Better State-of-Good-Repair Indicators for the Transportation Performance Index

FINAL REPORT
July 2014

Submitted by:

Sue McNeil[1]
Professor

Farzana Atique[1]
Graduate Assistant

Hong Yin[1]
Undergraduate Research Assistant

Ryan Burke[2]
Graduate Assistant

Yaw Adu-Gyamfi[1]
Graduate Assistant

1. Department of Civil and Environment Engineering
2. Disaster Research Center

University of Delaware
Newark DE 19716

External Project Manager
Deb Miller
Cambridge Systematics

In cooperation with

Rutgers, The State University of New Jersey
And
U.S. Department of Transportation
Federal Highway Administration
And
US Chamber of Commerce

Disclaimer Statement

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. CAIT-UTC-008	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Better State-of-Good-Repair Indicators for the Transportation Performance Index**		5. Report Date July 2014 6. Performing Organization Code CAIT/University of Delaware
7. Author(s) Sue McNeil, Farzana Atique, Hong Yin, Ryan Burke and Yaw Adu-Gyamfi		8. Performing Organization Report No. CAIT-UTC-008
9. Performing Organization Name and Address Department of Civil and Environmental Engineering and Disaster Research Center University of Delaware Newark DE 19716		10. Work Unit No. 11. Contract or Grant No. DTRT12-G-UTC16
12. Sponsoring Agency Name and Address Center for Advanced Infrastructure and Transportation Rutgers, The State University of New Jersey 100 Brett Road Piscataway, NJ 08854		13. Type of Report and Period Covered Final Report 9/1/12-1/31/14 14. Sponsoring Agency Code
15. Supplementary Notes U.S. Department of Transportation/Research and Innovative Technology Administration 1200 New Jersey Avenue, SE Washington, DC 20590-0001		

16. Abstract

The Transportation Performance Index was developed for the US Chamber of Commerce to track the performance of transportation infrastructure over time and explore the connection between economic health and infrastructure performance. This project revisits performance indicators related to state of good repair and safety, and their relative weights to be sure that state of good repair is adequately captured in the transportation performance index (TPI). This includes evaluating the TPI for 2010 and 2011 and understanding the relationship among the estimates, as well as the relationship with economic health. Based on this analysis we concluded that our original data, methods and weights are robust and therefore would not be enhanced by changes at this time. However, the importance of good data and future improvements are emphasized.

Modest improvements in the TPI over the last five years come from reductions in both vehicle miles of travel and ton miles of travel, and significant strategic investment focused on state of good repair, intermodal connectivity, mobility and accessibility. Case studies focusing on both prospective and retrospective scenarios to better understand the TPI reinforce the need for comprehensive investments across all modes and holistic policies that focus on all modes and all regions.

17. Key Words State of good repair, safety, infrastructure, performance, economic health		18. Distribution Statement	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 47	22. Price

Form DOT F 1700.7 (8-69)

ACKNOWLEDGMENTS

This research depended on resources and input from many sources. Janet Kavinoky, Executive Director, Transportation & Infrastructure and Vice President, Americans for Transportation Mobility Coalition of the US Chamber of Commerce supported the initial development of the Transportation Performance Index and the project that leveraged our resources and provided the opportunity to explore alternative models. Susanne Trimbath provided input, comments and completed the economic analysis that connects the TPI to the US economy. She is a valuable collaborator providing not just technical expertise but mentoring and advice to the students. Mosi London a PhD student in the Department of Civil and Environmental Engineering at University of Delaware completed the analysis for the retrospective case study.

Staff from the Federal Highway Administration, American Association of Railroads and Federal Aviation Administration assisted us with data and concepts.

The survey participants, friends, colleagues, acquaintances, staff from local Chambers of Commerce, company representatives, government officials and others, willingly gave of their time and provided valuable input that allowed us to confirm that we had a robust methodology.

Finally thanks to Deb Miller from Cambridge Systematics and former Secretary of Transportation for Kansas DOT for her willingness to serve as an external client.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

DESCRIPTION OF THE PROBLEM

The Transportation Performance Index was developed for the US Chamber of Commerce to track the performance of transportation infrastructure over time and explore the connection between economic health and infrastructure performance. The index had been computed for the period 1990 to 2009 and shown to influence economic health. The University of Delaware team had been involved in construction of the index and is very familiar with its strengths and limitations. In the construction of the index, our objective had been to develop a transparent process that uses publicly available date to capture infrastructure performance. While this approach provided insights into the relationships between economic health and infrastructure, additional research was needed to better understand the TPI, update the estimates and better connect the TPI to state of good repair and safety. (Li et al, 2010; Oswald et al, 2010; US Chamber of Commerce, 2010; US Chamber of Commerce, 2011)

This project revisits performance indicators related to state of good repair and safety, and their relative weights to be sure that state of good repair is adequately captured in the transportation performance index (TPI). This includes evaluating the TPI for 2010 and 2011 using both the original method and any new method, and understanding the relationship among the estimates, as well as the relationship with economic health. Furthermore, the US Chamber of Commerce provided resources to update the TPI for each state.

Background

Currently there is no systematic way to track progress towards national goals, such as state of good repair and safety, in terms of the performance of physical infrastructure. Since the proposal was originally written this research has become even timelier as requirements to track performance are part of the MAP-21 legislation.

This research provides a method to track this performance explicitly focusing on state of good repair and safety and then relating these measures to economic competitiveness. There is a large body of literature on the importance of performance measurement related to strategic goals. Transportation infrastructure performance measurement is no exception and while individual programs, states, or infrastructure have limited experience, a national measure tied to economic competitiveness promises to help benchmark new policies and investment strategies.

This project will "Further USDOT's mission to advance methodologies for making strategic, comprehensive and cost effective investment decisions recognizing critical changes in the context in which decisions are made"[1].

State of good repair and safety are important elements of transportation performance. In the current version of the index, state of good repair is directly represented by two of the twenty one performance indicators and indirectly represented by another seven indicators, or 10% and 37% of the performance index based on weight. Three indicators capture safety. These indicators represent 22% by weight.

Objectives

The goal of this project is to revise the Transportation Performance Index to better capture the role state of good repair and safety play in transportation infrastructure performance. To accomplish this goal the following objectives are addressed:

---

[1] Proposal for Tier 1 UTC to US Department of Transportation, Center for Advanced Infrastructure and Transportation, Rutgers University, 2011.

- Explore alternative indicators for state of good repair that go beyond roughness and bridge integrity. This includes looking at thresholds above or below which the current indicators that indirectly capture state of good repair change to reflect performance.
- Explore alternative indicators for safety focusing on fundamental improvements.
- Weight the indicators to capture state of good repair and safety as attributes of performance.
- Compute the TPI for 2010 and 2011 using the original and new methods.
- Develop a relationship if needed between the original and any new methods.
- Explore the relationship between the updated TPI and economic health.

In summary, the original objective was to produce a revised TPI that can be used to assess the economic impact of maintaining the physical infrastructure in a state of good repair and safety improvements. In turn the TPI can be used to evaluate alternative infrastructure repair and improvement policies.

Scope

The TPI is intended to make the case for investment in transportation infrastructure to support maintaining the infrastructure in a state of good repair and improving safety.

Like the initial development of the TPI, the revised TPI will be transparent and repeatable. The index will use publicly available data and the processes and data will be extensively documented so anyone can use the methods.

One of the challenges is to work out how to use the TPI. We developed three case studies that demonstrate how the TPI can be used to explore alternatively policies. One case study is retroactive answering the question "Can we see changes in the TPI based on past policies?" and one case study is proactive "How will economic competitiveness benefit from maintaining transportation infrastructure in a state of good repair?" A third case study explores the impact that implementing regional long range transportation plans can have on the TPI.

A well-documented methodology can be used for assessing the TPI in future years or to explore alternative policies. While this project is aimed at a national index, a similar effort can be applied to states or regions.

Outline of this Report

This report documents the research undertaken for this project. The report draws heavily on reports developed for the companion project for the US Chamber of Commerce (McNeil et al, 2013a; McNeil et al 2013b; McNeil et al, 2014a) and two conference papers (McNeil and London, 2013; McNeil et al, 2014b). The report is organized as follows. The following section documents the approach used. The next section develops the methodology including the literature review, alternative indicators, new weighting and data collection. The next section presents the findings including the updated TPI estimates for 2010 and 2011. Conclusions and recommendations are then presented. The report includes references.

APPROACH

This complex multi-disciplinary project draws on several methodologies to assemble a rigorous approach to estimating and using the TPI. Elements include:

Alternative indicators: Building on our experience working with the data we explore adding thresholds to the data to better capture the impacts of infrastructure not in a state of good repair. Methods include exploratory data analysis, factor analysis and using charts and graphs to check data quality.

Weighting the indicators: Explicitly grouping indicators related to the state of good repair and safety, we establish appropriate weights using the analytical hierarchy process (AHP). This involved engaging appropriate stakeholders in a telephone survey. While we originally proposed a web-based survey, the telephone survey provided an opportunity for the research team to reach out to academics, government employees, and the business community to talk about infrastructure.

Computing the TPI: Drawing data from the diverse data sets used to estimate the TPI we assess the TPI value for 2010 and 2011 (we expect the 2011 data to be available in early 2013) and forecast values for 2020 under several scenarios intended to capture alternative futures.

Model relationships: Using growth models, we explore the relationships between the TPI and economic competitiveness.

Case study development: To demonstrate the use of the TPI in evaluating alternative investments, we use case studies.

As set out in the original proposal, the tasks involved in accomplishing the objectives outlined above are:

Task 1. Updated literature review and exploration of data sources.
This includes a review of publications and conference proceedings related to performance measures including proceedings of the TRB Conference on Performance Management (from 2011) and FHWA's "A Primer on Safety Performance Measures for the Transportation Planning Process" (2009). Potential data sources for state of good repair and safety were identified and explored.

Task 2. Identification of new measures to better reflect state of good repair and safety.
Based on task 1, new measures were identified and explored. New measures explored include new variables and the use of thresholds to construct indicators that represent the infrastructure that is in an unacceptable state of good repair or facilities that are relatively less safe than others. Criteria for selection include representativeness and stability.

Task 3. Assemble data using current and new indicators for 2010 and 2011.
Data for 2010 and 2011 was assembled from websites,

Task 4. Conduct surveys to weight indicators.
As in the past, the Analytical Hierarchy Process (AHP) was used to determine weights. In the past stakeholder were sought from the private sector. In this case, participants include both public and private sector stakeholders. This task involved:

- Design of the survey using Expert Choice or similar tool.
- Institutional Review Board approval for an exempt projects with Human Subjects (no identifying information will be recorded.)
- Conduct the survey

Task 5. Estimate values of the Transportation Performance Index for 2010 and 2011.
The TPI was estimated based on the data and weights.

Task 6. Analysis and Discussion of Results.
This includes understanding the changes and trends, and exploring the relationship between the current new approaches to the TPI, and exploration of the relationship between the TPI and economic health using growth models as explored in the TPI work for the US Chamber.

Task 7. Develop two case studies to demonstrate how the TPI can be used to explore alternatively policies.
Three different case studies are developed. One case study is retroactive in the sense of looking at the impact of projects already implemented. The other two case studies are proactive looking at the impact of potential investments. The intent of the case studies is to help understand how the TPI can be used to guide policy and investment.

Task 8. Document the results.
The products of the research are:

- This report documenting alternative measures,
- A proposed strategy for maintaining a consistent TPI,
- The calculation of the TPI for 2010 and 2011, and
- The relationship between past and proposed measures.

The report also documents the case studies. Presentations have been and will be made at appropriate conferences and meetings. A brown bag discussion was held at UD in November 2013, a paper presented at the World Conference on Transport Research (WCRT) in Rio de Janiero in July 2013 and a paper will be presented at the American Society of Civil Engineers Transportation Congress in Orlando in June 2014.

METHODOLOGY

Estimation of the Transportation Performance Index

This section summarizes the process developed to create the Transportation Performance Index (TPI). Interested readers are referred to the Technical Report (US Chamber of Commerce 2010), which documents the complete development of the Transportation Performance Index (and includes an analysis of the results for the initial time periods – 1990-2009).

By design, the TPI is generated from publicly available data using a transparent process that can be replicated by interested parties in any jurisdiction and used to benchmark and measure the improvement or decline in the performance of transportation infrastructure over time. As such, the TPI brings a rigorous, quantitative, and repeatable methodology to the assessment of infrastructure performance. In the past, studies that attempted to relate infrastructure to economic growth and prosperity have largely had to rely on measuring infrastructure by *expenditures* rather than infrastructure *performance*. The TPI is based on a well-defined methodology and addresses this essential flaw in what we know about how infrastructure supports economic activity. (See Trimbath 2010 for a review of other research on the role of infrastructure in economic prosperity.)

The Transportation Performance Index (TPI) for the USA (nation) was developed using a hierarchical structure (as shown in Figure 1):

- The geographic areas are broken down into two groups based on population: large Metropolitan Statistical Areas (MSAs), and other MSAs. The other MSAs are further broken down into those with a primary airport and those without a primary airport. (All of the large metropolitan areas have primary airports.)

- Next, we examine the categories of transportation infrastructure – road, rail, transit, air, marine and inter-modal – within the MSAs.
- The next level covers the overarching criteria for assessing performance: supply, quality of service, and utilization.
- Within each criterion, we select measurable indicators of the performance of the system. The indicators vary for each criterion.

The final step is to identify the available data that can be used to represent the indicators that were selected by users and experts as critical to measuring performance.

The methodology for constructing a national infrastructure index that can be used to assess the impact of infrastructure on economic performance builds on a broad base of existing research that includes:

1. Academic knowledge of indices and decision support tools;
2. Methodologically rigorous sampling strategies to ensure representation of all sectors of the economy and regions of the country;
3. Integration of expert and user input to captures what is most important about "performance."

With the goal of implementing a rigorous methodology for determining a single, annual number to represent the performance of the nation's infrastructure, builds on the three previous steps and is applied through:

4. Identification of appropriate performance indicators;
5. Data collection and normalization;
6. Expert and user survey-based comparisons of the criteria to develop weights;
7. Weighting of sample data to represent the nation;
8. Calculation of the Index – a single number for every year to measure the performance of US transportation infrastructure.

These 8 elements of the design of the TPI provide the outline for the remainder of this section.

1. Research Background on Index Development

The first step in the methodology is researching background literature on index development, and specifically indicator identification. A review of a selection of indices used in economics, finance, ecology, health, green building, and sustainability led researchers to a four step process suggested by Bossel (1999) for the development of an index:

- Understand, conceptually, the entire system
- Identify representative indicators
- Quantify the degree to which the needs of business are met
- Conduct a participative process

The results of the first step, understanding the total system, are represented in Figure 1. The second step, identifying the representative indicators, is perhaps the most challenging step. Typically, indicators must be chosen from a vast number of potential candidates based on their representation and contribution to the purpose of the index (Bossel, 1999). In the case of the TPI, recognizing that performance is a latent, unobservable variable, the indicators are intended to capture the underlying behavior (Ben-Akiva, Humplick, Madanat, and Ramaswamy, 1993; Ramaswamy and Ben-Akiva, 1993). The third step requires a prioritization of the indicators in order to translate the information content into business needs. For the TPI, decision-making tools, such as AHP, can be used to weight and prioritize indicators based on their importance to infrastructure performance. The final step requires input through external opinions in order to counterbalance the choices and decisions made by the index developer. By having appropriate outside reviewers, a wide range of knowledge, experience, mental models, and social/environmental concerns can be brought forward (Bossel, 1999).

Oswald and McNeil (2010) expanded Bossel's methodology to a seven step process as a way to universalize measuring infrastructure performance using a rating scale. Their revised methodology serves as the basis for the specific steps to constructing the TPI. The methodology consists of seven steps:

- Define infrastructure sectors;
- Identify representative samples based on geography and economy;
- Create hierarchy models for each sector;
- Identify indicators for each sector;
- Explore data sources and collect indicator data;
- Weight the indicators using AHP pairwise comparisons;
- Compute the index based on normalized indicators, relative weighting, and economic relevance.

2. Sampling Strategy

Given the impossibility of gathering all the data necessary to measure the performance of every piece of infrastructure in the entire USA, a sampling strategy was designed. Since data on the measurements are collected by geographic area, sample selection criteria are identified to ensure a representative sample with attributes that demonstrate sufficient variability to capture all the factors that influence infrastructure usage and performance over time. Some of these attributes interact with each other, and it is important to develop a full design to account for those interactions. For example, the size of the population will be related to the size of the economy in a geographic area both because more people produce more output and because more output requires more people to produce it.

The primary objective in developing a sampling strategy is to select a representative sample of geographic areas that reflects the diversity of geography as well as the type and intensity of economic activity that makes use of infrastructure. The initial set of geographic areas consists of the 366 metropolitan statistical areas (MSAs) for which the Department of Commerce's Bureau of Economic Analysis reports industry level economic data (BEA, 2006). It is important to note that "MSA" is not a synonym for "urban" in this context. Some rural geographic areas will necessarily be included in MSAs by virtue of their connectivity via workforce commuting patterns.

Thirty six MSAs were selected based on the 2003 BEA definitions. (The determination of the sample size and the selection of the sample are documented in U.S. Chamber, 2010). The thirty-six MSAs are grouped into three types:

- Population over 1 million (all of these MSAs have airports) – 23 MSAs, Type 11;
- Population under 1 million with a primary airport – 7 MSAs, Type 01; and
- Population under 1 million without a primary airport – 6 MSAs. Type 00.

The sample provides the following coverage: 34.7% of total U.S. population and 34.7% of U.S. MSA economic output based on 2007 data. (Representativeness is further evaluated in the US Chamber report (2010) for share of GDP by industry types, geographic distribution and State coverage.)

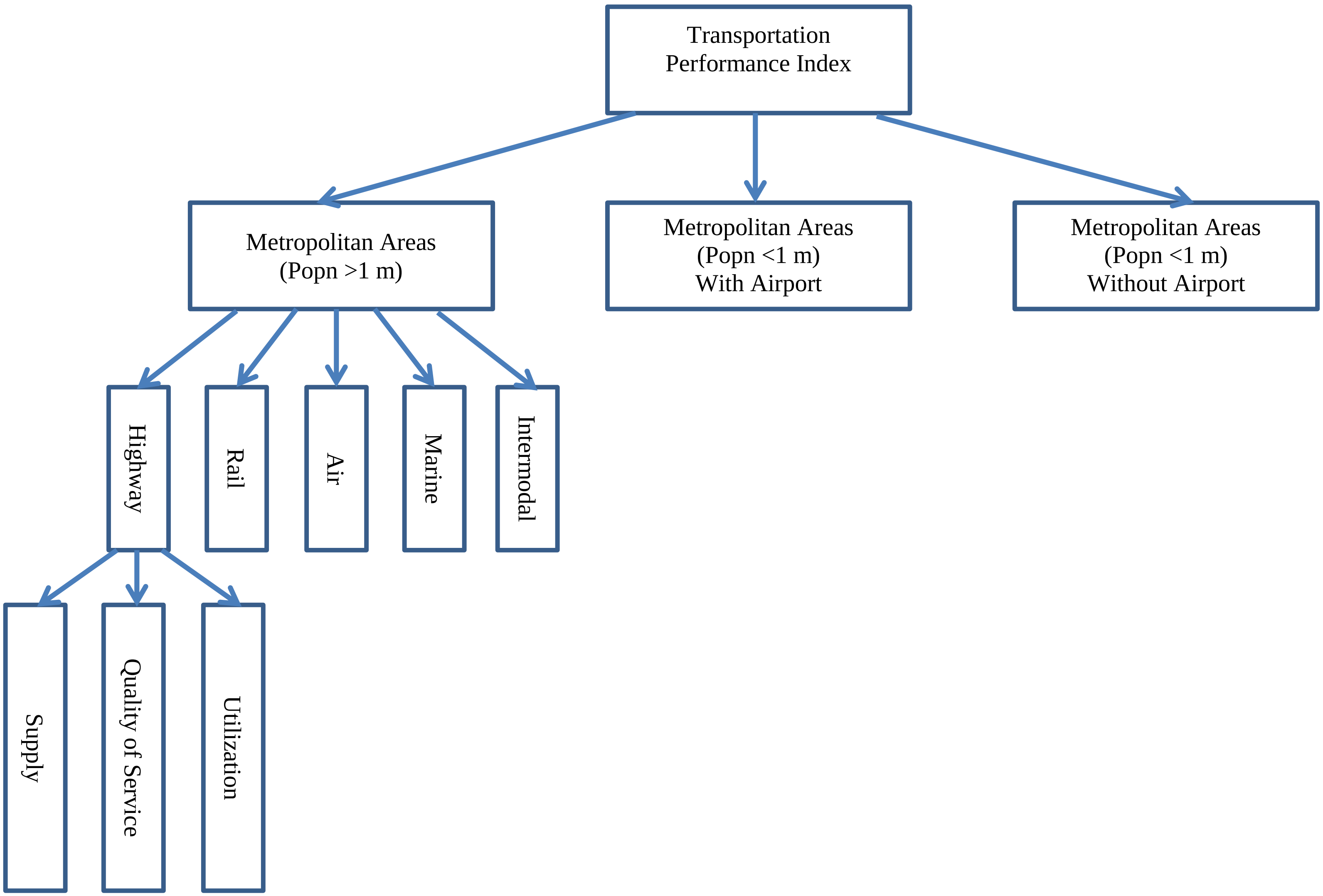

Figure 1 Hierarchy of the Transportation Performance Index

3. Expert and User Input

A review by industry and academic experts was part of the iterative process for identifying indicators. The process was vetted and evaluated in three ways. In Phase I of the research, a prototype index was constructed to understand the data challenges and limitations of the methodology. Data were collected for 2000 and 2007. This step validated the feasibility of the processes and methodology. In Phase II an extensive series of workshops were conducted. The workshops involved two groups -- stakeholders and experts. The workshops with stakeholders sought input on what aspects of infrastructure are important to the stakeholders (business users, service providers, etc.). The workshops with experts provided input on the specific indicators, measures, data sources, and the overall methodology. The methodology and indicators described above reflect the inputs from both groups. Most importantly, the experts stressed the importance of documenting the current process but seeking opportunities for refinement and continuous improvement. To that end, the US Chamber of Commerce (and/or the National Chamber Foundation) has undertaken funding of updates and revisions to the TPI on a bi-annual basis.

4. Indicators

Transportation performance indicators serve as the building blocks for the Transportation Performance Index. The objective is to identify a set of indicators that reflects the performance of the transportation infrastructure in a way that captures its relationship to economic growth and prosperity. The indicators are selected based on the following definition of transportation infrastructure: "Moving people and goods by air, water, road and rail" (US Chamber, 2010).

The list of indicators evolved over the course of the project. Interaction with the transportation experts and stakeholders suggested several interesting indicators. In some cases, data are available to measure these indicators and in other cases not. In most cases the concerns voiced at the stakeholder meetings are captured by the indicators. However, addressing the issues identified by the experts is more challenging. We continue to monitor data releases from a broad array of public sources in an on-going effort to identify data that could be added to the TPI calculation. The current list of indicators is shown in Table 1.

5. Data Collection and Normalization

The ground rules for developing the TPI are that the indicator should reflect infrastructure performance in the context of economic growth and prosperity, and the data should be publicly available, and can be obtained back to 1990. To meet these requirements, an extensive review was conducted to identify the appropriate databases. Many sources are used for gathering data, including Bureau of Transportation Statistics, National Transportation Atlas Data, Highway Performance Monitoring Systems, National Bridge Inventory, National Transit Database, Aviation System Performance Metrics, Federal Aviation Administration's Runway Safety Database, Terminal Area Forecast, Federal Railroad Administration, and U.S. Army Corps of Engineers. (A complete list of the databases explored for this project is available in US Chamber Commerce 2010.)

Data for each indicator are initially assembled from 1990 to 2007. The 10,440 pieces of data are assembled from approximately 10 Gigabytes of raw data from the above mentioned databases using spreadsheet, database, and Geographic Information System (GIS) tools.

The process used to normalize the data is described in detail in the Project Initiation report (U.S. Chamber 2009). This process is necessary as each indicator has a different scale. For some indicators larger values are desirable for better performance (e.g., percentage of lane miles uncongested), and for others, smaller values are more desirable (e.g., runway incursions per million operations). The range method is used to convert each indicator to a scale from zero to one, where one is the better measure. Data from 2000 is used as the base year. A normalized indicator for a specific MSA in a particular year will have a value of "1" if the indicator measure is equal to the "best" MSA in 2000. Similarly, a normalized indicator will have a value of "0" if the indicator measure is equal to the "worst" MSA in 2000.

6. Expert survey of the importance of values

In order to establish a rigorous methodology for constructing the index, a decision support tool is used; in this case, Analytic Hierarchy Process (AHP) (Saaty, 1982). AHP is used to compare entities that have different units of measure through pairwise comparisons. The results of pairwise comparisons are used to assign weights to each of the criteria and indicators based on their relative importance or contribution to the overall index.

Following the work of Bossel and using AHP, a process was developed to combine the indicators. The process reflects the value placed on the different performance measures and components by constituent users. The survey (Available in Appendix E of US Chamber 2010) and the Comparison tool, a web-based interface for administering Expert Choice surveys, are used to solicit responses from experts and stakeholders. The survey was distributed to a mailing list that included participants in the workshops and US Chamber of Commerce members who had indicated an interest in the project. The survey went out to 447 participants. The weights for each indicator are shown in Table 2.

7. Weighting the Sample

Before applying the indicator weights, two more adjustments are needed. The first adjustment reflects the different types of MSAs. The number of indicators is slightly different for the three types of MSAs. Table 2 lists the weights assigned to each of the indicators used in the Transportation Performance Index for each of the MSA types. Shaded cells represent indicators that are not relevant for that type of MSA. For example, where a type 00 MSA does not have an airport, the "Air Transportation" indicators are irrelevant. Hence, those weights are re-distributed before the index can be calculated.

The second adjustment reflects the contribution of each MSA to the U.S. economy so that a national representative value is obtained. This step assures that several small MSAs or several large MSAs cannot dominate the national values. Each MSA type is weighted by the percent of the U.S. economy that *all* MSAs of that type contribute divided by the contribution of the sampled MSAs. (The calculation and application of the MSA weightings are described in detail in US Chamber 2009.)

8. Calculating the Index

Utilizing assembled data sets for each MSA in the same type, an index is constructed to represent the performance of the transportation infrastructure for benchmarking and measuring change (improvement or decline). Below are the technical specifications used to calculate the Transportation Performance Index.

For each year, the Transportation Index is defined as:

$\text{Index}_{\text{Tran}}$ =

$$= \sum_k \left[\sum_{i=1}^{I_k} \left(\left(\sum_{j=1}^{J} w_{jk} N_{ij} \right) e_{ik} \right) \left(\frac{\sum_{p=1}^{P_k} e_{pk}}{\sum_{i=1}^{I_k} e_{ik}} \right) \right] \qquad (2)$$

Where

$$k = 1 \ldots . K \; is \; the \; MSA \; type$$

$p = 1 \ldots . P_k$ *is the MSA* in the population of type k

$i = 1 \ldots . I_k$ *is the MSA* in the sample of type k

$$e_{ik} = contribution\ of\ MSA\ i\ of\ type\ k\ to\ US\ economy$$

$$\frac{\sum_{p=1}^{P_k} e_{pk}}{\sum_{i=1}^{I_k} e_{ik}} = economic\ expansion\ factor$$

$$j = 1 \ldots J\ is\ the\ indicator$$

$$w_{jk} = weight\ for\ indicator\ j\ in\ type\ k$$

$$N_{ij} = normalized\ measure\ of\ indicator\ j\ for\ MSA\ i$$

For Further Information

US Chamber of Commerce (2010) documents the development of the Transportation Performance Index (and includes an analysis of the results for the initial time periods). The appendices in that report include:

- Summaries of meetings with the stakeholder community and transportation experts,
- Data sources and alternative measures for the national index (and state-by-state) indices, and
- Description of the survey used to determine the relative weights of the indicators.

US Chamber of Commerce (2010) also documents method for using the TPI to forecast changes in performance under a variety of “what if” scenarios.

Table 1. Transportation Performance Indicators (U.S. Chamber of Commerce, 2010)

Criteria	Mode	Description	Measure
Supply	Highway	Highway Density (Availability of highways)	Route-miles per 10,000 population
	Transit	Density (Availability of transit)	Miles of transit per 10,000 population
	Air	Access (Proximity of airports)	Percent of population within 50 miles of major airport(s)
		Capacity (Availability of airport service)	Airport arrival rate and departure rate per hour
	Rail	Density (Availability of railroads)	Route-miles per 10,000 population
	Marine	Density (Availability of marine)	Miles of waterways per 10,000 population
		Port Access (Proximity of ports)	Distance from the center of MSA to the closest international container port
	Intermodal	Freight Access (Proximity of intermodal facilities)	Number of facilities per 10,000 population
Quality of Service	Highway	Travel Time Reliability (Variability in travel time due to congestion)	Travel Time Index
		Safety (Fatal highway crashes)	Fatalities per 100 million Vehicle Miles Traveled
		Road Roughness (Highway ride comfort)	Percent of lane miles in poor or fair condition (based on an International Roughness Index greater than 170 in/mi)
		Bridge Integrity (Ability of bridges to meet the needs of the users)	Percent of bridges structurally deficient or functionally obsolete
	Transit	Safety (Transit incidents)	Number of incidents per million Passenger Miles Traveled
	Aviation	Congestion (Airport congestion)	Percent of on-time performance for departures
		Safety (Chances of crashes)	Runway incursions per million operations
	Rail	Safety (Railroad incidents)	Number of incidents per million train miles
	Marine	Congestion (Delays on inland waterway)	Average lock delay per tow
Utilization	Highway	Reserve capacity	Percent of lane miles uncongested defined as Level of Service C or better
	Transit	Reserve capacity	Passenger miles traveled per capacity (standing and seating)
	Aviation	Reserve capacity	Percent of capacity used between 7 am and 9 pm
	Rail	Reserve capacity	Ton-miles per track mile

Table 2 Weights Based on Surveys

Indicator	MSAs under 1 million		MSAs over 1 million
	Without Airport	With Airport	
Highway Density (Availability of highways)	0.099	0.093	0.085
Transit Density (Availability of transit)	0.052	0.049	0.045
Airport Access (Proximity of airports)	0	0.018	0.016
Airport Capacity (Availability of airport service)	0	0	0.028
Rail Density (Availability of railroads)	0.055	0.052	0.047
Waterway Density (Availability of marine)	0.017	0.016	0.015
Port Access (Proximity of ports)	0.038	0.036	0.033
Intermodal Connectivity (Proximity of intermodal facilities)	0.052	0.049	0.045
Highway Congestion (Variability in travel time due to congestion)	0	0	0.113
Highway Safety (Fatal highway crashes)	0.112	0.089	0.068
Road Roughness (Highway ride comfort)	0.043	0.034	0.026
Bridge Integrity (Ability of bridges to meet the needs of the users)	0.121	0.096	0.073
Transit Safety (Transit incidents)	0.059	0.047	0.036
Air Congestion (Airport congestion)	0	0.029	0.022
Air Safety (Chances of crashes)	0	0.067	0.051
Rail Safety (Railroad incidents)	0.033	0.026	0.02
Waterway Congestion (Delays on inland waterway)	0.102	0.082	0.062
Uncongested Roads	0.132	0.132	0.117
Transit Utilization	0.044	0.044	0.039
Percent of Air Capacity Utilized	0	0	0.024
Rail Usage for Freight	0.042	0.042	0.037
Totals	1.001	1.001	1.002

LITERATURE REVIEW

Context

Transportation infrastructure is understood to be a foundation for economic health and competitiveness. However, no study has taken a comprehensive, quantitative look at transportation infrastructure performance over time. The American Society of Civil Engineers' (ASCE) Report Card is a qualitative presentation of the state of US infrastructure based on data and expert judgment (ASCE, 2010). More recently, ASCE has attempted to link this analysis to economic health (ASCE, 2011). Other studies have focused on trying to correlate infrastructure expenditure, rather than infrastructure performance, with economic productivity. A recent review of such studies (Shatz et al, 2011) confirms the positive relationship between infrastructure and economic growth. These studies capture the positive and significant direct and indirect impacts of transportation investment including the condition of the infrastructure as well as network effects. The complexities involved in these relationships mean that it is particularly difficult to understand the causal interactions. Cost benefit analysis based on microeconomic analysis does not capture the network effects. Macroeconomic analysis requires more than a simple production function but a general equilibrium model that captures both supply and demand (Lakshmanan, 2011). The difficulties in formulating and calibrating such a model are daunting. As an alternative approach, this study uses the Transportation Performance Index to better understand what it takes to significantly improve the performance of transportation infrastructure in the United States and ultimately support economic competitiveness.

Add to this the complexity of the decision making process and how investments actually get made, it is no wonder that it is difficult to connect physical infrastructure performance and economic health. For example, the Federal-Aid Highway Act of 1962 required the formation of a Metropolitan Planning Organization (MPO) for any urbanized area with a population greater than 50,000 (23 U.S.C. §§ 134–135). MPOs are required to develop and update a fiscally constrained long range transportation plan (LRTP) covering a planning horizon of at least twenty years. The plans must address mobility and access for people and goods, efficient system performance and preservation, and quality of life (Federal Highway Administration and Federal Transit Administration, 2007). LRTPs are further required to reflect public input, forecasted demographics and the anticipated needs of the region. Given the challenging funding environment and fiscal constraints, much of the available transportation funding is committed to the stewardship of existing transportation assets and, only if resources remain, can funding be applied to strategies for adding capacity

Furthermore, funds are often insufficient to move all asset to a state of good repair. Therefore, regional plans typically include scenarios reflecting the constrained funding. In this paper we use the Transportation Performance Index (TPI), developed under funding from the US Chamber of Commerce, to measure the performance of infrastructure based on scenarios and projects proposed in regional LRTPs.

The most recent federal legislation - Moving Ahead for Progress in the 21st Century (MAP-21) - implements a performance and outcome-based program in which states will use established performance measures, and set targets or thresholds. These measures and targets are intended to align with national goals in the areas of safety, infrastructure condition, congestion reduction, system reliability, freight movement and economic vitality, environmental sustainability and reduced project delivery delays. (Federal Highway Administration, 2013c)

While the performance measures (pavement condition on the Interstate System and on remainder of the National Highway System (NHS), performance of the Interstate System and the remainder of the NHS, bridge condition on the NHS, fatalities and serious injuries—both number and rate per vehicle mile traveled—on all public roads, traffic congestion, on-road mobile source emissions, and freight movement on the Interstate System) will be identified under DOT rules, the states are then required to establish performance targets within one year. The TPI has the potential to provide additional insights for states.

Despite these recent changes, conferences (such as the 2011 TRB Performance Management Conference) and increased interest in connecting decision making and performance there is still a dearth of relevant and consistent data.

Alternative Indicators

Indicators and Sources for Data

State of good repair (SOGR) and safety data figure prominently in the calculation of the TPI, particularly quality. In fact, for the national index, weighted indicators related to SOGR (road roughness and bridge integrity) represent 21 % of the quality of service measures and weighted indicators related to safety (highway, transit, rail and air) represent 46% of the quality of service measures. The remaining 33% are congestion related measures as shown in Figure 2.

However, road roughness and bridge integrity are clearly not comprehensive or complete measures of SOGR. The measures rely on the Highway Performance Monitoring System (HPMS) and the National Bridge Inventory (NBI). While the limitations of both these data sets are well understood, there are no real alternatives. In addition, FHWA migrated to a new format for HPMS reporting and in 2009 the data was only partially complete (US Chamber of Commerce, 2011). The data for 2010 and 2011 according to FHWA are not consistent and FHWA has not computed any of the derived variables. Building on our prior research on alternative indicators (US Chamber of Commerce, 2010), the gaps are:

- Road roughness is a measure of comfort rather than structural integrity.
- NBI data are based on visual ratings and do not necessarily reflect substantive issues.
- No indicators are available that consistently reflect the SOGR of
    - non-pavement and bridge assets
    - railroads
    - ports and waterways
    - transit systems

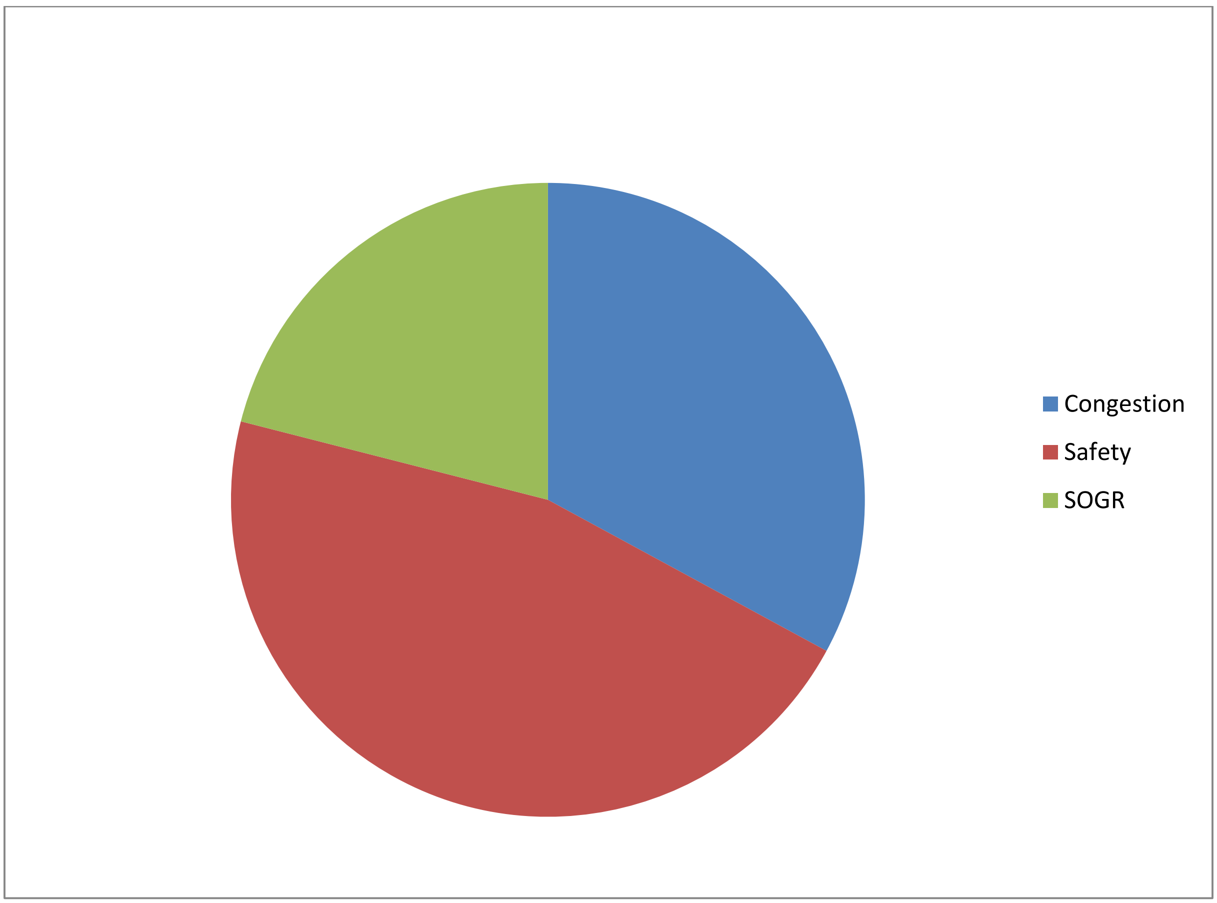

Figure 2. Relative Contribution of Quality of Service Indicators

The revised HPMS format offers some hope as fields have been added to reflect data on various types of pavement distress. Not all states are collecting this data and it will be several years before the database has been populated.

Looking to the future, FHWA's Integrated Transportation Data Platform (ITDP) is promising as shown in Figure 3 (Federal Highway Administration, 2013b). The platform included the Highway Infrastructure Performance Analysis Toolkit (HIPAT) and includes more data, easier access, location referenced data and network analysis capabilities as shown in Figure 4.

Safety is the other important class of indicators with several gaps. Highway safety data focuses on fatal accidents. While this measure is not ideal it is widely accepted as a relatively robust measure of highway safety, particularly in comparison to data for all other modes. Careful analysis of the existing data reveals inconsistent reporting, improperly defined measures and missing data. Discussions with agencies (including those generating the data, and those curating the data) failed to identify alternatives, although all agree that the data are important.

As a result, no new data was identified for inclusion in the TPI

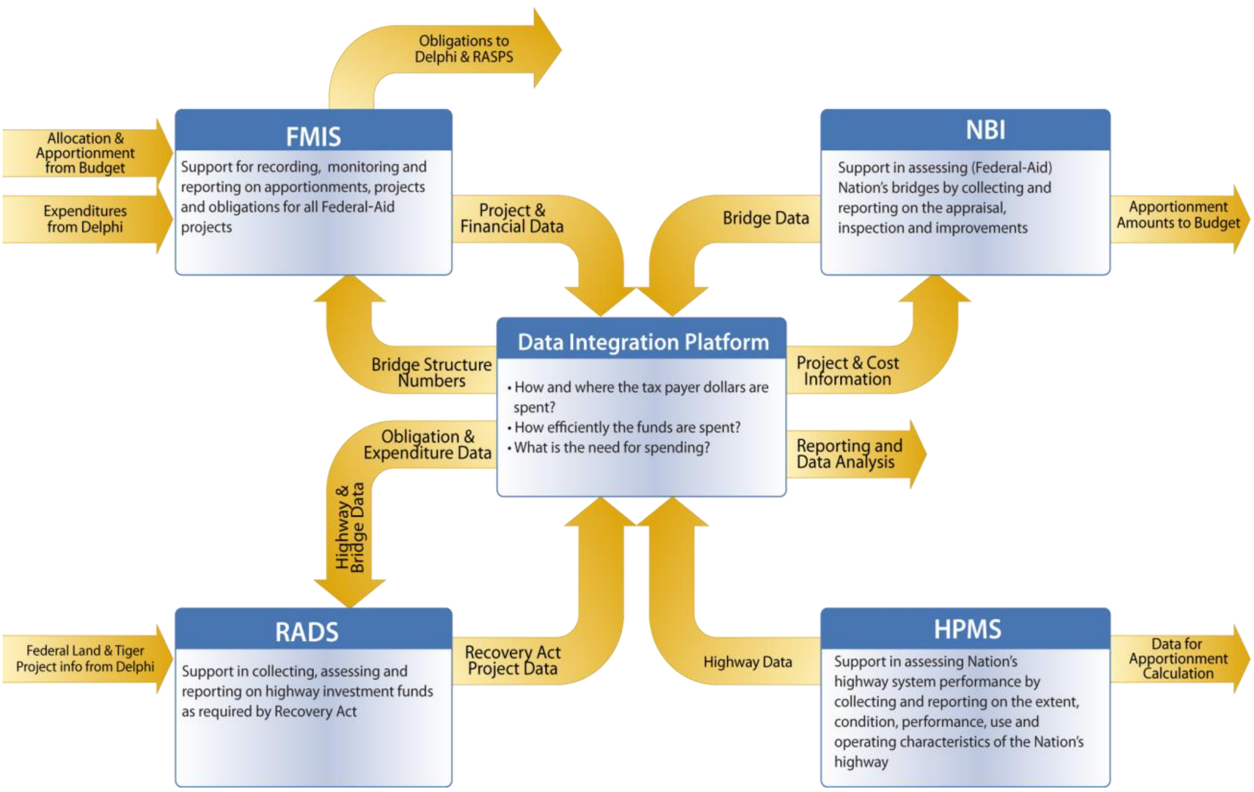

Figure 3 FHWA's Integrated Transportation Data Platform

Normalization

For the 2010 and 2011 TPI, indicators are normalized using the maximum and minimum values across all MSAs for 2000. Although no changes were made for 2013 to the normalization strategy, several different approaches were explored. These include:

- Alternative 1: Indicators are normalized by MSAs using the max and min value for each indictor and each MSA for the years 1990-2011.
- Alternative 2: Indictors are normalized using the max and min values for all years and all MSAs
- Alternative 3: A weighted average indictor is developed for each year, where the weighting is based on the economic contribution of the MSA, the indicator is then normalized using the max and min value for each indicator for the years 1990-2011.

The resulting values of the TPI were found to be highly correlated as shown in Table 3. The strength of the original normalization scheme is that the method remains stable from year to year.

In addition consideration was given to using thresholds for additional indicators. For example the indicator for Uncongested Roads is based on a threshold of a level of service of C or better. This reflects the concept that levels of service worse than C are unacceptable and there is no added information by differentiating acceptable levels of service. While this concept is interesting, preliminary exploration of the data indicates that other indicators do not have obvious thresholds or thresholds based on current practice. The simplest way to set thresholds is to use expert opinion but experience with the weights suggests that extracting such specific information from a panel of experts is very difficult. If established organizations, such as TRB, AASHTO or FHWA, adopted the TPI, they could convene expert panels and more proactively set thresholds in a meaningful way.

Alternative Weights

The original indicator weighting was developed using an internet based survey administered using Comparion™ Suite, a web-based tool for implementing Expert Choice Surveys. The survey went out to 447 participants. Twenty one (21) responses were received, a 4.7% response rate. Given the relatively low response rate, there was some concern that the responses were not representative. A plan to develop revised weights was developed.

The plan focused on using personal contacts and a snowball sampling strategy to attempt to get representation from each of the 36 MSAs in the sample including one government or academic representative and one representative of the community. Initial contact was made by email and with follow up phone calls and then a phone appointment scheduled to administer the survey.

Participants were all asked to do the pairwise comparison of criteria (supply, quality and utilization) and the pairwise comparison of indicators for one set of criteria. The response rates are shown in Table 4.

A different scale was used for the pairwise comparisons than in the original survey. The original survey used a scale from 1 to 9 (ranging from equal to extremely strong) to compare the importance of different indicators (Saaty, 2008). However, the subtle differences in scale are difficult for respondents to identify when assessing the indicators. In developing the revised weights, respondents were simply asked to indicate whether they strongly or moderately preferred one indicator over another (they could also indicate that they had no preference.) Moderate was coded as “3” (or “1/3”) and strong as “5” (or “1/5”). While this is easier for the respondents, consistency is reduced as shown in Table 4.

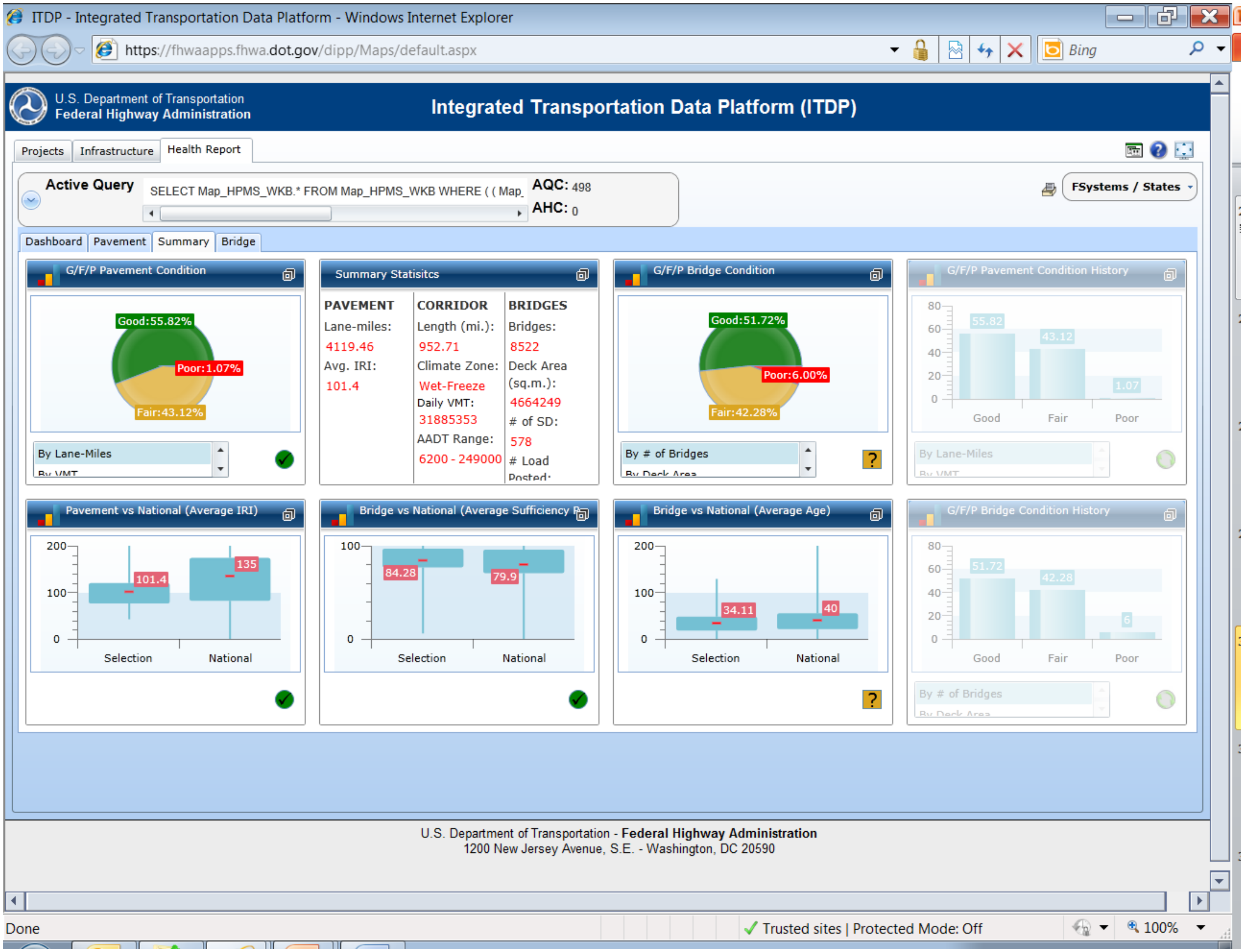

Figure 4 Screen Shot of ITDP Showing Capabilities

Table 3 Correlations for TPI values for Alternative Normalizations

	Original	Alternative 1	Alternative 2	Alternative 3
Original	1.000			
Alternative 1	0.759	1.000		
Alternative 2	0.858	0.783	1.000	
Alternative 3	0.583	0.679	0.614	1.000

Table 4 Survey Responses

Measure	Original	Updated			
		Criteria	Supply	Quality	Utilization
Participants Invited	447	65			
Responses	21	33	14	10	9
Response Rate	4.7%	46%			
Consistency Ratio	0.01	0.10	0.25	0.38	0.21
MSAs represented		21			

Survey Results

The results of the survey are shown in Table 5, along with the weights originally computed. Initially the pairwise comparison was used to compute the weights for MSAs with population over 1 million. These MSAs use all 21 indicators. The weights are then computed for the MSAs with population under 1 million that have an airport and those that do not have an airport. The correlation between the original weights and the revised weights is 0.64.

The largest changes, in terms of absolute value of the weight, are the weights for Transit Utilization (0.05) and Highway Congestion (0.05). The largest changes in terms of the percentage change are Transit Utilization (+135%) and Railroad Safety (+120%). Percent of Air Capacity Utilized (+101%) and Airport Access (Proximity of airports) (+101%) also show significant percentage increases.

Again, the original weights were adopted to ensure consistency from year to year. This approach is further reinforced when the TPI was computed using the revised weights as discussed below.

Data Collection and Assessment

In general the data originally selected continues to be available and published on a regular basis. Access to the Highway Performance Monitoring System proved to be the most challenging. As mentioned above, FHWA migrated to a new format for HPMS reporting and in 2009 the data was only partially complete (US Chamber of Commerce, 2011). The data for 2010 and 2011 according to FHWA are not consistent and FHWA has not computed any of the derived variables. Therefore data for Highway Reserve Capacity were not available

In addition some data fields required clarification, despite our best attempts to document the methods to compute each indicator. No retrospective changes were made to the data. The clarifications are summarized in Table 6.

Table 7 shows the TPI calculated using the updated weights and the original weights. These TPI values are plotted in Figure 5. The two estimates of the TPI follow the same general pattern. The correlation between the TPI values calculated using the original weights and the updated weights is 0.95. The TPI using the updated weights are on average 2.45 points higher than the TPI using the original weights. The largest differences occur in 2002 (4.34), 2003 (3.83) and 2009 (3.31). The largest percentage differences occur in 2002 (8.2%), 2003 (7.2%) and 2006 (6%) with the average percentage difference being 4.7%.

The most important value in interpreting the TPI is the change from year to year. From 1990 to 2011 the largest differences in the annual change when comparing the original data and the updated data occur between 1995 and 1996 (-1.14), 1997 and 1998 (1.44) and 2001 and 2002 (2.88). The average difference in the annual change is 0.05.

Given the fact that the updated weights provide estimates of the change in the TPI that are very consistent with the original weights, and that the stakeholders have some familiarity with the TPI, we propose to continue to use the original weights and calculation method.

Table 5 Original and Revised Weights Based on Surveys

Status	MSAs under 1 million				MSAs over 1 million	
	Without airport		With airport			
	Original	Updated	Original	Updated	Original	Updated
Highway Density (Availability of highways)	0.099	0.072	0.093	0.061	0.085	0.053
Transit Density (Availability of transit)	0.052	0.067	0.049	0.058	0.045	0.049
Airport Access (Proximity of airports)	0	0	0.018	0.037	0.016	0.032
Airport Capacity (Availability of airport service)	0	0	0	0	0.028	0.030
Rail Density (Availability of railroads)	0.055	0.043	0.052	0.037	0.047	0.031
Waterway Density (Availability of marine)	0.017	0.018	0.016	0.015	0.015	0.013
Port Access (Proximity of ports)	0.038	0.035	0.036	0.030	0.033	0.026
Intermodal Connectivity (Proximity of intermodal facilities)	0.052	0.048	0.049	0.041	0.045	0.035
Highway Congestion (Variability in travel time due to congestion)	0	0	0	0	0.113	0.063
Highway Safety (Fatal highway crashes)	0.112	0.109	0.089	0.093	0.068	0.080
Road Roughness (Highway ride comfort)	0.043	0.030	0.034	0.026	0.026	0.022
Bridge Integrity (Ability of bridges to meet the needs of the users)	0.121	0.068	0.096	0.058	0.073	0.050
Transit Safety (Transit incidents)	0.059	0.074	0.047	0.063	0.036	0.054
Air Congestion (Airport congestion)	0	0	0.029	0.042	0.022	0.036
Air Safety (Chances of crashes)	0	0	0.067	0.062	0.051	0.053
Rail Safety (Railroad incidents)	0.033	0.060	0.026	0.051	0.02	0.044
Waterway Congestion (Delays on inland waterway)	0.102	0.046	0.082	0.040	0.062	0.034
Uncongested Roads	0.132	0.141	0.132	0.121	0.117	0.104
Transit Utilization	0.044	0.124	0.044	0.107	0.039	0.092
Percent of Air Capacity Utilized	0	0	0	0	0.024	0.048
Rail Usage for Freight	0.042	0.067	0.042	0.058	0.037	0.050
Totals	1.001	1.000	1.001	1.000	1.002	1.000

Table 6 Clarification of Indicators

Indicators	Status
Air Access	Percent of population within 50 miles of major airport: The following Airports were used for this indicator: 'ABI','AOO','ATL','BWI','BMI','BOS','BUF','CLT','CHA','ORD','CLE','DFW','DAY','DEN','DTW','PSC','LAX','MEM','MSP','BNA','PHL','PIT','PVD','RDU','ONT','SGO','SLC','SAT','TPA','TUS'
Air Capacity	Airport arrival rate and departure rate per hour: For the following 4 MSAs the listed airports listed were used: Los Angeles-Long Beach-Santa Ana, CA MSA: LAX, SNA, BUR, LGB; Chicago-Naperville-Joliet, IL-IN-WI MSA: ORD, MDW; and Dallas-Fort Worth-Arlington, TX MSA: DFW and DAL.
Rail Density	Route miles per 10,000 population: The following list of Class I railway was used for determining the indicator: 'BNSF', 'CN', 'CSXT', 'KCS', 'NS', 'CP','UP'
Port Access	Distance from the center of MSA to the closet international container port: The following ports were used for determining this indicator: 'Baltimore, MD', 'Boston, MA', 'Portsmouth, NH', 'Gloucester, MA', 'Buffalo, NY', 'Chicago, IL' , 'Cleveland, OH', 'Detroit, MI', 'Los Angeles, CA' , 'Long Beach, CA', 'Philadelphia, PA', 'Camden, NJ', 'Gloucester City, NJ', 'Paulsboro, NJ', 'Pensauken, NJ', 'Wilmington, DE', 'Pittsburgh, PA', 'Fort Pierce, FL', 'Providence, RI', 'New Bedford, MA', 'Fall River, MA', 'Tampa, FL', 'Port Manatee, FL'.
Highway Safety	Fatalities per 100 million Vehicle Miles Traveled: The HPMS data we received from FHWA containing 2010 VMT data was incomplete. So we used average value of 2009 and 2011 data to obtain some of the MSA's values for this indicator. The following MSA's had missing numbers and average values were used for 2010 VMT data: Abilene, TX (MSA) (10180), Chattanooga, TN-GA (MSA) (16860), Dallas-Fort Worth-Arlington, TX (MSA) (19100), Harrisonburg, VA (MSA) (25500), Memphis, TN-MS-AR (MSA) (32820), Nashville-Davidson-Murfreesboro-Franklin, TN (MSA) (34980), Salt Lake City, UT (MSA) (41620), Winchester, VA-WV (MSA)
Road Roughness	The HPMS data we received from FHWA containing 2010 IRI data was incomplete. So we used average value of 2009 and 2011 data to obtain some of the MSA's values for this indicator. The following MSA's had missing numbers and average values were used for 2010 IRI data: Abilene, TX (MSA) (10180), Chattanooga, TN-GA (MSA) (16860), Dallas-Fort Worth-Arlington, TX (MSA) (19100), Harrisonburg, VA (MSA) (25500), Nashville-Davidson-Murfreesboro-Franklin, TN (MSA) (34980), San Antonio, TX (MSA) (41700) , Winchester, VA-WV (MSA) (49020).
Aviation Safety	Runway Incursion per million operations : Due to hurricane Irene North Carolina state recorded high number of airport incidents in August 2011.We opted to use to average values from 2001 to 2010 or Charlotte-Gastonia-Concord, NC-SC (MSA) (16740) MSA for 2011.
Highway Capacity	FHWA is still working on 2010 and 2011 data for this indicator. So we used 2009 values for 2010 and 2011 for this indicator

Table 7 TPI Using Update Weights and Original Weights

Year	Updated Weights	Original Weights
1990	49.24	48.17
1991	51.16	49.42
1992	54.08	51.73
1993	52.45	50.65
1994	54.13	51.50
1995	55.85	53.07
1996	53.39	51.75
1997	52.70	51.55
1998	54.60	52.02
1999	53.67	51.36
2000	52.86	50.62
2001	53.36	51.90
2002	57.19	52.85
2003	56.82	52.99
2004	54.25	51.30
2005	53.10	50.42
2006	54.04	50.99
2007	53.35	50.74
2008	55.92	52.82
2009	60.87	56.60
2010	58.25	55.85
2011	59.45	57.26

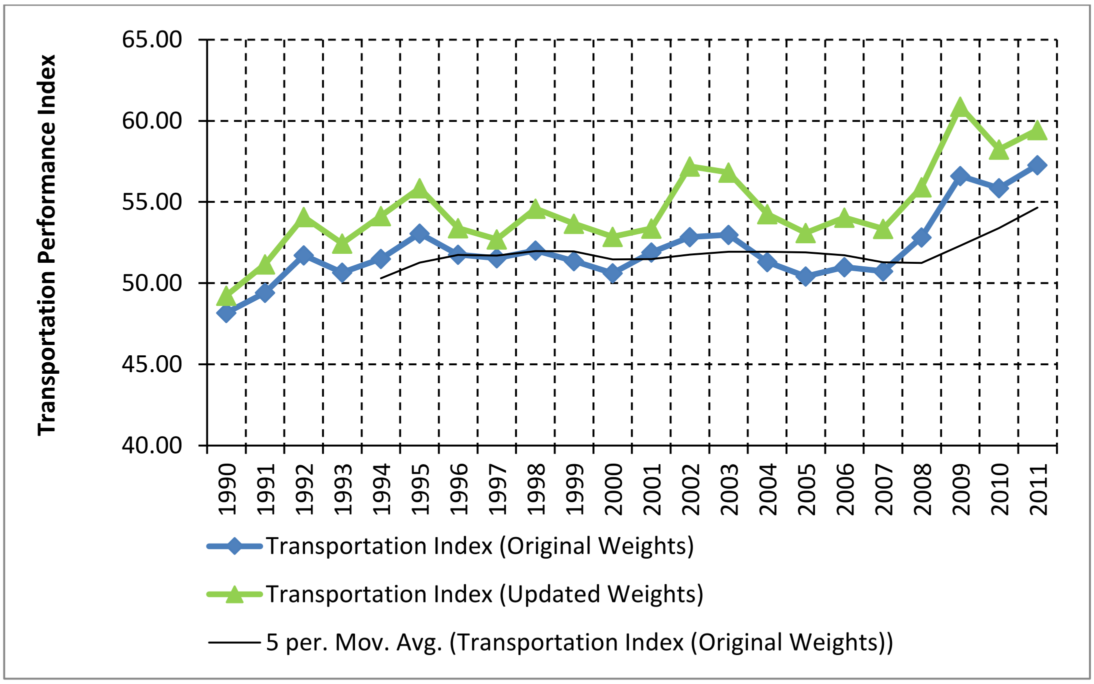

Figure 5 TPI Using Updated Weights an Original Weights

FINDINGS

2010 and 2011 TPI

The TPI was computed for 2010 and 2011 using the same methodology developed in 2010 and using the same indicators, indicator normalization and weights as summarized in the Methodology section of this report.

Although the TPI wavered in 2010 and 2011, the improvements seen in 2009 (reported in the 2011 report) appear to be holding. The complete TPI series from 1990 to 2011 is shown in Table 8 and plotted with a 5 year moving average in Figure 6.

Table 8. Transportation Performance Index 1990-2011

Year	Transportation Index
2011	57.26
2010	55.85
2009	56.60
2008	52.82
2007	50.74
2006	50.99
2005	50.42
2004	51.30
2003	52.99
2002	52.85
2001	51.90
2000	50.62
1999	51.36
1998	52.02
1997	51.55
1996	51.75
1995	53.07
1994	51.50
1993	50.65
1992	51.73
1991	49.42
1990	48.17

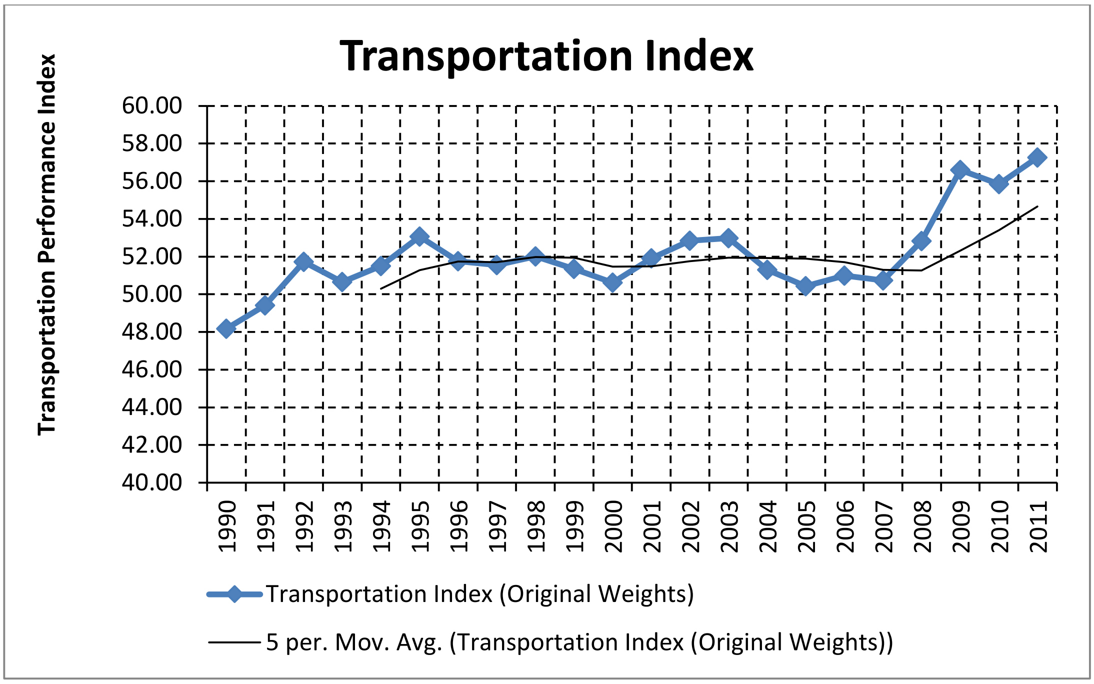

Figure 6 Transportation Performance Index 1990-2011

Relationship to Economic Growth

The new observations on the TPI, when added to the existing economic model, confirm the original results with a slightly stronger impact: a 1 point increase in the TPI correlates with about a 0.4% increase in the growth of GDP per capita (a measure of prosperity). We estimate the TPI with a 95% confidence interval. In any year, a "significant" improvement would require a change of at least 2.5 from the previous TPI value. Therefore, it might be more accurate to write that a *significant* improvement in the performance of transportation infrastructure could result in about a 1.0% increase in the growth rate of the economy.

Interpretation of Results

Figure 6 shows the TPI declining slightly in 2010 (by less than 1) and increasing in 2011 by about 1.5 – or just 0.66 above the 2009 TPI. The magnitude of these changes suggests a continuance of an upward trend in the TPI as can be seen in the 5-period moving average. Beginning in 2009 with the "Stimulus Package," there have been significant investments in infrastructure fueled by the funding of "shovel-ready" projects despite the fact that only 52% of the federal transportation budgeted was actually spent in 2009. Meanwhile, passenger travel, as evidenced by vehicle miles of travel (VMT), began to climb out of a slump in 2009, as did freight traffic. The increasing pressure on the infrastructure appears to be somewhat balanced by the larger investments.

Our initial interpretation of these results is that the big drop-off in traffic with the recession of 2007-2008 resulted in an improved TPI for 2009 possibly just from reduced usage. Then, as traffic picked up in 2010, the TPI declined slightly, but, by 2011, the bigger investments (initiated from 2009 onward) offset the increasing pressure from recovering economic activity. We are compiling a list of infrastructure initiatives to make this point in the final report. For example, a wide variety of projects were funded under expanded TIGER grants which served to reduce automobile congestion (street cars, bike paths), improve port access, and make bridges safer.

Looking to the future, doing nothing is not an option. This is reinforced by other related studies including the American Society of Civil Engineers "Failure to Act" report (ASCE, 2012), and American Society of Civil Engineers' 2013 report card. The report card gives an overall grade of D+ for America's infrastructure with individual grades of D for Aviation, C+ for Bridges, C for Ports, C+ for Rail, and D for Roads (ASCE, 2013). Table 9 shows the investment needs estimated by ASCE through 2020. While the estimated available funding is significant, the gap is also significant and in the case of surface transportation it is almost 50% of the total needs.

Table 9 Investment Needs to 2020 (in $2010 billions) (ASCE, 2013)

Infrastructure Systems	Total Needs	Estimated Available Funding	Funding Gap
Surface Transportation	$1,723	$877	$846
Airports	$134	$95	$39
Inland Waterways & Marine Ports	$30	$14	$16
Rail	$100	$89	$11

The US continues to decline in the global rankings for poor transportation infrastructure (World Economic Forum, WEF, in Table 10). When we calculated the TPI with 2009 data, WEF had the US ranked as 14th worldwide on quality of infrastructure; in the 2010-2011 period, that ranking dropped nearly 10 positions to 23 and has declined one more position each year since US road, rail and even port rankings manage to stay in or near the top 20 in the world in the WEF ranking.

Table 10 US Global Ranking for Transportation Infrastructure

Year	World Economic Forum Rank
2006-2007	8
2007-2008	9
2008-2009	9
2009-2010	14
2010-2011	23
2011-2012	24
2012-2013	25

Case Study – Prospective Analysis

To explore how the index might change in the future, three scenarios are modelled for 2020 as a part of the prospective analysis. In each scenario, the population of the US is assumed to be growing at 1% per year, which is approximately the annual US population growth rate over the last 20 years (The World Bank Group, 2013). The analysis also assumes that the structure of the economy does not change in the sense that the relative contribution of each MSA does not change. Specifically, the total contribution of each MSA to the US economy measured by GDP remains at 80%, as described in the background. The scenarios are defined as follows:

- Prospective Analysis:
  - Scenario 1 – No New Investment - assumes no new investment. Additional capacity is not added and additional investments in maintenance are not made in response to aging infrastructure.
  - Scenario 2 – State of Good Repair - assumes no new investment other than accomplishing a state of good repair as outlined in the surface transportation funding bill titled Moving Ahead for Progress in the 21st Century Act (MAP-21) and signed into law in July 2012. This scenario assumes the physical condition of transportation infrastructure – roads, bridges, transit, railroads, airports and ports – is upgrading to a satisfactory level but no new capacity is added.
  - Scenario 3 – Significant Investment (State of Good Repair and Congestion Reduction) - assumes significant investment beyond the provisions outlined in MAP-21. These investments not only improve the condition but add capacity.

The specific changes for each indicator for scenarios 1, 2, and 3 are shown in Table 11. Changes are reported as percentage changes or as a specific value for the indicator. In terms of the desired direction for the improvement of an indicator, refer to Table 1. For example, for air, transit and rail reserve capacity indicators (i.e., IDN19, IDN20 and IDN21), the desired direction is a negative percent increase, where the indicators improve with a decrease in the amount of network capacity that is being utilized for the specific mode. The magnitude of the change is based on the expected change in population, the scenario, and the indicator. For example, highway density (measured as lane miles of highway per 100,000 of population) is computed based on a 1% increase per year in population for scenarios 1 and 2, but there is no change in scenario 3 as investments will keep pace with the growth in population. The new values for the indicators in each scenario are used to calculate projected TPIs, using the procedure outlined in the background section.

The results for the specific changes to TPI are shown in Figure 7. In general, the results for each of the scenarios are as expected:

- Scenario 1 (no new investment) results in a significant decline in the TPI.
- Scenario 2 (state of good repair) results in a decline in the index to 2008 levels. So while important, state of good repair is just one aspect of transportation infrastructure performance.
- Scenario 3 (significant investment) results in a markedly improved TPI.

In summary, the prospective analysis using different investment policy scenarios it is shown that increased investment is essential in improving the performance of our transportation infrastructure. However, the key is the level of investment that is pledged and whether it's towards supply, quality of service or utilization for transportation services. The analysis demonstrated that the TPI can capture changes in investment, changes in demand (due to population growth) and alternative policies such as maintaining the status quo (scenario 1) versus focusing on state of good repair (scenario 2).

Table 11 – Changes in Indicators 2009-2020 for Three Scenarios

#	**Description**	**Scenario 1**	**Scenario 2**	**Scenario 3**
IND1	Highway Density	-10%	-10%	No change
IND2	Transit Density	-10%	-10%	+15%
IND3	Airport Access	No change	No change	Indicator=1
IND4	Airport Capacity	No change	No change	+15%
IND5	Rail Density	-10%	-10%	+15%
IND6	Waterway Density	-10%	-10%	No change
IND7	Port Access	No change	No change	-15%
IND8	Intermodal Freight Access	-10%	-10%	+15%
IND9	Highway Travel Time Reliability	+11%	+11%	-15%
IND10	Highway Safety	No change	No change	-15%
IND11	Road Roughness	+11%	Indicator = 0	-15%
IND12	Highway Bridge Integrity	+11%	Indicator = 0	-15%
IND13	Air Congestion	-10%	-10%	+15%
IND14	Air Safety	No change	No change	-15%
IND15	Rail Safety	No change	No change	-15%
IND16	Waterway Congestion	+11%	+11%	-15%
IND17	Transit Safety	No change	No change	-15%
IND18	Highway Reserve capacity	-10%	-10%	+15%
IND19	Air Reserve capacity	+11%	+11%	-15%
IND20	Transit Reserve capacity	+11%	+11%	-15%
IND21	Rail Reserve capacity	+11%	+11%	-15%

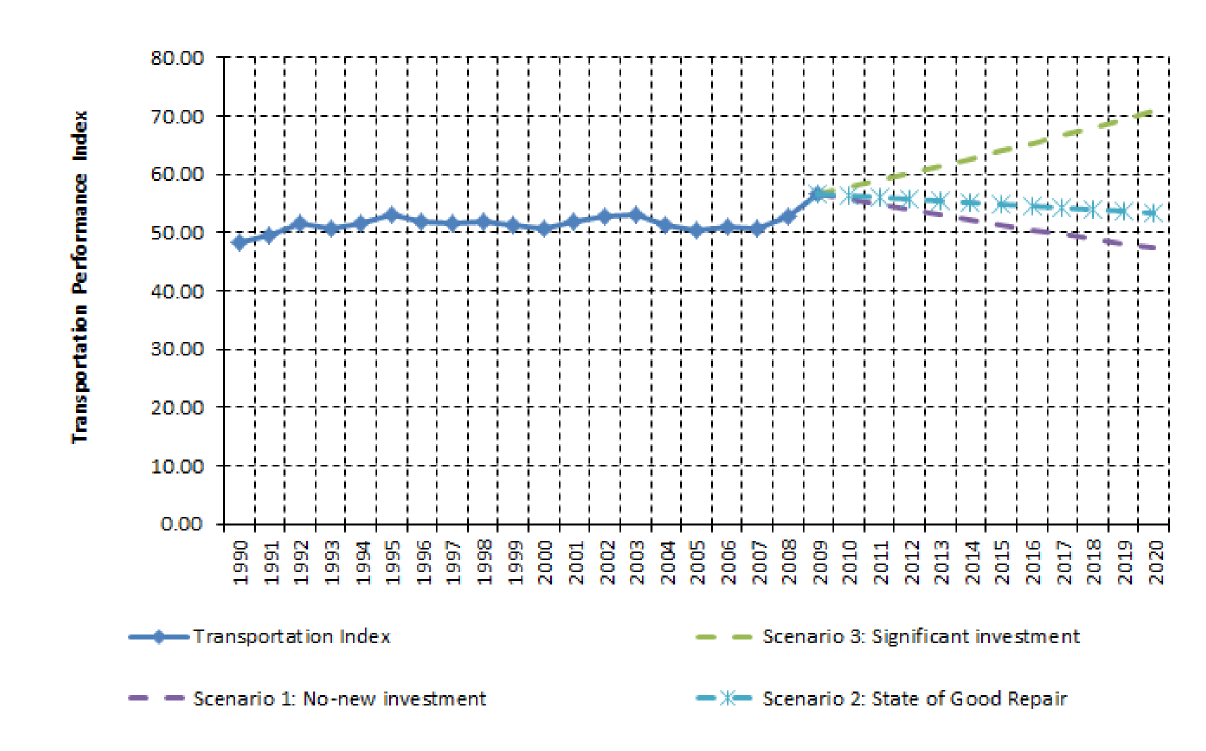

Figure 7 Extrapolated TPI for Three Prospective Analysis Scenarios

Case Study – Retrospective Analysis

To explore how the index might have looked, the effects of not implementing nine individual projects are modelled as a part of the retrospective analysis, which is defined as follows:

- Retrospective Analysis:
  - This analysis assumes nine major projects are not implemented. These projects were identified as significant projects from the Transportation Project Impact Case Studies (TPICS) database (Economic Development Research Group, Inc. 2011).

For the retrospective analysis, we explore the impact on the TPI of NOT implementing nine significant projects. These projects, which are shown in Table 12, were identified as projects of significance in the sampled MSAs and occurring within the TPI analysis period from 1990 to 2009. These projects include intermodal facilities, transit and highway improvements, as well as reconstruction and congestion relief projects. The projects total \$20.8b in constant 2008 dollars and include the Central Artery project in Boston, the largest construction project ever. Each project was reviewed and the impacts on the indicators assessed.

Using the TPICS database, the description and data for each project were reviewed to assist in estimating the change in the TPI indicators beginning in the year in which the project was completed. For three projects (Lindberg Station, MARTA; Anderson Regional Transportation Center; and Dallas High Five Interchange, where the first two projects are multi-modal transit hubs and the last project is an interchange), no indicator captured the changes that occurred. This is consistent with our earlier assessment of the limitations of the TPI (Oswald et al, 2011).

For the other six projects, a change in the value of four specific indicators could be estimated based on the data and descriptions as follows:

- In the case of highway renewal projects (Boston Central Artery Tunnel and I-15 Reconstruction), the projects were assumed to reduce the International Roughness Index (IRI) to a value less than 170 (IND11) and improve the Level of Service (LOS) to C or better (IND18).
- The improvement project for US 75 North Central Expressway is also assumed to improve the LOS to C or better (IND18).

- The intermodal terminal project, Fairburn CSX Industry Yard, was assumed to add one intermodal facility to the MSA (IND8) but this was not a significant change to the MSA.
- The Carolina Factory Shops Infrastructure and the DART projects both add route miles (IND1) but these are also insignificant in terms of changes in the MSA.

Table 4 shows the change in the indicators for each project and the year in which the change occurred (based on when the project was completed). For completeness, the three projects with no changes in the indicators are also included in the table. For all other projects only indicators with estimated changes are included, with the insignificant changes in indicators denoted as approximately zero (~0).

The changes to the indicators shown in Table 4 are then used to compute a revised TPI shown in Table 5, assuming the changes in the indicators apply for future years as well as the year in which the project was completed. The renewal and improvement projects are likely to have also resulted in safety improvements but insufficient information was available to estimate the magnitude of these improvements. However, it can be reasonably assumed that the improvements are not likely to be significant across the MSA. Also, none of these renewal and improvement projects added route miles (IND1). Overall, these assumptions may not be strictly applicable to the entire project or fail to capture other improvements or the changes in the TPI may diminish over time; they mainly serve as an approximation to indicate the magnitude of the changes.

Table 5 also shows the change in the TPI and the cumulative expenditures, based on the assumption that all costs are incurred at the end of the project. The first project to be completed in 1997 did not result in any changes in the TPI and it is not until US 75 North Central Expressway is completed that any changes in the TPI are realized. The data indicates that the changes in the TPI are not significant as the magnitude of the change is smaller than the error in the estimation. However, the cumulative expenditures for these nine projects between 1997 and 2009 are highly correlated (0.87) with the changes in the TPI.

Table 12 – Projects of significance (Source: Based on the TPICS database (Economic Development Research Group, Inc, 2011))

MSA	Project Name	Description	Actual Cost (2008 $m)
Atlanta-Sandy Springs-Marietta, GA	Fairburn CSX Industry Yard (Fairburn, GA)	The Fairburn CSX Intermodal Center was built to create a high volume rail corridor for reliable intermodal service on the lines connecting Southern California ports with Atlanta and with the rest of the southeast region.	$ 206.1
	Lindberg Station, MARTA (Atlanta, GA)	The Lindbergh Station City Center project was planned as a mixed-use transit-oriented development (TOD). Twenty four million dollars were invested by MARTA which included platform additions, stairs, escalators, elevators, concourse areas, fare gates, an upgraded bus transfer system, and a ground-level street plaza. The development around the station included 1 million square feet of office space, 300,000 square feet of retail space, and 714 residential units.	$31.6
Boston-Cambridge-Quincy, MA-NH	Central Artery Tunnel (Boston, MA)	The original six-lane highway, built in 1959 on an elevated structure, was plagued by tight turns, an excessive number of exits, entrance ramps without merge lanes, and continually escalating traffic. The Central Artery project was developed in response to these challenges. Construction started in 1991 and by 1995, the Ted Williams Tunnel and the Storrow Drive Connector Bridge were finished. In 2003, the extension of I-90 to Logan Airport via the Ted Williams Tunnel was completed. By 2005, all lanes in the new Central Artery Tunnel were opened to traffic.	$17,712.5
	Anderson Regional Transportation Center (Woburn, MA)	The Anderson Regional Transportation Center (ARTC) is a multi-modal transit hub with commuter rail and bus service to Boston and points north. The project involved cleanup of a superfund site, and construction of the intermodal facility, new surface roads and a highway interchange.	$73.7

MSA	Project Name	Description	Actual Cost (2008 $m)
Charlotte-Gastonia-Concord, NC-SC	Carolina Factory Shops Infrastructure	Construction of water system and access roads to serve the Carolina Factory Shops site. The project included 3 phases and grew 400,000 sq ft & 800 jobs by 1998.	$1.4
Dallas-Fort Worth-Arlington, TX	Dallas High Five Interchange (Dallas, TX)	The Dallas High Five Interchange is a reconstruction of an existing three-level interchange at the intersection of Interstate 635 and U.S. 75 in Dallas, Texas. The project involved extensive reconstruction of an existing loop interchange to complement other planned transportation improvements in the area, including improvements to the I-635 and US 75 corridors.	$305.4
	US 75 North Central Expressway, (Dallas, TX)	TxDOT, DART, and the Cities of Dallas, University Park and Highland Park entered into a partnership to reconstruct a 9-mile segment of US 75 to eliminate short sight lines, redesign on-ramps and acceleration lanes, and add capacity. The highway now has a minimum of eight continuous general purpose lanes and is in a trench for six of the nine miles between downtown and I-635 (the LBJ Freeway).	$428.5
	DART	The LBJ-Skillman is on DART's light rail system on the Blue Line. The project included vehicle access ramps, new roadway infrastructure, the widening of the Miller Road bridge, and a new frontage road. However, the planned TOD here has not yet been developed.	$103.8
Salt Lake City, UT	I-15 Reconstruction (Salt Lake City, UT)	The I-15 Reconstruction Project involved the rebuilding and widening of a deteriorated, congested 17 mile stretch of Interstate 15, running through Salt Lake City. The project was necessary to accommodate the rapid growth the region was experiencing, much of which was due to in-migration from California.	$ 1,964.3

Table 13 – Change in indicators if projects were not implemented

Project	Year Completed	IND1	IND8	IND11	IND18
Fairburn CSX Industry Yard, (Fairburn, GA)	1999		~0		
Lindberg Station, MARTA (Atlanta, GA)	2004	No Changes to TPI Indicators			
Central Artery Tunnel (Boston, MA)	2006			4.43	-4.43
Anderson Regional Transportation Center (Woburn, MA)	2001	No Changes to TPI Indicators			
Carolina Factory Shops Infrastructure	1997	~0			
Dallas High Five Interchange (Dallas, TX)	2005	No Changes to TPI Indicators			
US 75 North Central Expressway (Dallas, TX)	1999				-2.82
DART	2002	~0			
I-15 Reconstruction (Salt Lake City, UT)	2001			31.59	-31.59

Table 14 – Impact on TPI if projects were not implemented

Year	Transportation Performance Index w/o projects	Transportation Performance Index w/ projects	Overall Change in TPI due to Projects (%)	Cumulative Expenditure on Significant Projects ($m)
1990	48.17	48.17	No change	No investment
1991	49.42	49.42	No change	No investment
1992	51.73	51.73	No change	No investment
1993	50.65	50.65	No change	No investment
1994	51.50	51.50	No change	No investment
1995	53.07	53.07	No change	No investment
1996	51.75	51.75	No change	No investment
1997	51.55	51.55	0	1.4
1998	52.02	52.02	0	1.4
1999	51.31	51.36	+0.05	636.0
2000	50.58	50.62	+0.04	636.0
2001	51.76	51.90	+0.14	2674.0
2002	52.71	52.85	+0.14	2777.8
2003	52.94	52.99	+0.05	2777.8
2004	51.17	51.30	+0.13	2809.4
2005	50.28	50.42	+0.14	3114.8
2006	50.78	50.99	+0.21	20827.4
2007	50.52	50.74	+0.22	20827.4
2008	52.60	52.82	+0.22	20827.4
2009	56.37	56.60	+0.23	20827.4

The retrospective analysis, using specific projects, demonstrates the impact of the magnitude and timing of specific projects. The results showed that an investment of almost $(US) 23 billion in nine projects changed the TPI by only 0.23%. The analysis also demonstrates the importance of network effects, comprehensive and coherent planning, and the limited impact of isolated regional investments on national infrastructure performance. In addition, it further supports the idea that not one project, investment in a single region or a single mode, will significantly change the value of the TPI, where a system or network approach is needed to create considerable change in transportation performance.

Case Study – Impact of Regional Transportation Plans

The question is often asked: how do we improve the TPI? To answer this question we have hypothesized various scenarios including no new investment, investing in a state of good repair, and significant new investment to forecast the TPI in the future (US Chamber of Commerce, 2010). In this research, we also used the long range plans produced by Metropolitan Planning Organizations (MPOs) for 9 of the 36 MSAs sampled for the TPI to assess the changes in the TPI from 2011, our most recent assessment of the TPI, and 2035, the forecast year most commonly used by LRTPs.

To address the objectives outlined above, we constructed three scenarios:

- Scenario 1: Do Nothing – This scenario assumes no new investment. Additional capacity is not added and additional investments in maintenance are not made in response to aging infrastructure.
- Scenario 2: Selected MPOs – This scenario assumes implementation of LRTPs in selected MSAs. Additional capacity and investment in state of good repair are made consistent with LRTP.
- Scenario 3: All MPOs – This scenario assumes implementation of LRTP-like investments in all MSAs.

The "Do Nothing" scenario is based on 1% annual population growth and no new investment. Over the 24 year period (2011 to 2035) the projected changes in each of the indicators of performance used in the TPI are shown in Table 15.

The "Selected MPOs" scenario is based on investments presented in LRTP's. Drawing from the LRTPs for MPOs that correspond to the MSA's used to develop the TPI, the impact of the fiscally constrained investment scenario in the LRTP on the TPI indicators can be estimated. Based on these estimates the value of the TPI can be forecast assuming that the long range transportation plans are implemented. For a specific MPO, the steps are as follows:

a) Identify the long range transportation plan for the MPO corresponding to the MSA.
b) Identify the year that the LRTP was published and the forecast year.
c) Identify changes in indicators based on proposed projects.
d) Compute the change in indicator.
e) Assuming a linear change over time, compute the percentage change between 2011 (the most recent TPI) and 2035 (the most commonly used forecast year).
f) Repeat steps 3 to 6 for each indicator.
g) Compute the TPI.

Table 15. Do Nothing Scenario

Indicator	Description	Change 2011-2035
IND1	Highway Density	-21.2%
IND2	Transit Density	-21.2%
IND3	Airport Access	0.0%
IND4	Airport Capacity	0.0%
IND5	Rail Density	-21.2%
IND6	Waterway Density	-21.2%
IND7	Port Access	0.0%
IND8	Intermodal Freight Access	-21.2%
IND9	Highway Travel Time Reliability	27.0%
IND10	Highway Safety	0.0%
IND11	Road Roughness	27.0%
IND12	Highway Bridge Integrity	27.0%
IND13	Air Congestion	-21.2%
IND14	Air Safety	0.0%
IND15	Transit Safety	0.0%
IND16	Rail Safety	0.0%
IND17	Waterway Congestion	27.0%
IND18	Highway Reserve capacity	-21.2%
IND19	Air Reserve capacity	27.0%
IND20	Transit Reserve capacity	27.0%
IND21	Rail Reserve capacity	27.0%

The application of these steps to the Baltimore-Towson MSA illustrates the process. The MPO is the Baltimore Metropolitan Planning Council. The LRTP was published in 2011 for a forecast year of 2035. The plan is based on a visioning process called "Imagine 2060" (Baltimore Metropolitan Planning Council, 2011). The plan covers safety, preservation, accessibility, mobility, environment, security, economic and public participation goals. Data was identified to support the estimation of changes in highway density, transit density, travel time reliability, safety, road roughness, bridge integrity and highway reserve capacity – the relevant TPI indicators. For example, four new transit projects are described in the plan and the miles of transit are estimated as follows:

- Red line light rail transit (14 miles – 22.4 km)
- Green line extension from Johns Hopkins Hospital to North Avenue (1.5 miles – 2.4 km)
- Yellow line extension from Baltimore Washington International Airport to Dorsey Avenue and Anne Arundel County line to MD 32 (10 miles -16 km)
- Bus rapid transit from US 29 and Broke Land Parkway to MD 198 (7.3 miles – 11.7 km)

Assuming a 1% growth in population, Table 16 illustrates the calculation of the value of the transit density indicator used in the TPI for 2035. For indicators where no data are available (or where no change is indicated by the LRTP), the value is assumed to be that of the "Do Nothing" scenario.

Table 16. Computation of the Change in Transit Density (2011-2035)

Measure	2011	2035
Miles of Transit	3566.9 (5707 km)	3599.7 (5759.5 km)
Population	2,729, 110	3,465,000
IND2 (Transit Density)	13.07	10.39
% Change		-20.5%

Eight MSAs were selected for analysis to represent different parts of the country, using both small and large MSA's. The MPO covering the Los Angeles MSA also covers the Riverside MSA so the changes were applied to both Los Angeles and Riverside, giving a total of nine MSAs in this analysis. The nine MSAs and the calculated forecast changes from 2011 to 2035 in the relevant indicators are shown in Table 17. The changes in the other indicators (the shaded cells in Table 3) follow the "Do nothing" scenario using the percentage change shown in Table 1. The process outlined above is repeated for all MSAs and all indicators. MSA's not included are assumed to follow the "Do Nothing" scenario. The TPI is then computed for 2035.

The "All MPOs" scenario is an extrapolation of the "Selected MPOs" scenario. The nine MSAs represented in the "Selected MPOs" scenario account for 36.4% of US GDP based on their contribution to the US economy. The TPI for 2035 is computed as follows:

$$TPI_{2035\ \text{–All MPOs}} = TPI_{2035\ \text{–Selected MPOs}} + (TPI_{2035\ \text{–Selected MPOs}} - TPI_{2035\ \text{–Do Nothing}})/0.364$$

Impact on the TPI

Using the methodology outlined above, the forecast values for the TPI for the three scenarios are shown in
Table 18 and Figure 8. The results show that over a 24 year period (2011 to 2035) investing in the fiscally constrained plans presented in the LRTPs developed by MPOs can result in significant improvement in the TPI of approximately 19%. This change is of similar magnitude to the change from 1990 to 2011 – a period of significant investment in infrastructure improvement. It is also important to note that the "Select MPO" scenario is not a realistic scenario but is really an intermediate step to estimate the magnitude of the impacts.

Table 17. Changes in MPOs

MSA/ MPO	Altoona, PA (MSA)	Baltimore-Towson, MD (MSA)	Chicago-Naperville-Joliet, IL-IN-WI (MSA)	Denver-Aurora-Broomfield, CO (MSA)	Jefferson City, MO (MSA)	Los Angeles-Long Beach-Santa Ana, CA (MSA)	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD (MSA)	Riverside-San Bernardino-Ontario, CA (MSA)	Tucson, AZ (MSA)
Year Published	2011	2011	2010	2008	2008	2012	2012	2012	2010
Forecast Year	2035	2035	2040	2035	2030	2035	2035	2035	2040
IND1 Highway density	26.0%	-19.0%	6.7%	36.8%	31.9%	23.0%	-1.9%	23.0%	23.4%
IND2 Transit density		-20.8%	12.0%	18.2%		18.8%	-3.0%	18.8%	
IND5 Rail density							3.0%		
IND8 Intermodal access	20.0%			17.7%			8.0%		9.4%
IND9 Travel time		0.0%	0.0%	318.0%	0.0%	10.6%	-43.0%	10.6%	
IND10 Highway safety		0.0%	7.4%	3.1%					
IND11 Road roughness	0.0%	-1.0%	23.3%	-38.0%					-21.2%
IND12 Bridge integrity	9.1%	0.0%	12.1%	-45.0%					-33.6%
IND18 Highway capacity		13.0%							

Table 18. Forecast Results

Scenario	2011	2035	% Change
Do Nothing	57.26	42.36	-26.03%
Select MPOs	57.26	49.30	-13.92%
All MPOs	57.26	68.34	19.34%

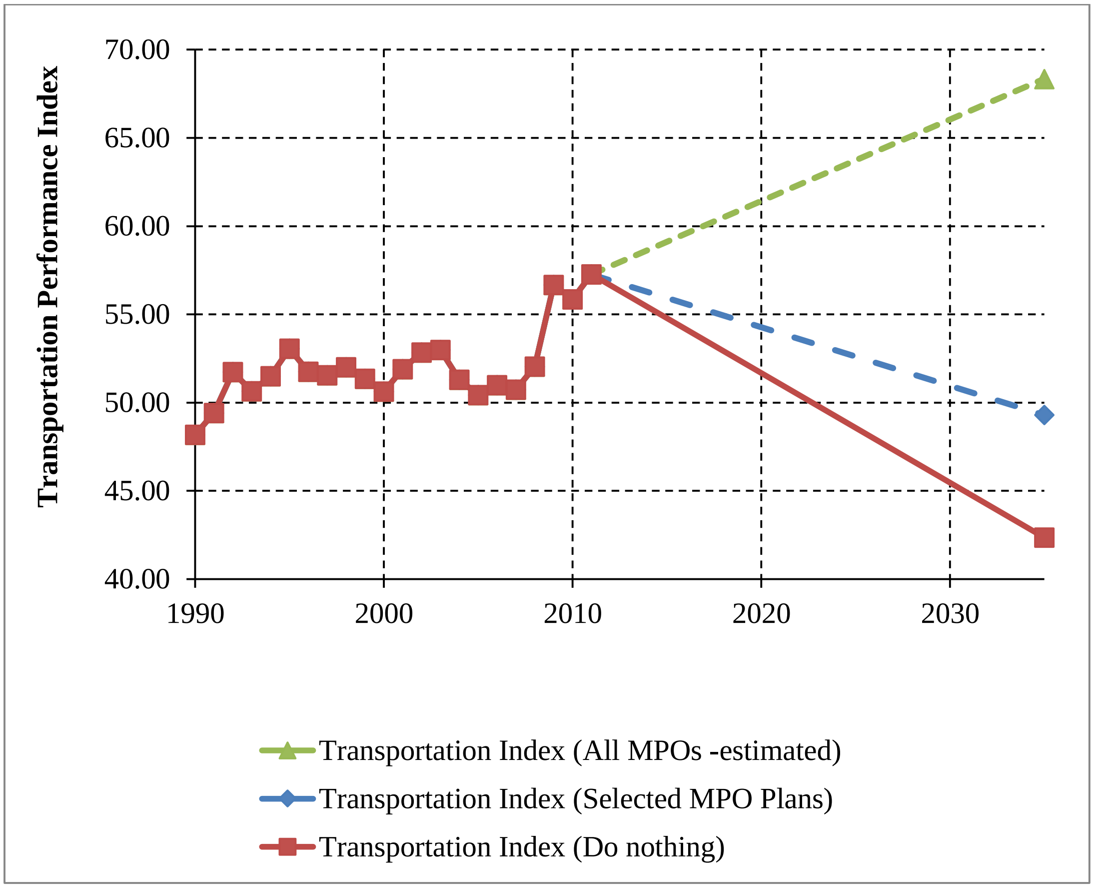

Figure 8. Forecast TPI

Observations

Although this analysis involves many assumptions and estimations, the results suggest that the TPI is capturing significant changes in transportation performance. Without investment, the TPI is shown to decline significantly. However, investing in the projects proposed in long range transportation plans shows a marked improvement in the TPI. As these investments reflect strategic investments, and regional priorities and needs, it is encouraging that these investments do in fact result in a significant change. Furthermore, the original intent of using indicators is not to present a comprehensive measure of the infrastructure improvements but to capture trends – this demonstration appears to confirm that the goal was achieved.

Further exploration of the LRTPs will be completed to test whether the estimated values are consistent with a comprehensive analysis. Sensitivity of the inputs should also be explored as well as the changes in high growth regions. Finally, the estimated cost to implement these changes should be determined based on the data in the LRTPs.

CONCLUSIONS

This research project explored alternative formulations for the Transportation Performance Index to help better understand the connection between infrastructure performance and economic growth, specifically recognizing the role of state of good repair and safety. Before developing the 2010 and 2011 estimates of the TPI we critically reviewed the data sources for the indicators and the methodology. Some minor changes in how we estimated the indicators were made. We also explored alternative indicator weights and indicator normalization strategies. Based on this analysis we concluded that our original data, methods and weights are robust and therefore would not be enhanced by changes at this time.

Modest improvements in the TPI over the last five years come from reductions in both vehicle miles of travel and ton miles of travel, and significant strategic investment focused on state of good repair, intermodal connectivity, mobility and accessibility. The case studies explored what this means for the future. For example, to achieve the significant improvement suggested by the TPI forecast, an almost 20% increase from 2011 to 2035, using data from LRTPs, a focus on all modes, and all aspects of transportation infrastructure performance is required.

Identifying both specific projects and policies to improve infrastructure performance is challenging. This is further evidenced by the generic nature of the key solutions proposed by ASCE that include (ASCE, 2012):

- Increase Federal Leadership in Infrastructure
- Promote Sustainability and Resilience
- Develop Federal, Regional, and State Infrastructure Plans
- Address Life-Cycle Costs and Ongoing Maintenance
- Increase and Improve Infrastructure Investment from All Stakeholders

Working with the data and information that are used to develop the TPI, the following portfolio of strategies for improving infrastructure performance was developed:

- Wise investments in all modes and connectivity between the modes
- Responsible stewardship of existing infrastructure
- Recognition of the life costs of infrastructure investment and the commitment to the cost of owning, using and operating infrastructure
- Innovative operating and maintenance practices
- Willingness to pay for a world class infrastructure.

Implementing any of these strategies also requires us to understand who is going to pay, when are we going to pay (assuming we do not want to transfer the cost to future generations), and what tradeoffs are we making (including environmental costs). These are clearly difficult decisions.

In summary, infrastructure investment can not only improve the economy but is necessary to support economic growth. These investments need to be both significant and strategic.

Another set of strategies focus on innovation to improve operations and the performance of our transportation infrastructure. Over the past three decades many innovative technologies, practices, materials and processes have been deployed to improve the performance of our transportation infrastructure. Examples include:

- ITS technology

    - Improved operations (response to non-recurring congestion, information to support distribution of recurring congestion over longer peak)
    - Improved passenger information for transit
    - Streamlined methods for paying for transportation such as EZ-Pass and SmartCards
- RFID technology to help speed up inventory/ delivery (Fedex and UPS has some great examples) – also container management
- Improved maintenance and renewal of existing infrastructure using asset management and preservation strategies.
- Improved vehicle technology to improve safety (ABS, airbags, stability control)
- Anti-icing
- Better pavement designs (last longer, needless repair)
- Transit check (paying for commuting costs in pre-tax dollars)
- Real time information to support 3rd party logistics companies make better decisions
- Positive train control
- Continuously welded rail/ advances in rolling/ grinding/ lubricating rail
- Retroreflective materials
- Alternative fuels
- Nighttime maintenance (reduces non-recurring congestion)
- Innovative repair strategies, and
- HOT lanes

Many of these innovations have played an important role in maintaining the overall performance of our transportation infrastructure. The challenge is to develop policies to support continued innovation and opportunities to systemically and comprehensively support actions to enhance infrastructure performance.

RECOMMENDATIONS

Publically available, specific and reliable data that captures infrastructure performance is critical to the assessment of infrastructure performance and the implementation of MAP-21. While data collection is often considered a burden on operating agencies the importance of the data for policy and decision making cannot be over-emphasized.

Specific recommendations for supporting improved infrastructure performance include:

1. Create incentives to increase innovations in configuration, operations, and intermodal connections.
2. Create a coherent national transportation policy that recognizes tradeoffs between modes and performance measures.
3. Link funding to performance
4. Support more research to generate innovation and new ideas
5. Streamline the project delivery process

Our primary policy recommendation boils down to “Don’t blindly fund every project – strategically think about what makes sense.” McKinsey Global Institute (2013), for example, is suggesting three things to do to make infrastructure more productive: “selecting projects more carefully, delivering them more efficiently, and getting more out of existing assets as an alternative to building new ones.” Similarly, a key policy is the implementation of MAP-21. MAP-21 focuses on performance measures and the implementation of asset management to support strategic decisions. It is anticipated that rules for implementation will be available for comment during the summer of 2013. The proposed rules are expected to make the connections between transportation infrastructure performance and decision making that will support the provision and maintenance of effective and efficient transportation infrastructure.

Our past analyses and reports (US Chamber of Commerce 2010 and US Chamber of Commerce 2011) have also emphasized the importance of a holistic and strategic approach to improving and maintaining transportation infrastructure performance that includes:

- Operational improvements,
- Additional capacity to respond to growth,
- Enhanced network connectivity between facilities and across modes to recognize the interdependencies, the importance of redundancy and the complexity of transportation networks, and
- Renewal, maintenance and stewardship of existing infrastructure to ensure a state of good repair.

REFERENCES

American Society of Civil Engineers (2011). "Failure to Act: The Economic Impact of Current Investment Trends in Surface Transportation Infrastructure."

American Society of Civil Engineers (ASCE) (2012). Solutions. http://www.infrastructurereportcard.org/solutions (Accessed on October 27, 2012).

American Society of Civil Engineers (ASCE) (2010). American Society of Civil Engineers' (ASCE) Report Card. http://www.infrastructurereportcard.org/. (Accessed on June 28, 2011).

Baltimore Metropolitan Council (2011). "Plan It 2035", http://www.baltometro.org/plans/plan-it-2035 (Oct. 5, 2013).

Ben-Akiva, M., F. Humplick, S. Madanat, and R. Ramaswamy. (1993). "Infrastructure Management under Uncertainty: Latent Performance Approach," Journal of Transportation Engineering, 119 (1): 43-58.

Bossel, H. (1999). Indicators for Sustainable Development: Theory, Method, Applications. International Institute for Sustainable Development, Winnipeg.

Bureau of Economic Analysis (BEA). (2006). Gross domestic Product by State Estimation Methodology. U.S. Dept. of Commerce. http://www.bea.gov/regional/pdf/gsp/GDPState.pdf. (Accessed on February 12, 2010).

Bureau of Transportation Statistics (2013). Multimodal Indicators 2013, RITA.

Committee on Measuring and Improving Infrastructure Performance (1995). "Measuring and Improving Infrastructure Performance," National Academy Press, Washington DC.

Economic Development Research Group, Inc (2011). Highway Economic Impact Case Study Database and Analysis Findings, SHRP2 Project C03 Interactions between Transportation Capacity, Economic Systems and Land Use: Final Report http://www.edrgroup.com/pdf/SHRPC03FinalReport.pdf. (Accessed October 24, 2012).

Federal Highway Administration (FHWA) (2013a). Highway Construction Cost Increases and Competition Issues. http://www.fhwa.dot.gov/programadmin/contracts/price.cfm (Accessed on May 21, 2013).

Federal Highway Administration (FHWA) (2013b). HPMS Academic Workshop, Presentation Materials, Arlington Virginia, August.

Federal Highway Administration (FHWA) (2013c). MAP-21 Fact Sheet, Performance Management, http://www.fhwa.dot.gov/map21/pm.cfm Accessed August 19, 2013.

Federal Highway Administration and Federal Transit Administration. (2007). "The Transportation Planning Process: Key Issues, A Briefing Book for Transportation Decisionmakers, Officials, and Staff," FHWA-HEP-07-039.

Hartgen, D., M.G. Fields, and E. San José (2013). Are Highways Crumbling? State and U.S. Highway Performance Trends, 1989–2008, Reason Foundation Policy Study 407.

Lakshmanan, T.R. (2011). The broader economic consequences of transport infrastructure investments. Transport Geography, 19, 1-12.

Li, Q., S. McNeil, T.K. Foulke, J. Calhoun, M. Oswald, E. Kreh, M. Gallis and S. Trimbath (2011). "Capturing Transportation Infrastructure Performance: Data Availability, Needs and Challenges", Transportation Research Record No 2256, pp191-201.

Li, Q., S. McNeil, T.K. Foulke, J. Calhoun, M. Oswald, E. Kreh, M. Gallis and S. Trimbath (2011). Capturing Transportation Infrastructure Performance: Data Availability, Needs and Challenges. Transportation Research Record 2256, 191-201.

McKinsey Global Institute and McKinsey Infrastructure Practice (2013). *Infrastructure Productivity: How to Save $1 Trillion a Year*.

McNeil, S., S. Trimbath and F. Atique (2013a). "TPI Update 2013: Data for 2010, 2011." Discussion Draft submitted to the US Chamber of Commerce, July.

McNeil, S., S. Trimbath and F. Atique (2013b)."State by State TPI UPDATE 2013: Data for 2010, 2011." Discussion Draft submitted to the US Chamber of Commerce, September.

McNeil, S. and M. London (2013). "Capturing Changes in Investment, Demand and Policy Using the Transportation Performance Index," Proceedings of 13th WCTR, July 15-18, 2013 – Rio de Janeiro, Brazil.

McNeil, S., F. Atique, R. Burke, H. Yin, Y. Adu-Gyamfi and S. Trimbath (2014a)."Updating the Transportation Performance Index: Technical Report," US Chamber of Commerce, Washington DC.

McNeil, S., F. Atique, R. Burke and S. Trimbath (2014b)."Using the Transportation Performance Index to Understand the Impact of Regional Plans," Proceedings of the American Society of Civil Engineering Transportation and Development Institute Congress, Orlando Florida, June.

Office of Management and Budget (2010). Historical Tables Budget of the U. S. Government, Fiscal Year 2011. http://www.gpoaccess.gov/usbudget/fy11/pdf/hist.pdf. (Accessed on June 28, 2010).

Oswald, M., Q. Li, S. McNeil and S. Trimbath (2011). Measuring Infrastructure Performance: Development of a National Infrastructure Index, Public Works Management and Policy, Vol. 16, No. 4.

Oswald, M. and S. McNeil. (2010). "Rating Sustainability: Transportation Investments in Urban Corridors as a Case Study," Journal of Urban Planning and Development.

Oswald, M., Q. Li, S. McNeil, and S. Trimbath (2011). Measuring Infrastructure Performance: Development of a National Infrastructure Index, Public Works Management and Policy, Vol. 16, No. 4.

Ramaswamy, R. and M. Ben-Akiva (1993). "An Approach for Predicting Latent Infrastructure Facility Deterioration," Transportation Science, 27 (2): 174.

Saaty, T. Decision Making for Leaders, RWS Publications, 2008.

Shatz, H. J., K.E. Kitchens, S. Rosenbloom, and M. Wachs (2011). Highway Infrastructure and the Economy: Implications for Federal Policy, Rand Corporation, Santa Monica, DC.

The World Bank Group (2013). *Population Growth (annual %).* http://data.worldbank.org/indicator/SP.POP.GROW. (Accessed on March 20, 2013)

Trimbath, S. (2010). The Economic Importance of Transportation Infrastructure, STP Advisors Working Paper STP2010_01.

US Chamber of Commerce (2010). Transportation Performance Index: Complete Technical Report, Washington, D.C. http://www.uschamber.com/sites/default/files/lra/files/LRA_Transp_Index_Technical_Report_100919.pdf > (Mar. 29, 2013)

US Chamber of Commerce (2011). Transportation Performance Index: 2011 Supplement, Report to U.S. Chamber of Commerce, and Chamber Foundation. http://www.uschamber.com/sites/default/files/TPI_2011%20Update%20Technical%20Report.pdf >(Oct 5, 2013)