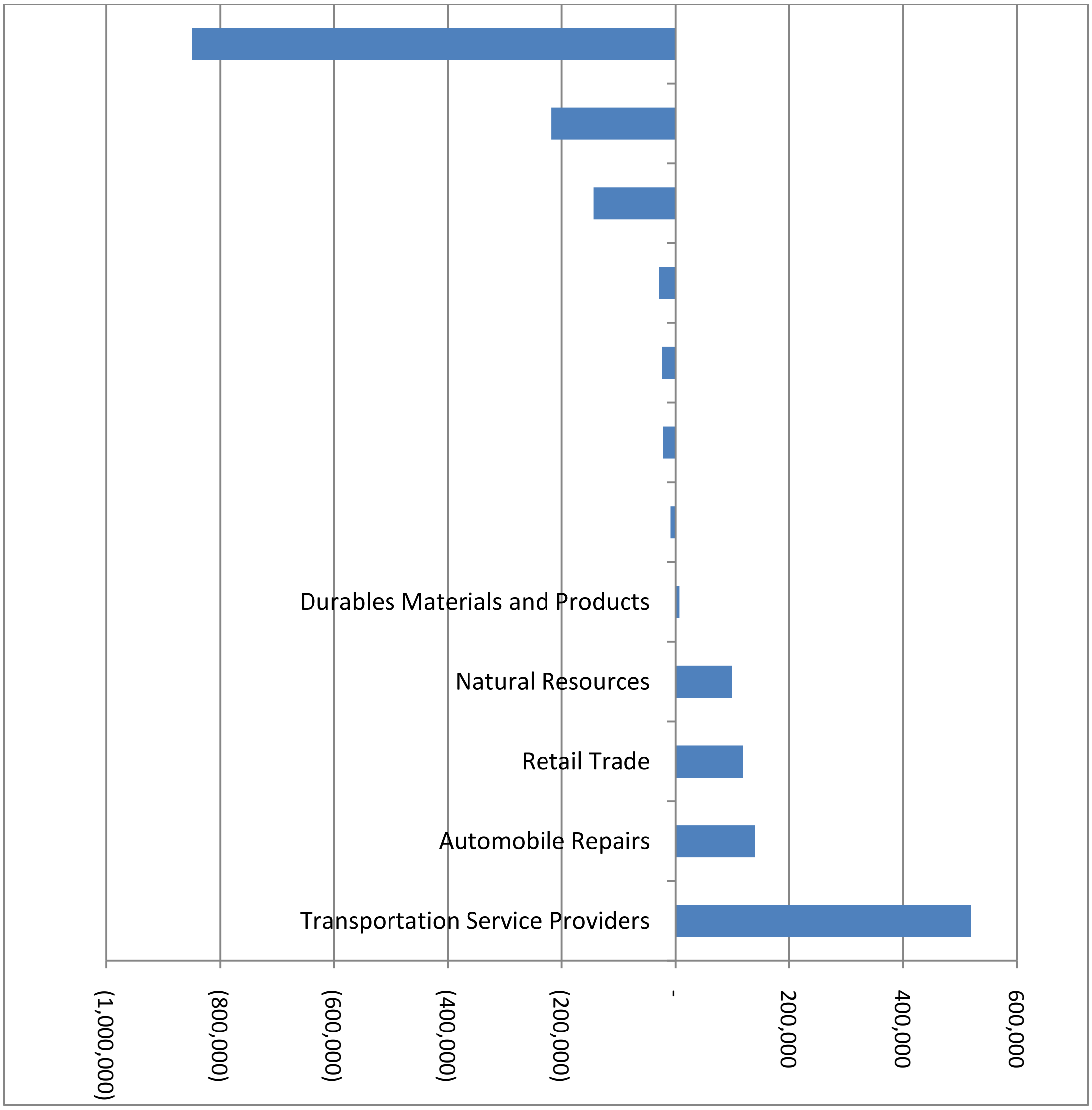

FIGURE 6 Change in composition of US job market due to deteriorating infrastructure.

Overall, industry sectors gaining jobs as a result of infrastructure deficiencies in 2040 have an average annual income level of 28% less than the income level of those sectors losing jobs. By requiring Americans to take lower paying jobs to support the needs of deficient infrastructure, transportation shortfalls have a significant effect on personal income for all Americans.

With deteriorating surface transportation infrastructure, United States exports of products and services will face elevated price pressures in one or two ways:

1. Exporting firms directly experience higher transportation costs with their own truck fleet for shipments to the Mexican and Canadian borders or to an airport or seaport; and

2. Exporting firms absorb price increases related to transportation costs on some portion of intermediate supplies that arrive by truck and go into a final product. Those intermediate supplies may be domestically produced, or they may be foreign imports that must incur a landbridging cost from an airport or seaport, or from the Canadian or Mexican borders.

If the condition of surface transportation does not stabilize at current levels, 79 of 93 tradable commodities are expected to experience lower export transactions in 2020 and 2040. Table 3 shows the 10 commodities in each year that will lose the export sales expected under current conditions.

In 2020, the 10 commodities that are expected to lose the highest levels of export dollars account for 53% of the export value lost by the aggregated 79 commodities and 52% in 2040. Moreover, many exports shown on the 2020 and 2040 tables, both in terms of percent declines and dollar losses, are key technology sectors that drive national innovation. These include machinery, communications equipment, medical devices, transportation equipment, aerospace, other instruments and chemicals.

Methodological Findings

Overall, the methodologies of asset management, travel demand, user cost and economic impact models could be readily incorporated in a consistent manner to identify economic implications of different funding levels and shortfalls in ways that have not typically been part of the national or statewide needs planning process. When compared against federal highway statistics, the needs results were generally commensurate with published federal findings, and when translated into per-mile and per-vehicle costs these costs cross-checked with available BEA data about transportation expenditures by mode and by region, both in absolute terms and as a percentage of GDP. Furthermore the degree of re-assignment, and the regional effects (as mapped in Figure 5) appear intuitive in terms of state by state reports of congestion in federal highway statistics, as well as the TTI Urban Mobility report (11). This study does not find or recommend that the high-level of sketch modeling used to integrate the models in this case represents a best practice for state, multi-state or mega-regional planning, but only that such integration is possible, and that further refinement of the parameters of the models used here is expected to yield greater insight into the national economic significance of state, regional or national transportation investment choices.

CONCLUSIONS

Based on the approach, methods and data presented here, it is concluded that widely used models and data sources of asset management and traffic conditions and performance generally available at the state and national level provide the building blocks for assessing the national economic significance of different funding levels and strategies for national and multi-state programs. The analysis has found in particular that utilizing widely available asset management models to understand infrastructure conditions and performance as the basis for understanding national network effects, user costs and industry impacts yields a holistic view of how unmet transportation needs play out in the national and international economy.

This study is offered primarily as a paradigm for integrating asset management, travel demand, user cost/benefit and economic impact models into a holistic framework at the policy level. Based on the results of this high-level study, it is recommended that states may wish to consider coordinating with other states in the assessment of needs as well as the inter-regional traffic impact, allocation of benefits and impacts of statewide investment strategies to better show the national economic significance of key transportation initiatives. This could add value to the statewide planning process, but also may provide a way forward for developing multi-state investment strategies for mega-regions, and for national initiatives where funding is based on economic significance.

Of particular relevance are the findings showing that urban bottlenecks in some states can impose significant travel demand and associated costs on the economies of other states, and on non-urbanized regions of the same state. This finding, coupled with the economic findings showing that some industries nationally suffer in their economic competitiveness increasingly point towards a paradigm in which the bridge from engineering conditions and performance to economic competitiveness will be critical for comparing investment options. While this study offers only a beginning in that direction, its findings are important to practitioners for showing how readily available data and tools can be taken to the next level to address a significantly broader and policy relevant set of issues and questions.

RECOMMENDED FUTURE RESEARCH

The analysis presented in this report represents a general, sketch-level understanding of how different the traditional tools of asset management and statewide planning can be used and interpreted within the context of 'national economic significance'. The models applied in this demonstration include the most simplistic application of HERS-ST, TERM, NBIAS, CUBE Voyager with the FAF network, TREDIS and LIFT. There is significant room for further research into the integration of asset management, statewide planning, travel demand, user cost and economic impact models at the national and multi-state level.

A key area for future research is developing best practices for arriving at appropriate performance targets (or minimum tolerable conditions), unit-cost assumptions and other parameters for multi-state applications HERS-ST, TERM and NBIAS. Related to this is research into the appropriate scale and resolution of multi-state network traffic assignment analysis. While it is widely understood that statewide and multi-state travel models generally do not require the survey data and resolution of metropolitan area models, appropriate practice for multi-state planning when a state with a sophisticated model may seek to collaborate with states that have only "sketch-level' model applications like the one used in this study.

Because the national network/routing of traffic analysis in this study was only sketch-level, further research is clearly recommended to better understand the role and sufficiency of the interstate highway system, and specifically in the impact of urban capacity deficiencies on national intra-state traffic flows and their associated economic costs.

This report has been intended to highlight not only how infrastructure deficiencies impose costs on the economy, but also how these costs relate to the productivity and competitiveness of industries as well as the prosperity of households. Further research in best practices for consistently incorporating the "transportation cost to industry performance" linkage as a regular part of transportation planning and programming process is encouraged to build on the work of this report.

The findings on international competitiveness point to a potential emerging area of research into the comparative economic advantages of infrastructure sufficiency in the global trade environment. Further research is needed into how major US trading partners and international competitors measure and benchmark transportation performance, and the comparative efficiencies of foreign ground transportation systems relative to the US may affect industrial competitiveness and the terms of trade.

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