

Integrating Transportation and Economic Models to Assess the Impact of Infrastructure Investment

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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. This paper explores how a sequence of these models when applied to a consistent data set with consistent assumptions can address the overall relationship between physical transportation system conditions and performance, traffic patterns, transportation costs and economic impacts. The results point to a vertically integrated and economically defensible approach to needs-based planning with an understanding of the national economic significance of transportation investment choices.

INTRODUCTION

This paper's objective is to explore how available data sources and models can be synthesized to offer a consistent physical and economic perspective on multi-modal investment needs, deficiencies and impacts at multi-state levels. In today's fiscally constrained national policy environment, this objective is especially pertinent due to the growing need for an understanding of how the 'national economic interest' or 'nationally significant projects' can be defined and compared in funding decisions. Furthermore, the need to use national data sets and widely accepted models spanning state boundaries is growing in importance for planning for the needs of complex mega-regions.

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. 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 data sets are combined in this research to (1) assess current conditions of transportation facilities; (2) provide assumptions for expectations of current and future system performance; (3) make estimates of current funding levels and (4) make assumptions regarding future funding levels.

Models are combined in the research to assess (1) the level of current sufficiency or deficiency on different transportation modes and systems, (2) the degree to which traffic patterns are affected by speed or congestion changes attributable to deficiencies (current and forecast) , (3) the costs imposed on households and businesses by deficient conditions and performance and (4) the economic consequences of meeting or not meeting funding levels to achieve desired conditions and performance standards. The analytical framework joins models and data sets as noted in Table 1 and Figure 1.

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 (1).

Economic Development Research Group, Inc.'s "Failure to Act: The Economic Impact of Current Investment Trends in Surface Transportation Infrastructure" for the American Society of Civil Engineers in July, 2011 combined the models and data sets described in Figure 1 for an analysis at national and multi-state regional levels (2)

A Cambridge Systematics study (3) explored rail system capital investment needs, but did not address the operations and maintenance requirements associated with 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 (4) 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 (5) 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 (6) 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 (7) 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 (8) analyzed the economic trade-off between road-bridge Rehabilitation and repair (R&R) and increased capacity/new roads (IC/NR). The study assessed both construction period economic impacts and long-term economic impacts. This paper is interested in the latter. The Urban Institute, Cambridge Systematics, and the Pennsylvania Economy League (9) evaluated four potential funding scenarios for SEPTA, assessing relative impact of VMT, VHT and overall user cost. Tanner and Jones(10), found 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 preservation and expansion needs) to estimating network impacts of unmet needs and assessing economic costs and impacts in a multi-modal national or multi-state setting.

METHODOLOGY

The current study analyzes projected national surface transportation 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. Quantifying 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. Estimating how national traffic patterns may change in response to these shortfalls (especially the routing of truck and passenger car traffic changes in response to the speed impacts of urban congestion and deteriorating conditions)
3. Assessing the accruing costs to America's households and businesses based on the performance implications of unmet needs (including the costs of re-routing traffic) and
4. Quantifying 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 paper.

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 dollar amounts and quantified performance outcomes relative to a specified set of condition and performance standards (which are generally defaults provided by the federal government as part of the nationally available models described below). These models are publicly available on the web, used by the United States Department of

Transportation (USDOT) and provided by USDOT for the use by states in their planning and asset management efforts.

The needs models used in the report include:

- Highway Economic Requirements Model – HERS-ST (Federal Highway Administration (FHWA))
- 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. Traffic growth assumptions provided by states in their Highway Performance Monitoring System (HPMS) submittal were used, with rates of growth or decline by functional system controlled so as not to exceed three times the 10 year historic trend at the state level. This equates to an average annual traffic growth level of 0.2% in national VMT. The “Full Engineering Needs” analysis relied on adjustments to the HERS-ST default parameters to place a ceiling on the returns associated with adding highway lanes to congested facilities, and not to find widening needs on segments coded as “widening infeasible” by HPMS.

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, slightly less than ‘minimum tolerable conditions’, and much less free-flow traffic conditions in even a fully funded system.

The highway system conditions and performance results of the HERS-ST “Full Engineering Needs Analysis” provide the baseline level of highway investment needs and performance levels associated with a fully funded system. For subsequent scenarios, any funding or performance level less than that of the “Full Engineering Needs” scenario is understood as a deficiency, and may generate costs associated with deficient infrastructure.

The fiscally constrained scenario represents a funding level commensurate with current highway spending levels (on an average annual basis). Using the HERS-ST model, significant differences in speeds were found on each functional classification of roads between the fully funded and deficient scenarios. 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

While CUBE/Voyager is not a needs model (it is a travel demand modeling tool), its role in this sequence is to interpret needs within the context of the national traffic assignment patterns.

CUBE/Voyager software is applied in this study to provide a generalized origin-destination matrix estimation to US 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 is 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 (by functional classification and area type) found by HERS-ST. The result is the traffic reassignment map (later as Figure 5), 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. The inclusion of the CUBE/Voyager reassignment represents not only a further interpretation of highway needs, but also a source of economic cost (due to network assignment effects on VMT and VHT) that would not otherwise be found in the “built-in” benefit-cost algorithms of HERS-ST alone.

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 (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 (by 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 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, with current funding levels (consistent with FHWA statistics, 2008) the analysis anticipates a reduction in bridge deficiencies over time, fully resolving the backlog in both the fully funded and fiscally constrained cases before 2040. Therefore, the only difference between the fully funded and fiscally constrained 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.

Statistics compiled from the 2010 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 illustrates how the magnitude of the effects of unmet highway investment needs was derived.

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. It should be noted that not only the internalized costs (vehicle operating, travel time and reliability costs) were computed, societal costs (including safety and environmental costs, derived from VMT) were also included in the TREDIS cost calculation. Second, in order to estimate economic impacts, transportation cost savings were allocated to households and industries based on which modes and trip purposes are affected. While in the TREDIS model all costs (including personal travel time and reliability, personal and freight travel time, external safety and environmental costs) are estimated and can be reported, “personal time” was not included as part of the travel cost and subsequent economic impact and trade calculations. Personal time savings was not a part of the input-output analysis because it does not have a transactional cost in the national economy.

Travel costs in the economic input-output analysis 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 LIFT 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 sub-national regions (BEA). Figure 3 illustrates the relationship of TREDIS to 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).

LIFT calculates all of the major nominal economic balances for an economy: personal income and expenditure, the government fiscal balance (at federal, 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 conditions and performance results of traditional asset management models tell a consistent story when interpreted through the assignment of a network traffic forecasting model—the story can further be meaningfully interpreted in terms of industry impacts and global trade. Each set of models in the sequence highlights a different aspect of the story—whether the magnitude of unmet needs (from the asset management models), how traffic responds to unmet needs and generates further costs (from a travel network approximation), how the costs of unmet needs are passed to users (user benefits model), and how industries respond to those costs and create impacts throughout the economy (through an economic impact model). One advantage of using the models (or model-types) in an internally consistent sequence as presented here is the creation of a consistent and mutually supporting set of assumptions and conclusions for policy makers.

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 primarily focuses 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 Benefit 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. The results of this paper emphasize how the combined results of the models together support a consistent and meaningful understanding of the economic significance of transportation funding, and how unmet needs are represented from the observed and projected condition of highways, bridges and transit – all the way to national economic performance. 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 national economic significance of transportation funding choices.

Transportation Performance & Needs Findings

Based on the synthesis of models and data sources described above, maintaining minimum tolerable conditions on America's highways, bridges and transit systems will require roughly \$220 billion of average annual investment (2010 dollars) from 2010 to 2040. This is the investment level required to achieve the "minimum tolerable conditions" specified in the FHWA defaults constituting a needs threshold in the HERS-ST, TERM and NBIAS models. This need accounts for an average investment of approximately \$196 billion per year in highway pavements and bridges, including \$161 billion in congestion mitigation and \$35 billion in preservation of existing facilities. In addition, \$25 billion per year in transit capital infrastructure investment (including rolling stock, 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 deficiency' 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 in the sequence. 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 (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.

In Figure 5, interstate highways are shown in bold, with other arterials shown as thin lines. Shades of blue indicate routes from which traffic is re-assigned to avoid lowered speeds due to congestion or deteriorating infrastructure condition on urban interstates. Shades of red indicate routes that pick up the re-assigned traffic.

It is evident from the figure that congested interstates in urban areas may cause a re-routing of 'overflow' traffic onto alternative routes on state arterials – extending far beyond congested urban areas; placing vehicle miles and hours of traffic onto rural and sub-urban arterials with lower costs and design standards. This re-assignment of capacity creates costs and impacts on areas far outside of the urbanized areas where the interstate congestion actually occurs.

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.

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 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 (on average) more than 400,000 jobs in any given year. Some economic activity is created by deficiencies on the transportation system. Examples include the creation of jobs in sectors such as auto and bus repair, retail sales of gasoline, vehicle services and parts and jobs required due to less efficient operation of businesses. The economic activity created by infrastructure deficiencies is ultimately offset by the costs imposed by a deficient system. In particular, 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 larger shares of household budgets 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.

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 across the US.

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 2040. Table 2 shows 10 commodities that will lose the export sales expected under current conditions.

In 2040, these 10 commodities that are expected to lose the highest levels of export dollars account for 46% of the export value lost by the aggregated 79 commodities. Moreover, many exports shown in Table 2, both in terms of percent declines and dollar losses, are key technology sectors that drive national innovation. These include aerospace, communications equipment, transportation equipment, 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 (illustrated 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 vertically integrating national highway, bridge and transit asset management models with a high-level travel demand model assignment derived from the FAF network as the basis for applying standard user-benefit calculations and a general equilibrium economic impact model yields a consistent and vertically integrated view of how unmet transportation needs play out in the national and international economy.

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, and 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 suffer nationally 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.

RECOMMENDED FUTURE RESEARCH

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. Future research may also address the appropriate scale and resolution of travel demand assumptions for multi-state network traffic assignment analysis as part of an economic modeling sequence.

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.

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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TABLE 1 Combination of Models and Data Sets

Model	Data Set	Purpose
HERS-ST	Highway Performance Monitoring System	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.
TERM	National Transit Database	
NBIAS	National Bridge Inventory	
CUBE/Voyager	Freight Analysis Framework (FAF3)	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.
TREDIS	BEA and other data sets from the US Department of Commerce and Bureau of the Census	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.
LIFT		Based on inputs from TREDIS, assesses international competitiveness and impacts of international trade on domestic economy on a national scale.

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

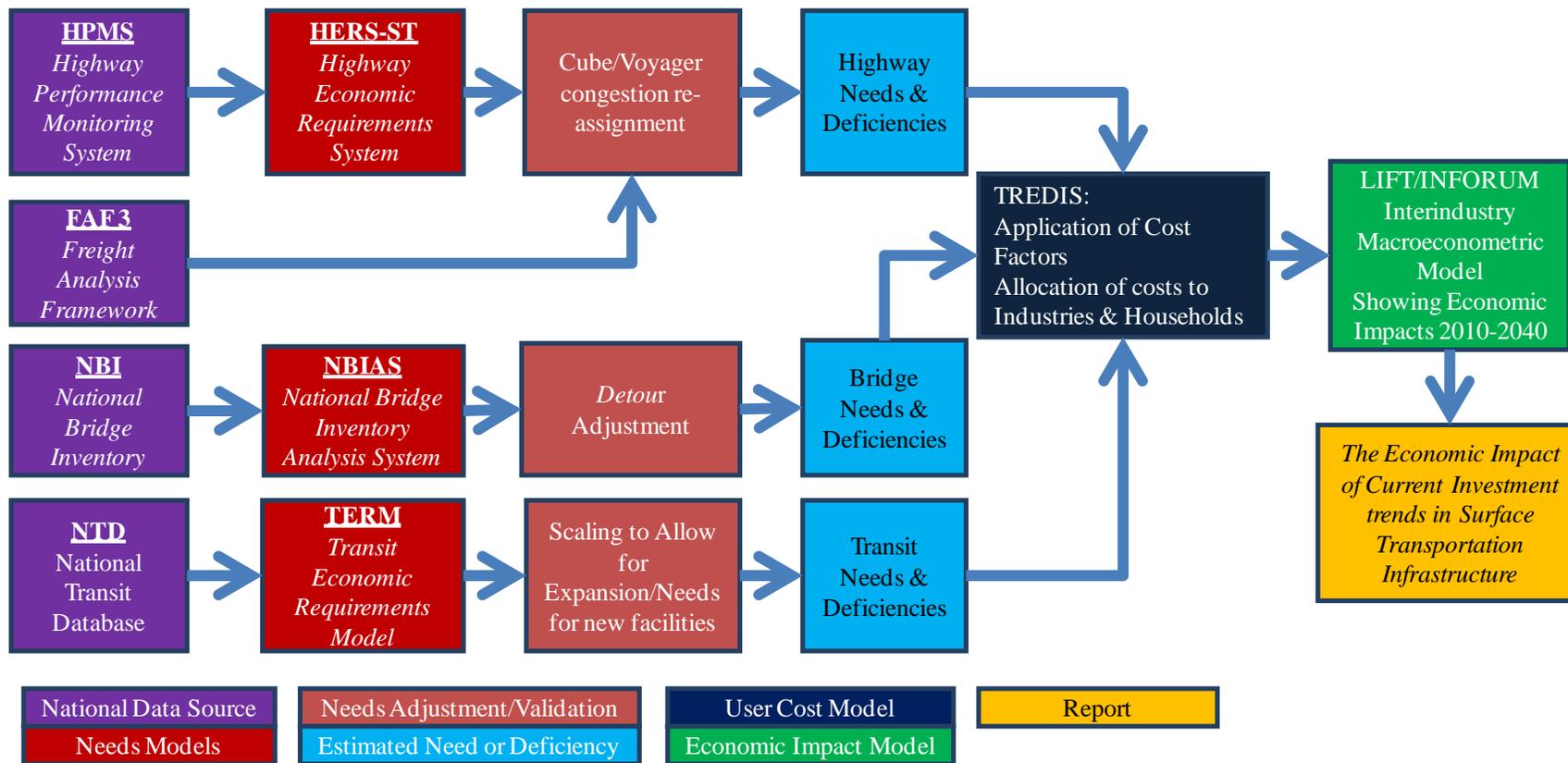


FIGURE 1 Modeling Process: From needs to impacts combining asset management, traffic assignment and economic impact models.

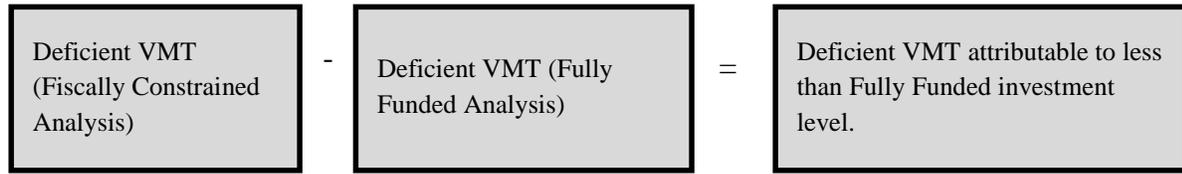


FIGURE 2 Arriving at deficient highway VMT.

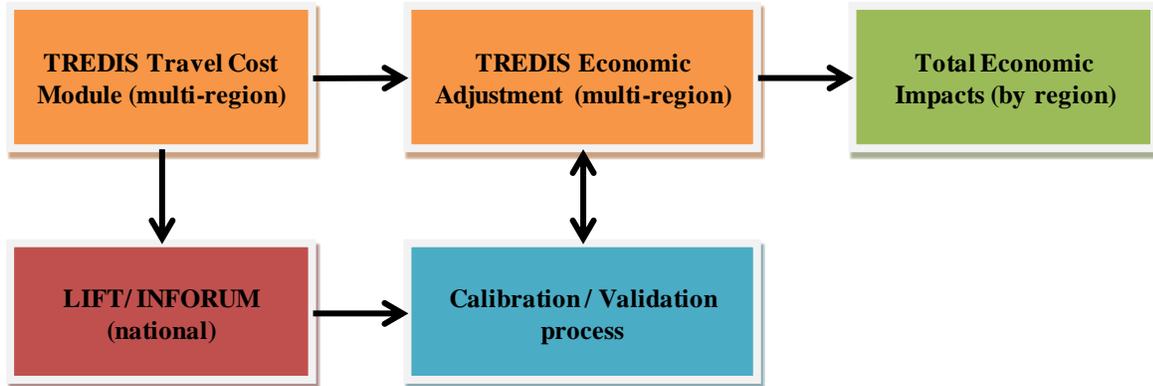


FIGURE 3 Interaction between TREDIS and LIFT.

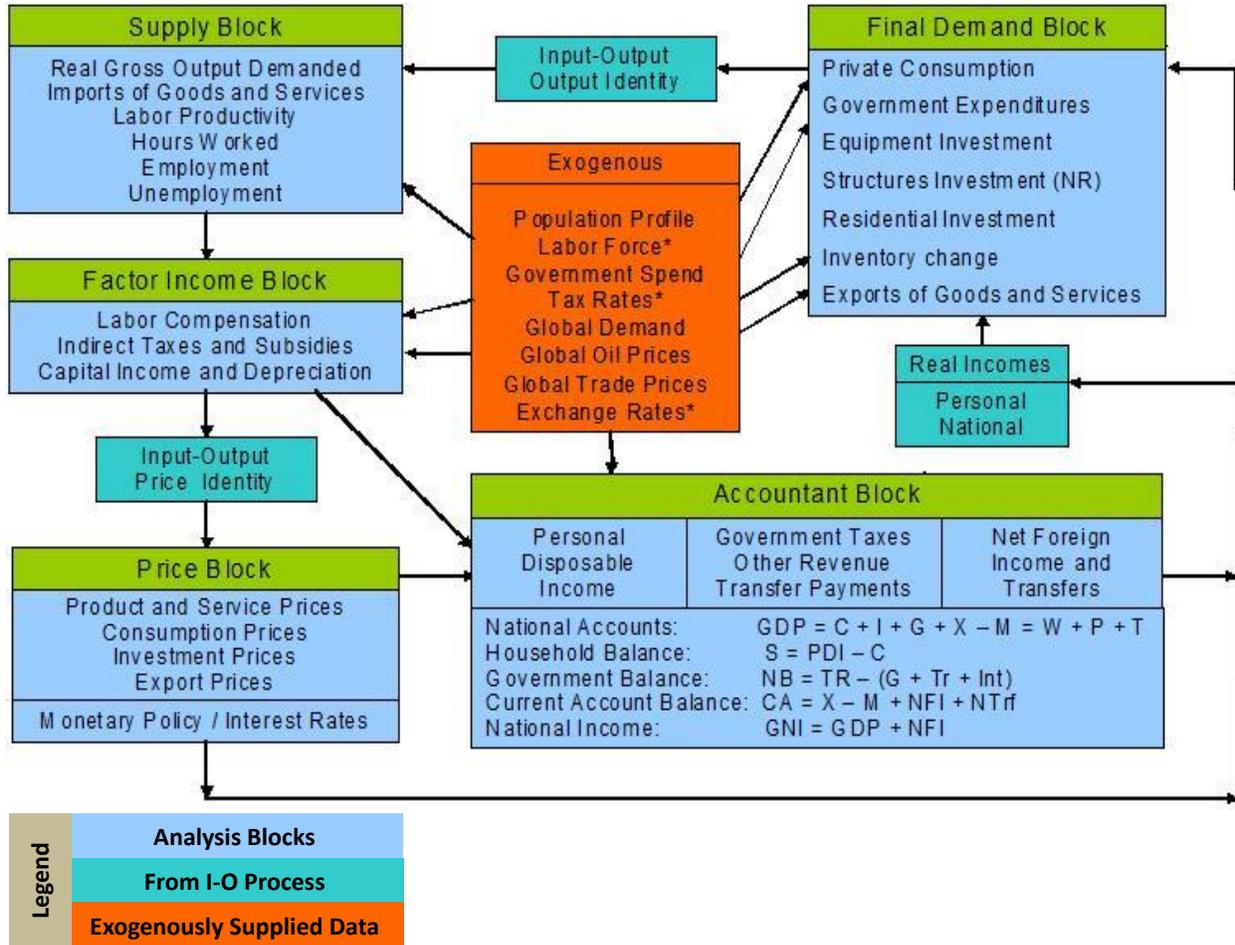


FIGURE 4 LIFT model schematic diagram.

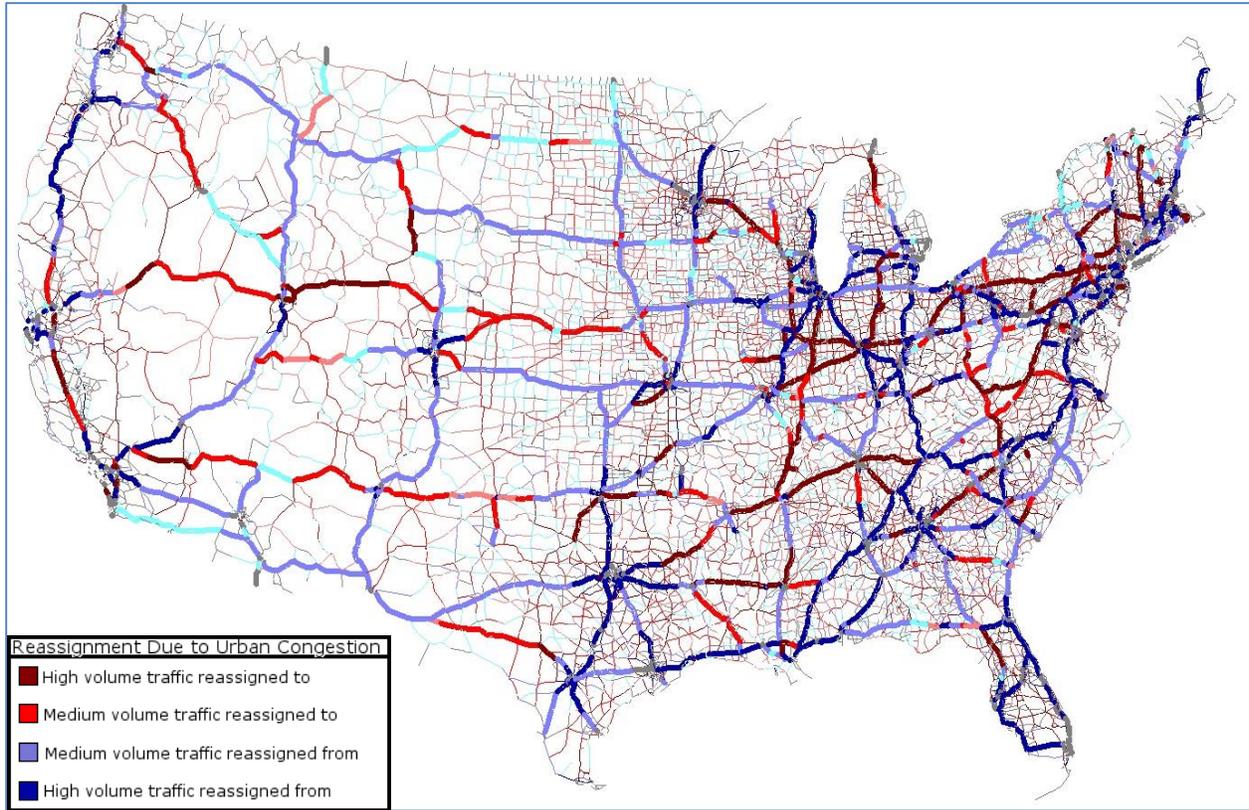


FIGURE 5 Urban congestion affects the national routing of traffic.

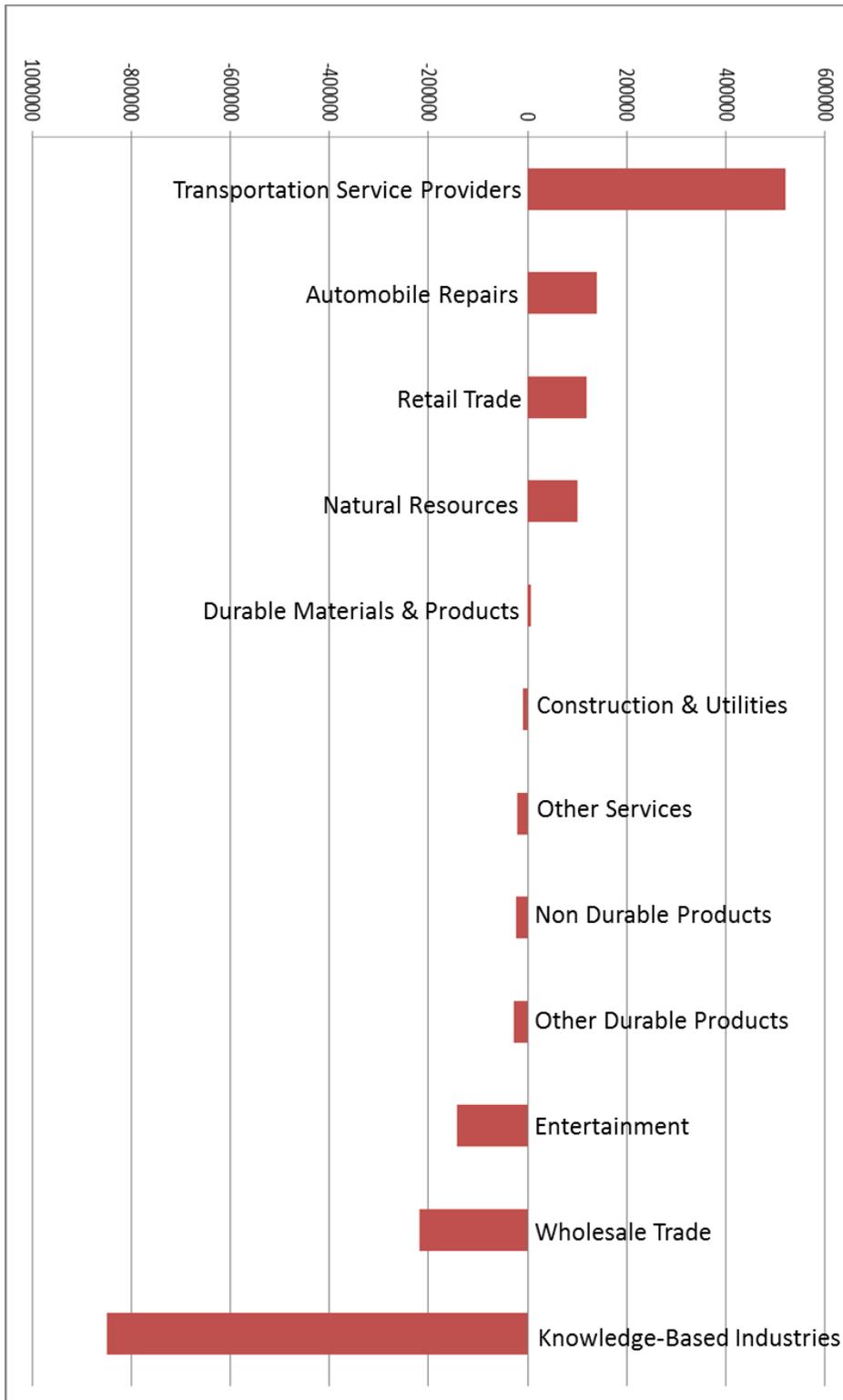


FIGURE 6 Change in composition of US job market due to deteriorating infrastructure.

TABLE 2 Losses in US Exports in the Year 2040 (in 2010 Dollars) Attributable to Deteriorating Infrastructure Conditions

<i>Commodity with ID#</i>	ranked on % impact	<i>Commodity with ID#</i>	Export \$ lost (BIL 2010)
Electric utilities	-12.922	Finance & insurance	(\$8.08)
Communications equipment	-11.315	Wholesale trade	(\$6.06)
TV, VCR, radios, phonographs, etc.	-4.513	Aerospace	(\$5.85)
Ships & boats	-3.216	Communications equipment	(\$5.39)
Ophthalmic goods	-2.85	Agriculture, forestry, fisheries	(\$2.66)
Ag. fertilizers & chemicals	-2.737	Other instruments	(\$2.39)
Rubber products	-2.45	Air transport	(\$2.23)
Motor vehicle parts	-2.368	Professional services	(\$2.05)
Government enterprises	-2.212	Other chemicals	(\$1.43)
Other transportation equipment	-2.203	Meat Products	(\$1.20)
		Other (69 Sectors)	(\$34.37)
		Sum export \$ lost (BIL 2005)	(\$71.71)