Developing an Infrastructure Index – Phase I

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Overview

Over the past decade the American Society of Civil Engineers has used the Infrastructure Report Card to raise awareness of infrastructure issues. Aging and deteriorating infrastructure has recently been highlighted in the popular media. However, this is not enough. The US is losing its competitive capacity as the gap between an ageing and deteriorating American infrastructure and that being developed around the world in developed and emerging economies and trading blocs is growing.

To be able to build the private and public support for the investments needed to provide a world class infrastructure that supports the economic competitiveness of the US, and restores the US to a position of technological leadership, a clear concise, consistent mechanism for communicating the state and implications of our underinvestment and support future investments. Recognizing these issues, the U.S. Chamber of Commerce, as part of the "Let's Rebuild America" initiative, invited Michael Gallis & Associates to assemble a team to develop an infrastructure index to benchmark US infrastructure. The University Transportation Center at University of Delaware, STP Advisors and Global Systems Solutions are key players in that team.

The first phase of the work focused concepts for sector specific infrastructure indices for transportation, energy, water and broadband, exploring strategies to combining the sector specific indices into a composite infrastructure index, identifying possible sources of data and developing a prototype index for transportation.

The following report *Let's Rebuild America: Infrastructure Index-Initiation Phase Report* was developed by the research team to document the research conducted. The team includes:

- U.S. Chamber of Commerce Team.
  - Janet Kavinoky, Director of Transportation Infrastructure, and
  - Murphie Barrett, Manager of Let's Rebuild America
- Consulting Team
  - Michael Gallis & Associates
    - Michael Gallis (team leader)
    - Erik Kreh and
    - Zach Petersen
  - University of Delaware
    - Sue McNeil
    - Qiang Li
    - Michelle Oswald and
    - Laura Black.
  - Massachusetts Institute of Technology
    - Michael Flaxman
  - STP Advisory Services
    - Susanne Trimbath
  - Global Systems Solutions
    - Tom Skancke

INITIATION STAGE

Measuring and Benchmarking Infrastructure Performance

INFRASTRUCTURE **INDEX**

LET'S REBUILD

AMERICA

US Chamber of Commerce

April 6, 2010

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EXECUTIVE SUMMARY

Improving the condition and performance of U.S. infrastructure is the foundation for national competitiveness in a global age. Yet, business has found it necessary to enter into a debate with policy makers about the role of infrastructure in economic prosperity. As a result, the U.S. Chamber of Commerce saw the need for a new tool to effectively communicate these ideas. At their request, the project team set out to create an Infrastructure Index. The Index includes measures of the performance of infrastructure as it meets the needs of productive businesses working toward economic prosperity. Once completed, the Infrastructure Index can be used to measure the effect of infrastructure on the U.S. economy by relating changes in the Index to changes in U.S. economic performance.

The Initiation Stage of the project, presented in this report, lays the foundation for finishing the Index by focusing on developing and testing the concepts and procedures. Additional work is needed to bring this project to its full potential. So far, we have developed a sound methodology for defining and realizing the concepts. The important results are these:

- We defined infrastructure specifically as the underlying structures, that is, the permanent installations that encompass the four components of infrastructure: transportation, broadband, water and energy.
- We defined performance as "the degree to which the infrastructure system serves U.S. economic and multi-level business community objectives."
- We measured performance as meeting the broad criteria of quality, efficiency, utility and supply.
- We identified multiple indicators with realistically measurable data for those criteria.
- We tested this process on a limited data set for a Transportation Index by
    - identifying the sample geographies,
    - creating a set of categories unique to transportation infrastructure,
    - identifying a set of indicators of transportation infrastructure performance to meet the criteria, and
    - gathering data for a list of measures to fulfill the indicators.
- We now have a methodology in place to ensure that our "sample" is representative of the United States as a whole – by geography, population and contribution to the economy.
- Our Index will be generated from publicly available data – a completely transparent process that can be examined by any interested party and used

to benchmark and measure the improvement or decline of the performance of U.S. infrastructure over time.

In the process of achieving these initial results, we identified some significant barriers and found ways to overcome them. Here are a few:

- There is a general lack of the type of data that we need, particularly data measuring performance instead of condition. For example, no one has collected or could report the data on the number of gates at airports or the acreage at ports. For our analysis, we called every airport and port in the sample cities to get measurements of capacity.
- Few experts in infrastructure are focused on the performance of existing systems; they are more likely to be engaged in research toward building new systems. We plan to use a series of one-day workshops to engage the widest possible range of expertise in the next stage of the project.
- The definitions of infrastructure used by many experts are amorphous. Our written definitions of infrastructure and performance became the guiding light for every step in the process.
- The performance data is often tracked on widely different scales. We developed a process to normalize and standardize all the data used in the index calculations.
- The importance of one criterion for performance can vary from user to user, such as the importance of freight transportation over commuter trains, making it difficult to combine into one index. We are incorporating hierarchical comparisons from surveys of experts and users at several points in the methodology.
- The indicators for measuring the performance of infrastructure in an area with ports will be different than one without ports. We categorized the sample areas by size and the presence of airports and ports to account for these differences while retaining a representative sample of the United States.
- The size of the metropolitan area may influence the relative importance of some indicators. We devised a way to weight these indicators by types of geographic areas based on population and economic contribution.

The final Infrastructure Index will be able to recognize the interconnections among the different infrastructure networks for a balanced presentation of all components. In the next stage of the project, slated for completion in early 2011, the project team will break down the Index into state-by-state measurements, index the performance of the individual components of infrastructure, and extrapolate the Infrastructure Index into the future.

Once the Infrastructure Index is assembled and tested, we can conduct an economic analysis to demonstrate its usefulness for exploring the contribution of infrastructure to keeping American businesses competitive. The Index – and the economic analysis – can be updated on a regular basis to track the progress toward infrastructure that meets the needs of our dynamic economy.

The design of the Infrastructure Index avoids many of the theoretical and methodological problems encountered by both academic researchers and policy makers in the past. Study after study points to the need for a tool for measuring the importance of infrastructure to the economy. We believe that the Infrastructure Index is that missing tool.

PROJECT TEAM

The project team developing the Infrastructure Index is composed of staff and committees from the U.S. Chamber of Commerce and the consulting team led by Michael Gallis & Associates.

U.S. Chamber of Commerce Team

The Infrastructure Index project is a component of the *Let's Rebuild America Initiative* which was conceived and directed by Tom Donohue, President and CEO of the U.S. Chamber of Commerce (USCC). The USCC Infrastructure Committee was involved in reviewing and guiding the development of the Index. Janet Kavinoky, Director of Transportation Infrastructure, and Murphie Barrett, Manager of *Let's Rebuild America*, directed the project team.

Consulting Team

The consulting team is led by Michael Gallis of Michael Gallis & Associates with Erik Kreh and Zach Petersen.

Professor Sue McNeil, director of the University Transportation Center and professor of Civil Engineering in the Department of Civil and Environmental Engineering at the University of Delaware leads the research team assembling the information and creating the models. The team members are post-doctoral researcher Dr. Qiang Li, and graduate students Michelle Oswald and Laura Black.

Professor Michael Flaxman, associate professor of planning at MIT, coordinated an initial team of area experts from the faculty at MIT and Harvard to provide input and commentary on the development of the Index indicators.

Dr. Susanne Trimbath, Chief Economist at STP Advisory Services and former Milken Institute Senior Research Economist, worked closely with Professor McNeil and the research team on the methodology and especially the sampling strategy. She will provide an economic analysis using the Infrastructure Index.

Tom Skancke of Global Systems Solutions coordinated strategy and communications.

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GLOSSARY

Analytic Hierarchy Process (AHP) – a structured multi-attribute decision-making technique that can be used to weight indicators or indices

Categories – the functional sub-divisions within each component of infrastructure. For example, the categories for transportation infrastructure are all the modes of both freight and passenger movement, including air, water, rail, and roads. The categories will vary for each component.

Component – one of the four elements of infrastructure covered in the project, i.e., broadband, energy, water and transportation.

Component Index – an index, based on criteria, assembled indicators, and measures, designed to capture the performance of one of the four components of infrastructure.

Connectivity – topological property of a network representing how geographical features are attached to one another functionally, spatially or logically (University of Colorado, 2009)

Criteria – broad classes of infrastructure performance (supply, efficiency, quality of service, and utilization)

Gross domestic product (GDP) – the market value of goods and services produced by labor and property in the United States, regardless of nationality. The GDP-by-industry accounts are used for this analysis, which are a set of accounts that present the contribution of each private industry and government to the nation's GDP. An industry's contribution is measured by its value added, which is equal to its gross output minus its intermediate purchases from domestic industries or from foreign sources. The GDP-by-industry accounts are consistent with the annual input-output (I-O) accounts, which we also use. The I-O accounts are a set of tables, consistent with the GDP-by-industry accounts, which shows the relationships between all the industries in the economy and all the commodities that these industries produce and use.

Gross metropolitan product (GMP) – the market value of goods and services produced by labor and property in a Metropolitan Statistical Area (MSA).

Indicator – a specific measure that can be used to quantify infrastructure performance

Infrastructure Index – a composite measure of performance based on the integration of the four Component Indices

Metropolitan Statistical Area (MSA) – a potential sample geographical area for which both infrastructure performance measures and economic data are available. An MSA contains a core urban area of 50,000 or more population (Center for Business and Economic Research, 2009; Office of Management and Budget, 2008). For our purposes, the term "Large MSA" is used for those urban areas with population greater than 1 million and "Other MSA" for those with populations greater than 50,000 but less than 1 million.

Performance – a combination of supply, efficiency, quality of service and utilization specifically measuring the degree to which the infrastructure system serves U.S. economic and multi-level business community objectives.

THE ROLE OF INFRASTRUCTURE IN ECONOMIC PROSPERITY

Purpose

Policy makers and academics continue to profess that "nothing matters" when it comes to infrastructure and economic growth (starting with Levine and Renault 1992, based on Summers and Heston 1988). However, business behavior proves that infrastructure matters a great deal. Firms choose to locate where infrastructure is better. They leave areas where infrastructure is missing or deteriorated. U.S. firms look for good infrastructure when they consider placing offices overseas (Mataloni 2008), and foreign firms must do the same when they consider locating here. The idea that good infrastructure would enable economic specialization and lower costs – making U.S. businesses more efficient and more competitive – is again reflected in the way that businesses behave.

The purpose of this project is to create an Infrastructure Index that will be useful for exploring the contribution infrastructure makes in keeping American businesses competitive in an increasingly global economy. Emerging market countries remain economically competitive, and are constantly building and rebuilding their infrastructure as their economies develop. To illustrate the impact improving infrastructure has on those developing economies, an international study found that the labor pool expands by 15 percent for every 10 percent improvement in travel speeds, which improves productivity by three percent (Banister and Berechman, 2000, cited in Cevero 2006).

While data is still being collected on the impact improving infrastructure is having on countries around the world, it is becoming clear that deteriorating infrastructure in the United States may actually be contributing to increased costs (and decreased efficiency) for American businesses (Cambridge Systematics, 2008).

The differentiation of U.S. cities based on climate and geography, as well as public policies (taxes, regulation, public spending on capital improvements, institutions, etc.), highlights the critical need for the development of a national index capable of measuring how the U.S. competes not just among MSAs or states or even regions, but with the world.

The factors that differentiate infrastructure across geographic areas will be among those under review when the Infrastructure Index is broken down to state-by-state measurements. The challenge, however, is that because the four Component Indices of infrastructure under review – transportation, energy, broadband and water – are not necessarily geographically contained, and instead are interconnected through multiple states or regions, it will be virtually impossible to break down the results of the economic analysis by state. For example, the Transportation Index would rate the urban rail line that brings workers from the suburbs to jobs in the center of Chicago as highly as the freight railway that ferries goods from Denver to the ports of Los Angeles for export. Therefore, because the Infrastructure Index measures the performance of the national infrastructure, the economic analysis will encompass a national scope.

What is innovative about the project team's approach is that it includes an unprecedented measure of the *performance* of infrastructure, and not just the size and cost of infrastructure.

Background

Prior research on infrastructure and its connection to the economy has achieved mixed results. Development of the analytical framework began thirty years ago with studies of government spending on public capital infrastructure projects (the stock or flow of investment money) to analyze the impact on economic growth and productivity as well as on social welfare (reducing income inequality).

Before the mid-1990s, infrastructure research was conducted separately from studies on economic growth (Holtz-Eakin and Schwartz, 1995). In the early 1990s, the basic model was extended to specifically endogenize economic growth and to include private spending on infrastructure. Starting around 1990-1995, empirical modeling with data appeared as academic and policy researchers contributed both theoretical and empirical studies on the contribution of infrastructure development to growth and productivity (Calderón and Servén, 2008a).

Most of the policy work (e.g., Henderson, Shalizi, and Venables, 2000; Gausch and Kogan 2001) is based on examinations of countries where development may have been delayed by the lack of infrastructure. These studies compared countries to each other, usually including some selection of developed countries, implying that good infrastructure has a positive effect on the economy. Generally, that kind of research makes use of comparative cross-regional perspectives in an international context, and the findings measure the contribution of infrastructure to the level and growth of aggregate output and productivity. World Bank economists Calderón and Servén (2008a) offer the best published account of the literature on the growth and inequality effects of infrastructure.

In the last 20 years, literally hundreds of research papers have been published devoted to assessing the effects of infrastructure on growth, productivity, poverty and development, etc. The variety of data and empirical methodologies is nearly as great as the number of measurements. While there are almost as many ways to measure "economy" (e.g., income, output, productivity, growth, etc.), this discussion's focus will be on the differences in the way that "infrastructure" is treated and in the methodologies applied in the analyses.

Challenges with Measurement

As we began our research, we discovered that past global and national studies on infrastructure and the economy reported contradictory findings because they measured "Infrastructure" as "Spending" (Straub 2007). This approach is flawed for several reasons.

First, not all money designated for infrastructure is spent the same way for a variety of reasons, from government inefficiencies and political corruption to purchasing power and the size of the economy, so inconsistency in quantity and quality of infrastructure based on money spent makes measurement difficult. Differences in the efficiency of spending on infrastructure explain one-quarter of the growth differential between Africa and East Asia, and more than 40 percent of the growth differential between low- and high-growth countries (Calderón and Servén, 2008a). Another study from Sanchez-Robles (1998) finds no relationship between infrastructure development and the economy when using spending to measure infrastructure. However, when an index is built based on physical infrastructure, the results are not surprising – economies grow with infrastructure development.

Measuring infrastructure in terms of spending has also resulted in "bi-directional results," where infrastructure affects growth and growth affects infrastructure. In other words, that a growing economy can afford more infrastructure is just as likely a cause of positive statistical results as the possibility that more infrastructure helps the economy grow. Further, where spending is used to measure infrastructure, the model usually considers only public spending, ignoring the contribution of investments from private companies (e.g., the contribution of private satellites to communications infrastructure). Calderón and Servén (2008a) report that less than half of the empirical studies using expenditure-based infrastructure measures find that developing or maintaining infrastructure has significant positive effects on the economy. In contrast, over three-fourths of the studies using physical indicators find a significant positive contribution from infrastructure to the economy.

Note, however, that even in studies where physical measures were used, most included only one or two indicators. This was done of necessity in studies that included developing nations, where more data is not available. For example, Estache, Speciale and Veredas (2005, cited in Calderón and Servén 2008a) present pooled linear growth regressions based on an augmented Solow model including a variety of infrastructure indicators, one at a time. Their main conclusion is that roads, power and telecommunications infrastructure – but not water and sanitation – contribute significantly to long-run growth in Africa.

Other studies are arriving at the same results: the relationship between infrastructure and its impact on the economy is buried in the dollars with a model that uses spending to measure infrastructure, but that relationship becomes clear using multiple indicators based on physical measures. Calderón and Servén (2008b, unpublished, discussed and cited in Calderón and Servén, 2008a) found significantly positive effects "using a synthetic indicator of infrastructure quality." (Their index used only one measure of quantity and quality for each of three infrastructure components: broadband, energy and transportation.)

Methodological challenges

- **Social Welfare Goals:**
  Economic studies of growth by and large were initiated in search of answers to the questions: why are some countries poor while others are rich? And what do poor countries need to do to become rich? This latter question is addressed in research studies on "convergence." Existing research seeks convergence to a steady state of income equality – and so neglects the efficiency impacts, for example, which could improve global competitiveness. International studies look for a "social welfare" impact without differentiating the behavior and contribution of households from that of businesses.
- **Country Comparisons (including state versus state in the U.S.):**
  Money is often invested locally but policy is set nationally, making "convergence" unlikely in the horserace setting of existing empirical studies of the United States. Prior research may attribute the impact of local policies to infrastructure; for example, flexible parking and mortgage-qualification standards for housing near new rail investments in some states.
- **Upward Simultaneity Bias:**
  If it is true that rich countries spend more on infrastructure and get richer while poor countries spend less and stay poor, then upward bias may affect the results of time-series studies using production-function models (Straub, 2007). This problem is relevant in country comparisons and where infrastructure is measured by supply (size) and not performance.

Toward a Better Implementation

Our economic study will take, as given, the accuracy of the Infrastructure Index and its appropriateness to the analysis. There is no dispute that economic growth is necessary as long as there is an increasing population. We seek to address the question: is it possible for the economy to "hit a wall" because it runs out of usable infrastructure? In other words, the question is not if infrastructure helps the economy but rather can a lack of infrastructure impede the economy? Can the economy outgrow its infrastructure?

The specific improvements

- Existing research seeks convergence to a steady state of income equality and so neglects the efficiency impacts that could improve U.S. global competitiveness. Our goal is to provide a better understanding of why business cares about infrastructure. In the process, we will move this topic outside discussions solely focused on government spending and social policy. When we go to the data, we intend to "take the theory seriously" (Sala-i-Martin, 2002).

- We will not measure infrastructure as money spent, but by the actual content of the infrastructure: does it fulfill the purpose for which it was created? Since no other comprehensive index of infrastructure performance is available, the few prior studies that used one have created and implemented an index within their study. Sanchez Robles (1998) is one of the few published examples we found that used an index to measure infrastructure. She used a principal components methodology with a weighted sum of standardized variables. Because the index is very data rich, the economic model is a simple linear regression, taking advantage of the depth of the data included in the index. Our analysis will use some similar technologies.
- Most research that attempted to improve on earlier studies sought to disaggregate the data from the country level to the regional or state level. This was often done to overcome the problems described earlier where policy and implementation are at different levels. In a national study, this would only have an impact if the policy is so widespread as to be universally adopted across the United States. We believe that the aggregate level removes many of the problems that come about with regional comparisons. For example, Gale (1997) reports survey evidence that the rural-urban technology gap is eliminated in data after accounting for differences in the industry mix. A national study would not be affected by geographic gaps.

Time series approach

As the economy changes, so will the demands for infrastructure. By including the four Component Indices – transportation, energy, water and broadband – in the Index, we anticipate being able to have a consistent measure that can remain relevant across decades, even as the role of one industry may change within the economy. For example, while it is obvious that information-workers, such as computer programmers and software developers who increasingly work from remote locations, require access to broadband infrastructure, they also alter the way that transportation infrastructure is used. Knowledge-based activities which rely on spatial agglomeration place greater importance on rail/subway and less importance on roads (Cervero, 2006). Yet, that does not mean that a knowledge-based economy will need fewer roads – someone has to service those computers and that technician will likely travel to its customers on roads. Pure time-series models can suffer unless the researcher can establish "the existence of a single long-run relation" that "can be interpreted as 'the output equation'" (Calderón and Servén, 2008a). We rely on the specification and construction of the Infrastructure Index to provide the solution to measure the ability of infrastructure to meet the performance demands of productive businesses.

Our plan

Multiple infrastructure components represented by multiple performance indicators will be included for the first time in one economic study of the United States. The Infrastructure Index will measure performance defined as "the degree to which the infrastructure system serves U.S. economic and multi-level business community objectives." Our economic analysis can consider productivity, growth, efficiency effects, etc. from a business perspective, and does not set a limit on economic prosperity because it does not include a pre-conceived notion of "convergence," nor rely on analytics that do not accommodate competitive business models. The Infrastructure Index and the economic analysis can be updated regularly to take into consideration changes in the composition of the U.S. economy.

The specifications

We will rely in Sala-i-Martin (1996, 1997a, 1997b, 2002) for the specification of a pure time-series model following cointegration methods to estimate a long-run relation between infrastructure and the economy. The general form of the model is:

> Economic Prosperity = f (Infrastructure | size of economy, government policy, population health)

The Infrastructure Index will be used to measure "Infrastructure." If we were to include all of the performance indicators that are combined in the Index in our model, that data would likely overwhelm any evidence provided by the economic data. An Infrastructure Index in this setting might function much as the imposition of distribution restrictions on the underlying variables, a scenario that can easily be tested in statistics (Calderón and Servén 2008a). Likewise, we avoid problems of applying very general functions to a large number of measures by using the Infrastructure Index instead of the hundred or so underlying indicators (Moreno et. al., 2002).

The key determinants of economic growth, based on nearly twenty years of empirical analysis (Sala-i-Martin 2002), are 1) the initial level of the economy; 2) the "quality of government;" 3) health (but not "human capital"); 4) free market institutions; and 5) open economies. In our case, we are concerned only with the first three. Free market institutions are widely available in the U.S. In addition to being a globally open economy, advances like the Uniform Commercial Code have made U.S. markets open across state borders for decades. The other factors need to be accounted for since they may change across time in our study. Policy variables, in particular, are consistently found to matter in economic growth studies: "a government in disarray affects the nation's growth performance adversely" (Sala-i-Martin 1994). Examples of variables that could proxy for government policy include inflation, budget deficits and regulatory interference.

Key statistical problems encountered in similar economic studies of growth include heterogeneity, identification and measurement. Since we have only one unit under study (the United States), we are less concerned with heterogeneity. The cointegration method provides for the use of lead and lag variables. Common time effects can be managed by using period dummy variables, and "omitted variable" problems are avoided by using the new Infrastructure Index which includes multi-dimensional indicators for multi-component infrastructure.

Identification (or two-way causality) has been an issue in earlier studies that relied on measuring infrastructure based on spending – spending that is usually included in measures of the economy. Here, we will measure infrastructure performance independent of the public or private investment dollars. Calderón and Servén (2008a) employed demographic variables as instruments to address the issue of identification. The Infrastructure Index (described in this report) already accounts for population in the sample selection.

Measurement problems in the past also have resulted from the use of only one or two indicators (most often telephone density) and then usually only on one or two components of infrastructure (e.g., energy and roads but not water; similarly water and sewage but not storm runoff). In our case, we have a multitude of indicators entering the analysis by way of the Infrastructure Index. This measure of infrastructure is determined independent of the economic analysis.

Finally, we find no reason to think that endogeneity is a problem in this analysis. Economic production is just as likely to use up or deteriorate infrastructure performance as it is to induce the creation of and improvement in infrastructure.

Prior statistical studies have sought to measure the impact of the development of infrastructure (Ayogu, 2007), but ignore the question of whether or not better performing infrastructure aids the economy, because those studies were focused on developing infrastructure as a way out of poverty. Instead, we assume the existence of infrastructure and go on to measure whether its performance serves the needs of the business community.

Conclusion

We recognize that our analysis will not be the last word on the relationship between infrastructure and the economy. The purpose of the economic analysis in this project will be to demonstrate the usefulness of the Infrastructure Index for exploring the contribution of infrastructure to keeping American businesses competitive in an increasingly global economy. (For an example of a similar demonstration using another index, see Gelos and Wei, 2002.)

The Infrastructure Index is designed to accommodate the changing and diverse patterns of an economy as dynamic as that in the United States. We anticipate that the development of the Infrastructure Index will move the discussion away from the "one-size-fits-all" approach being taken on infrastructure development toward better integration with the economic activity that uses it. Infrastructure has the power to influence the spatial distribution of economic activity as well as to lead to sectoral restructuring (Moreno et. al., 2002). In our study, we will be looking to define the relationship between infrastructure and the economy, not just to measure it.

While our emphasis in this stage of the project has been on working with the Infrastructure Index for our economic analysis, it may be possible to break out the relationship of the economy to the Component Indices as well. There are two complications to overcome. The first is that businesses make tradeoffs and substitutions among certain elements of infrastructure. A simple example is when they use video conferencing in place of face-to-face meetings – in this case, they are using broadband infrastructure as a substitute for transportation. That problem results in the necessity of requiring a more complex methodology, for example, involving simultaneous equations (where one economic model is set up for each of the Component Indices and then all four models are solved as one problem). It is impossible within the scope of this project to sort out all the potential tradeoffs. Still, we anticipate being able to identify some of the relationships of the individual infrastructure components without having to account for every unmeasured substitution. The problem will be addressed in more detail during the Project Development Stage (detailed in the Next Steps chapter).

INFRASTRUCTURE INDEX PROJECT OVERVIEW

The U.S. Chamber of Commerce created the *Let's Rebuild America* initiative to focus on improving the condition and performance of U.S. infrastructure as a foundation for national competitiveness in a global age. They recognized the need for a new tool to effectively communicate the importance of this initiative to leaders in business, government and institutions, as well as the general public. At their request, the project team set out to create an Infrastructure Index. To measure the full range of effects on U.S. competitiveness, the Infrastructure Index was designed to include transportation, energy, broadband, and water infrastructures. Creating the Infrastructure Index requires developing an index for each of the component infrastructures. The Infrastructure Index will be generated by integrating the four Component Indices into a composite that reflects the overall performance of U.S. infrastructure. Once completed, the effect of the health of infrastructure on the U.S. economy could be measured by correlating changes in the Infrastructure Index with changes in U.S. economic performance.

A Two-Stage Process

Due to the complexity of the process necessary to create the Infrastructure Index, the process has two distinct stages. The Project Initiation Stage (presented in this report) is a foundational step focused on developing and testing the methodology for creating an index to measure the performance of U.S. infrastructure. During this stage, a model of the Transportation Index was created and used as a test to determine if the methodology was sound and would result in a meaningful measure of infrastructure performance. A conceptual model of each of the other three Component Indices (water, broadband and energy) was also created. The methodology for combining and integrating them into a single Infrastructure Index was designed as a functional model. During the Project Initiation Stage, an outline of the economic modeling methodology was created to demonstrate the feasibility of statistically relating the Index to U.S. economic performance.

Based on the findings and conclusions reached in the Project Initiation Stage, a second Project Development Stage (described in the "Next Steps" chapter) will be launched to complete the Infrastructure Index. This will encompass the additional work needed to finish the Transportation Index; the completion of the other three Component Indices for broadband, water and energy; the creation of the Infrastructure Index; and the completion of the economic analysis relating the Infrastructure Index to U.S. economic performance.

Technical Foundation

As the Infrastructure Index is intended to provide an objective measure of the performance of U.S. infrastructure, creating and generating the Transportation Index was the first step to ensure that the methodology can measure performance and will be applicable to each of the other three Component Indices and the Infrastructure Index. In the Project Initiation Stage, a methodology was constructed and each of the steps tested to determine if there were insurmountable barriers in any step that would prevent the construction of the Transportation Index or any of the other three Component Indices, or prohibit the final step of integrating the four to create the Infrastructure Index. The methodology was built on the requirement that the indices use publicly available data.

There are seven technical steps necessary to create the Component Indices that are the foundation for generating the Infrastructure Index.

1. Create Definitions

The first step in the process is to create an operational definition for each of the four components of infrastructure (transportation, broadband, water and energy). A summary definition and a technical definition were developed for each of the four components. The summary definition is used for communications purposes and the technical definition is used as a framework to guide our researchers in developing each Component Index.

We also were careful to define exactly what we plan to measure about infrastructure: performance. Performance is defined as "the degree to which the infrastructure system serves U.S. economic and multi-level business community objectives." Therefore, performance can be measured according to how it meets the broad criteria of quality, efficiency, utility and supply.

Finally, we defined indicators that could be used to measure performance by each criterion. Therefore, for the four infrastructure components, we defined multiple indicators for each of the four criteria.

2. Design Conceptual Models

Next we designed a conceptual model for each infrastructure component. These models incorporate the identified indicators into a fully integrated and operational structure. Each model follows the same structure and organization. First, a set of sample geographies is indentified; second, a set of categories unique to the infrastructure component would be created; third, a set of indicators is identified to meet the criteria; and finally a list of measures is located to fulfill the indicators.

Once the conceptual model for transportation was developed, work began on creating the Transportation Index. The categories unique to transportation were all modes of both freight and passenger movement including air, water, road, transit and rail. Indicators for each level of information had to be identified, operationalized and filled with data.

3. Select Sample

This step involved determining the geographic areas of the U.S. from which the data sets necessary to construct the Index could be derived. To be representative, the sample units had to be geographically dispersed, representative of the economy and consider the existing distribution of the population. In addition, we had to be mindful that this was not an exercise in theory: we had to be able to get data measuring the performance of transportation infrastructure in that geographical area. After a careful review of alternative geographical units, 36 MSA's representing different sizes of population and Gross Metropolitan Product (GMP), different dominant economic sectors and wide spatial dispersion across the nation were selected to be representative of the United States. For the Transportation Index, a screening matrix was created to evaluate the range of possible samples and determine an initial set. These samples were then reevaluated for their ability to provide an accurate representation of the United States.

4. Measure Indicators

Selecting the indicators involved identifying the specific characteristics of the transportation infrastructure to be measured as performance criteria. A primary criterion for selecting the indicators was that they must have publicly available data that is collected on a periodic (preferably annual) basis to ensure the Index could be updated regularly. Selecting the correct range of indicators became a major issue as it was important that, taken together, the set of indicator measures would reflect the performance (and not simply the condition) of infrastructure, yet be functional for gathering data. While many potential indicators were identified for transportation infrastructure performance, 13 were selected for the Project Initiation Stage to test the methodology. (In the next stage of the project, additional indicators will be included to create a more balanced and inclusive Transportation Index.)

5. Collect Data

This step involved indentifying data sources and collecting and assembling data from each of the sample geographical areas for all of the indicators. Creating the Transportation Index required a large data set with 36 sample areas and 14 indicators. Additionally, to test if the methodology could capture performance over time, data was collected from two test years, 2000 and 2007, necessitating the collection of 1,008 measures. Some of the indicators were composites of two different data sets. For example, to create passengers per gate for airports, both the number of gates and the number of passengers had to be collected separately and then combined to determine the number to be used in the Index. In addition, some geographic areas had more than one airport, so data from several airports had to be collected.

6. Weight Indicators

The sixth step involved weighting the relative importance of the indicators. Weighting the Transportation Index is accomplished by surveying stakeholders to elicit the relative importance of each of the indicators. These are synthesized and an average determined for use in the computation of the Component Index. Due to the time constraints the weighting from the U.S. Chamber staff was used in the Project Initiation Stage as a test. In the second stage, a true averaging of relative importance will be used drawn from the U.S. Chamber Infrastructure Committee and staff.

7. Calculate Component Index

The seventh and final step in creating the Transportation Index was the computation step, where the data sets were processed and numbers generated for each of the test years. This was only done for the Transportation Index as no data was collected on any of the other infrastructure components.

Creating the Infrastructure Index

The Infrastructure Index is intended to benchmark and measure the change (improvement or decline) of the performance of U.S. infrastructure over time. The Infrastructure Index must be developed using a rigorous, repeatable process anchored in existing data. The Infrastructure Index is created using the four indices developed for each of the four infrastructure components. In the process of creating the Infrastructure Index, each Component Index will be weighted to reflect the actual infrastructure needs of business. To determine the weights, we will engage stakeholders who have an understanding of the relative value of different infrastructure components. The Infrastructure Index will represent an integrated and comprehensive measurement of the total performance of infrastructure. The Index will be weighted to recognize the interconnections among the different infrastructure networks.

Measuring Performance over Time

One of the main goals of creating an Infrastructure Index is to register changes in the performance conditions of infrastructure over time to determine if there are positive or negative changes. As a result, when selecting the indicators and assembling the information, attention will be given to the availability of past information back to 1990 and to choosing sources that are stable enough to supply data in the future decades.

Economic Analysis

Once the Infrastructure Index is assembled and tested, we can conduct an economic analysis to demonstrate its usefulness for exploring the contribution of infrastructure to keeping American businesses competitive in an increasingly global economy. The design of the Infrastructure Index avoids many of the theoretical and methodological problems encountered by both academic researchers and policy makers in the past. As with our study, researchers have struggled to find readily available and consistently collected data to represent "infrastructure." When attempting to analyze the role of infrastructure in the economy, researchers identified the additional problem of matching units of measure (MSA versus state versus county, etc.) for both infrastructure and economic activity. Study after study points to the need for a tool for measuring the importance of infrastructure to the economy. Drawing on this rich body of work, our economic analysis will provide a straight-forward time-series model following estimation methods that have been widely tested in the economic growth literature.

The purpose of the project is to measure and benchmark infrastructure performance. To accomplish this we will develop four component specific indices – broadband, energy, water and transportation – using a common methodology. These Component Indices will then be aggregated into a single index to reflect the national infrastructure. The remainder of this report details the work completed in the Project Initiation Stage and describes the work planned for the remainder of the project.

BUILDING AN INFRASTRUCTURE INDEX

Overview - Creating the Infrastructure Index

The overall project objective is to develop an integrated Infrastructure Index for the United States that can be used to relate national infrastructure performance to national economic performance in a global age.

The Infrastructure Index will be created from individual infrastructure Component Indices using a set of indicators which are designed to be quantified using objective measures for a sampled set of geographic areas across the U.S. to benchmark and measure the improvement or decline in the performance of U.S. infrastructure. The Infrastructure Index must be developed using a rigorous, repeatable process anchored in publicly available data. Therefore, we being with the core concepts from Bossel's (1999) methodology (used to develop indicators for sustainable development) as the foundation.

The Bossel methodology defines a seven-step process based on widely accepted principles of indicator development, experience with using rating systems and a review of existing decision-making models. The steps of this "universal" methodology are as follows:

1. Define criteria for selecting the infrastructure under evaluation
2. Develop indicator categories
3. Develop indicators
4. Transform indicators into measures by identifying data associated with each indicator
5. Prioritize indicators by assigning weights
6. Allocate points
7. Develop a measurement scale

In addition to this Bossel methodology, we use techniques such as the Analytic Hierarchy Process (AHP), developed by Saaty (1982) to weight the indicators. AHP engages stakeholders in understanding the relative value of different indicators. This approach was employed successfully by members of the team to develop a sustainability index for transportation corridors (Oswald and McNeil, 2009).

The Process

Create the four Component Indices

This activity creates the foundation for the subsequent work. During the Project Initiation Stage of the project, the focus was on the methodology and developing one prototype Transportation Index.

Following Bossel's methodology, the following steps are required:

- Identify the indicators that will be used to measure the performance of each infrastructure component.
- Determine the geographic areas within which data will be gathered to ensure that the Index is representative of national conditions. This includes researching the sources and compiling the data sets for the economic structure to be used in the sampling strategy.
- Identify the data necessary for each of the infrastructure components from each of the selected geographic areas.
- Identify data sources.
- Create the templates and formats for entering and summing data sets.
- Research and enter the data, in alignment with the development of the data sets for the indices.
- Develop a process for combining the indicators following the work of Bossel and using the AHP or similar multi-attribute modeling method to reflect the value placed on the different measures and components.
- Utilizing assembled and completed data sets, develop a representative index for benchmarking and measuring change (improvement or decline) for each of the infrastructure components.

Create the Infrastructure Index

The Infrastructure Index is created using the Component Indices developed for each of the four infrastructure components. The Infrastructure Index represents an integrated and comprehensive measurement of the total performance of infrastructure. The Infrastructure Index recognizes the interconnections among the different infrastructure networks as a weighted index. This methodology has been used by members of the team on the Milken Institute's Capital Access Index and PriceWaterhouse Coopers' Opacity Index. The basic model is:

$$\text{Index} = f(w_B B, w_E E, w_W W, w_T T) \qquad (1)$$

where

Index ≡ Infrastructure Index value
w_i ≡ the weight given to the impact of infrastructure component i
B ≡ Broadband Index value
E ≡ Energy Index value
W ≡ Water Index value
T ≡ Transportation Index value

The values for w_i and the exact nature of f will be determined in the process of creating the infrastructure Component Indices and in discussions with infrastructure component experts. The process for weighting the individual indices may again use the AHP or other multi-attribute modeling methods.

This model can be updated easily by changing the values of the underlying indicators as new observations become available. Using the same methodology provides inter-temporal comparability and allows an assessment as to whether or not the incremental changes in infrastructure are increasing or decreasing in a given geographic area over time.

The model can also be used to forecast performance drawing on existing planning data developed by public and private agencies to understand future infrastructure performance.

Background: Performance Measures

The concept of infrastructure performance was introduced in the national study *"Fragile Foundations"* (National Council on Public Works Improvement 1988). The report presented the idea that the amount of infrastructure or its condition does not capture the ability or capability of the infrastructure to deliver the service expected or required by users.

In a National Research Council study (NRC 1995), the authors found that "performance is defined by the degree to which the system serves multi-level community objectives. Identifying these objectives and assessing and improving infrastructure performance occurs through an essentially political process involving multiple stakeholders." The report went on to state that

> "…no adequate, single measure of performance has been identified…Performance should be assessed on the basis of multiple measures chosen to reflect community objectives, which may conflict…The specific measures that communities use to categorize infrastructure performance may often be grouped into three broad categories: effectiveness, reliability, and cost."

While this report served as a foundation for more recent work and many agencies have adopted the concept of performance (see for example, Transportation Research Board (2006), and National Asset Management Steering Group (2006)), much work remains to be done to capture the performance of networks of infrastructure over the life cycle while recognizing the economic, environmental and social aspects of performance. For our purposes, we define performance as “the degree to which the infrastructure system serves U.S. economic and multi-level business community objectives.”

Once performance metrics are defined, identifying the performance response relationship (how performance changes over time) can still be challenging. There are different temporal and spatial scales plus interdependencies among the different components of infrastructure and the performance goals. The stressors influencing the performance of the infrastructure include demand for infrastructure through population and economic growth, aging, usage, environment including climate change, and changing global trade patterns.

Work of particular relevance for meeting these challenges is a latent variable approach (Ben-Akiva, Humplick, Madanat, and Ramaswamy, 1993; and Ramaswamy and Ben-Akiva, 1993) and work on indicators and indices (Catbas and Aktan, 2002).

Several factors arise which create barriers to performance measurement in studies of infrastructure. Barriers include:

- “Drowning in data, but starving for information” (Baets, 2005)
- Using data from the real-world full-scale laboratory rather than a well-designed experiment
- Unobserved elements of performance and causal relationships
- Incomplete data sets (both time series and cross sectional) leading to censored data
- Inherent variability in the performance of the infrastructure related to time of year, weather conditions and sampling
- Complex interactions; for example, how timing of maintenance influences the remaining life or condition of infrastructure
- Different perspectives; for example, organizational performance versus the infrastructure users’ perspective

Developing the Weights

An Analytic Hierarchy Process (AHP), developed by Saaty (1982), is a method used to simplify complex decision-making processes (Leskinen, 2000). AHP “breaks down a complex, unstructured situation into its component parts; arranging these parts, or variables into a hierarchic order; assigning numerical values to subjective judgments on the relative importance of each variable; and synthesizing the judgments to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation." (Saaty, 1982)

The process addresses the challenges of measuring relationships between elements that are of different scales by providing a new scale for measuring intangibles through pairwise comparisons. The pairwise comparison allows the decision maker to specify his/her preference for each pair of alternatives. In essence, this enables the systematic comparison of apples to oranges by recognizing their qualities as fruits.

In general, AHP has three basic principles that guide the development of a model. The first step, hierarchic representation and documentation, requires that the problem be broken down into separate elements or categories (Saaty, 1982). In the second step, priority discrimination and synthesis, the elements are ranked in order of importance. The third step, logical consistency, requires that the elements are grouped together and ranked consistently according to logical criteria.

Estimating the Index

The Index is estimated based on current and past indicators. These indicators are derived from publicly available data sources.

Estimating the Index based on predicted indicators

Estimating the future value of the Index based on predicted indicators requires modeling the change in the indicator values over time based on generally accepted forecasts of population, economic growth, etc.

Externalities

The Index does not necessarily reflect all externalities. For example, the supply of oil, the supply of water and political factors are outside of the model. However, the Index does need to capture externalities such as the changing patterns of global trade, and the impact on traffic out of U.S. ports from the opening of new ports in Mexico and the widening of the Panama Canal. Externalities are not included in the Project Initiation Stage but could be considered later if it is determined that these are important issues for forecasting.

Prototype Transportation Index

The hierarchical structure for developing the Transportation Index is depicted in Figure 1. This hierarchy serves as an example for the Project Initiation Stage where transportation infrastructure is evaluated with the intention of applying a similar process to the remaining three infrastructure components. The hierarchy is made up of five levels: infrastructure component, geographic sample area, category (unique to each component, as will be described later), criteria and measurable indicators.

The next three chapters of this report focus solely on the prototype Transportation Index, which was created in the Project Initiation Stage to demonstrate the feasibility of the concept for an Infrastructure Index. In addition, it afforded the opportunity to move forward on the structure of Component Indices for the other infrastructure components, which we return to later in the chapter Potential Indicators: Water, Energy and Broadband.

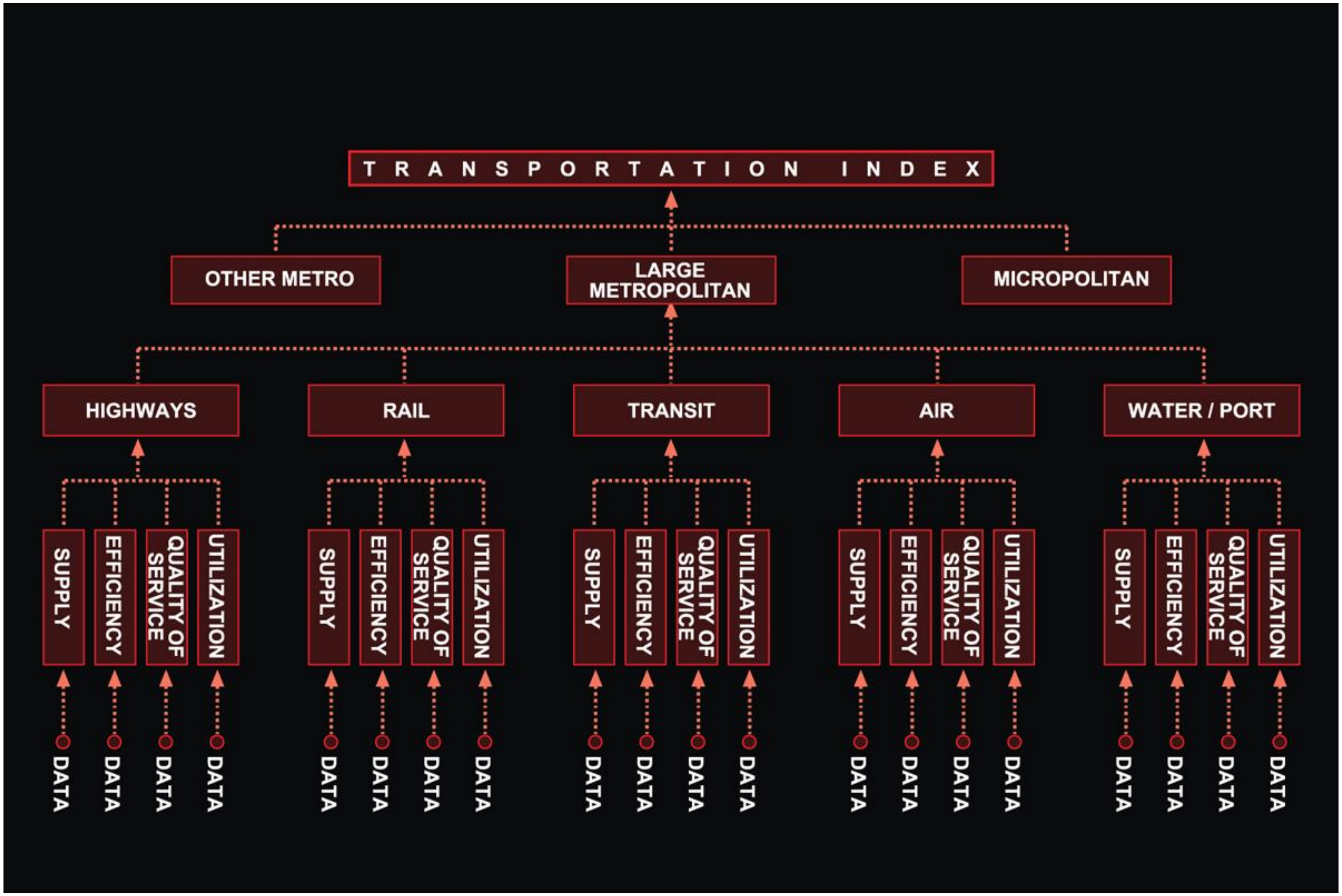


Figure 1: Transportation Infrastructure Hierarchy

SAMPLING STRATEGY FOR THE TRANSPORTATION INDEX

Introduction

It would be impossible to gather all the data necessary to measure and benchmark the performance of every piece of infrastructure in the entire United States. Instead, we need to design a strategy by which we can select a representative sample of transportation infrastructure. Since data on the measurements we need are collected by geographic area, we have to identify sample selection criteria to ensure a representative sample with attributes that demonstrate sufficient variability to capture all the factors that influence economic health and 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.

This chapter describes the sampling process in detail. While it is an integral part of the overall project report, the casual reader may skip this chapter without loss of substance relevant to the construction and use of the Infrastructure Index.

Sampling Objective

The primary objective in developing a sampling strategy is to select a representative sample of geographic areas throughout the United States that reflects the diversity of geography as well as the type and intensity of economic activity that make use of infrastructure. Our 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).

Our stratified sampling strategy will ensure the selection of infrastructure sectors within important geographic locations. Our design purpose is to allow us to use national economic data in the subsequent analysis. We determine a representative sample through a methodology that would minimize the potential for bias. Once the sample is determined, we provide a final test by measuring the coverage under various standards (population, size of economy, etc.) to determine if the sample can adequately represent the U.S. economy and infrastructure.

Sample Size Determination

We begin by determining the number of MSAs that have to be selected to ensure that we use a sufficient number of observations to meet the level of precision necessary for our study. The size of the sample can be calculated based on the accuracy, robustness and precision of the variables being measured.

For example, assume that one of the indicators of transportation infrastructure performance is the travel time index (TTI). If the average TTI is 1.29, the data series has a standard deviation (a measure of variability in TTI scores) of 0.11. We select our level of accuracy to be within 0.02 points with a 95 percent confidence interval (a measure of the "plus or minus" spread that we find acceptable). We could calculate a sample size of about 116 geographic areas to achieve the desired level of accuracy.[1]

The same calculation can be repeated for all other variables that will be used to measure infrastructure until we know the sample size required for the desired level of accuracy for every measure in the Index. We then select the largest sample size required to estimate any indicator and use that for all indicators. This has the advantage of allowing us to work with one sample while giving us confidence that we have met all the accuracy requirements.

The unit of analysis is not always consistent with a sampling strategy. For example, the calculation based on the International Roughness Index (IRI) would use an average IRI value of 102.15 inches per mile with a standard deviation of 23.84. The calculation for the number of observations required to meet our standard of accuracy is 87 segments. In reality, IRI is measured for many segments of roadway, not just once for an entire geographic area. Each metropolitan area will have many segments, so that a much lower number of MSA observations would meet our requirement.

For the purpose of creating a working concept for a Transportation Index in the Project Initiation Stage, we elected to work with a sample size of 36 MSAs based roughly on the indicator data but more importantly for feasibility within the time allotted for this demonstration. The 36 MSAs are then allocated across the different selection criteria according to the relative contribution of each relative to the composition of the U.S. This process is described in detail in the following sections.

Sampling Selection Criteria

We select two criteria to ensure a representative sample of geographic areas with attributes that capture all the factors that influence economic health and infrastructure performance over time. Each MSA is assigned to a population category (see Table 1), and an economic sector (which we describe in more detail below).

[1] The standard formula for this calculation is $(1.96*0.11/0.02)^2$ using our example of the TTI. The factor 1.96 is used in statistics to capture a 95 percent confidence interval.

Table 1 Sampling Selection Matrix

Sampling Strata	Source of Data	Stratification
Population	U.S. Census	Large Metropolitan Statistical Area: Population > 1 million Other Metropolitan Statistical Area: Population > 50,000 but ≤ 1 million
Economic Sectors	BEA	Service Trade Industrial Infrastructure

Defining Economic Sectors For Sampling

For the purpose of creating a workable sample selection matrix, we need to minimize the number of industry/sectors under consideration. Our intention is to have a representation of the U.S. economic importance of various geographic areas. Therefore, we elected to aggregate the various industries into four economic sectors: Service, Trade, Industrial and Infrastructure. The underlying industries for which the Department of Commerce Bureau of Economic Analysis reports metropolitan statistical area (MSA) output (contribution to U.S. GDP) were assigned to the Economic Sectors according to Table 3 (BEA, 2006).

Table 2 Economic Sector Definitions

Economic Sectors	Meaning
Industrial	Agriculture, mining, manufacturing
Infrastructure	All infrastructure industries plus government
Service	All services, including business, education, etc.
Trade	Wholesale and retail trade

Table 3. Specific Industries Included in Economic Sectors

High level industries	Economic Sector	BEA Industry ID
Agriculture, forestry, fishing, and hunting	Industrial	3
Construction	Industrial	11
Manufacturing	Industrial	12
Mining	Industrial	6
Government	Infrastructure	78
Information	Infrastructure	45
Transportation and warehousing	Infrastructure	36
Utilities	Infrastructure	10
Accommodation and food services	Service	74
Administrative and waste services	Service	63
Arts, entertainment and recreation	Service	71
Educational services	Service	66
Finance and insurance	Service	50
Health care and social assistance	Service	67
Management of companies and enterprises	Service	62
Other services, except government	Service	77
Professional and technical services	Service	58
Real estate and rental and leasing	Service	55
Retail trade	Trade	35
Wholesale trade	Trade	34

By including utilities, transportation and information (along with government) in "Infrastructure," we intend to represent the significance of geographic areas that produce infrastructure as part of their local economy, without causing the production of infrastructure to dominate the sample selection. For the purposes of sampling, we believe this aggregation is sufficient. There are 366 MSAs in the population from which we will draw a sample for analysis. We use 2007 GDP data because it is the most recent, fully-adjusted resource available at the time of our analysis.

This strategy includes a selection based on industries grouped by infrastructure dependence, a new concept that we are applying here for the first time. The concept is similar to the use of sectors in common market indices like the Dow Jones Averages (for stock prices). (For an example of the use of industry sectors in statistical analysis, see Trimbath (2002).) We defined the economic sectors to capture the idea that a region with a diversified economy (e.g., relying on retail plus service plus industrial) would also have diverse infrastructure requirements. By putting the economic industries into the infrastructure sampling methodology, information will “bubble-up” through the analysis, giving us confidence using national economic data later. We believe this process could allow the results of the national analysis to hold up if disaggregated to the regional level.

Selecting an MSA Sample for Transportation

The sample is intended to be representative; therefore, while the strata are selected by design, sampling will be random within any strata. This section describes and documents the process and the resulting sample of MSAs to be used for the prototype Transportation Index.

Step 1: Classifying MSAs by Economic Sector

Using 2007 GDP data, we calculated the proportion of GDP derived from each sector for each geographic area (MSA). Based on sensitivity testing and expert judgment, we determined that the 75^{th} percentile was the appropriate cut-off level at which we could achieve a representative, balanced sample of MSAs for our analysis. (The 75^{th} percentile is the level below which 75 percent of MSAs will fall for each sector.)

Specifically, we list the MSAs with the percentage of GDP in each sector and sort them from high to low by the percentage of GDP in, for example, the “Service” sector. The point where 25 percent of the 366 MSAs have a contribution to GDP from the “Service” sector is the cut-off for identifying an MSA as representative of the economic contribution of the industries in that sector. For any given MSA, all sectors that contribute to the local economy at a level above the cut-off were coded as “1”, and otherwise “0”. MSAs where multiple sectors contribute to local GDP at or above the U.S. top 25 percent share of GDP in that sector (with more than one sector coded “1” after the analysis) were classified as “Multi-Sector.” MSAs with one “1” were classified according to the sector with the “1” and an MSA with all “0s” (i.e. where no sector provided a contribution to local GDP above the cut-off level) was classified as “Diversified.” Three examples are provided in Table 4 – showing MSAs that were classified Diversified, Multi-sector and one sector (Industrial) – to illustrate the process that was applied to all 366 MSAs.

Table 4. Example of Identifying MSAs with Sectors

MSA	Industrial	Infrastructure	Service	Trade	MSA Total
75th Percentile for all MSAs	0.279	0.250	0.420	0.140	(cut-off)
Buffalo-Niagara Falls, NY (MSA) FIPS - 15380					
GDP by Econ. Sector	9,008	8,951	18,685	5,415	42,293
Proportion by Econ. Sector	0.210	0.151	0.180	0.089	
Coded	0	0	0	0	Diversified
Dalton, GA (MSA) FIPS - 19140					
GDP by Econ. Sector	2,900	440	884	419	5,832
Proportion by Econ. Sector	0.333	0.144	0.425	0.097	
Coded	1	0	1	0	Multi-Sector
Huntsville, AL (MSA) FIPS - 26620					
GDP by Econ. Sector	3,727	4,567	6,864	2,062	18,108
Proportion by Econ. Sector	0.306	0.180	0.396	0.118	
Coded	1	0	0	0	Industrial

Step 2: Classifying MSAs by Population

Population data for 2008 was downloaded from the Census website and the MSAs were classified into one of two groups

- Population greater than 1 million (52 MSAs)
- Population under 1 million (but greater then 50,000) (314 MSAs)

Step3: Combining Population and Economic Sector Classifications

Table 5 and Table 6 show the distribution of MSAs by economic classification and population size with the percentage contribution to GDP and the number of MSAs, respectively.

Table 5. Proportion of GDP by Economic Classification and Population Group

Economic Classification	Population < 1 million	Population > 1 million	Total
Diversified	7.0%	27.9%	34.9%
Industry	7.5%	0.4%	7.9%
Multi-Sector	9.1%	5.6%	14.7%
Other	3.9%	0.6%	4.5%
Service	5.6%	29.8%	35.4%
Trade	2.1%	0.6%	2.7%
Grand Total	*35.1%*	*64.9%*	*100.0%*

Table 6. Number of All MSAs in Each Economic Classification and Population Group

Economic Classification	Population < 1 million	Population > 1 million	Total
Diversified	57	24	81
Industry	65	1	66
Multi-Sector	73	6	79
Other	58	1	59
Service	31	19	50
Trade	30	1	31
Grand Total	*314*	*52*	*366*

Step 4: Determining Sample Size by Economic Classification and Population Group

Based on our selected sample size of 36 MSAs, the number of MSAs from each economic classification/population group combination is based on the contribution to the economy as shown in Table 5. The results are shown in Table 7. The idea is to achieve a similar distribution for the sample in each cell as there is in the total population.

Table 7. Number of Sample MSAs in Each Economic Classification/Population Group

Economic Classification	Population < 1 million	Population > 1 million	Total
Diversified	3	10	13
Industrial	3	0	3
Multi-Sector	3	2	5
Infrastructure	1	0	1
Service	2	11	13
Trade	1	0	1
Sample Total	*13*	*23*	*36*

Step 5: Selecting MSAs for the Sample

We begin by ordering all the MSAs by GDP share in economic classification within population groups. Next, we assign them sequential numbers. Finally, we generate n random numbers (where "n" is the sample size shown in Table 7). We then select the MSAs with sequential numbers corresponding to the random numbers.

For example, for a Diversified MSA with a population fewer than 1 million, three random numbers between 1 and 57 were generated. In this case, the numbers were 41, 51 and 53. The 41^{st}, 51^{st} and 53^{rd} MSAs in this category were selected.

The list of 36 MSAs for our sample is shown in Table 8, along with the economic classification and population group. The table includes the population and GMP of each MSA. Figure 2 shows a geographic map of the sampled MSAs. The map in Figure 3 shows the relative size of the economies represented by each of the sampled MSAs.

Table 8. MSA Sample

MSA	FIPS Code	Economic Class.	POPN >1m (1=yes)	MSA GMP ($M)	Population
Abilene, TX (MSA)	10180	Multi-Sector	0	5,247	159,521
Altoona, PA	11020	Multi-Sector	0	4,085	125,174
Atlanta-Sandy Springs-Marietta, GA	12060	Diversified	1	267,295	5,376,285
Baltimore-Towson, MD	12580	Service	1	128,819	2,667,117
Bloomington-Normal, IL	14060	Service	0	7,878	165,298
Boston-Cambridge-Quincy, MA-NH	14460	Service	1	289,415	4,522,858
Buffalo-Niagara Falls, NY	15380	Service	1	42,293	1,124,309
Charlotte-Gastonia-Concord, NC-SC	16740	Diversified	1	116,501	1,701,799
Chattanooga, TN-GA	16860	Diversified	0	20,358	518,441
Chicago-Naperville-Joliet, IL-IN-WI	16980	Diversified	1	510,666	9,569,624
Cleveland-Elyria-Mentor, OH	17460	Service	1	102,956	2,088,291
Dallas-Fort Worth-Arlington, TX	19100	Diversified	1	362,075	6,300,006
Dayton, OH	19380	Diversified	0	33,737	836,544
Decatur, AL	19460	Industry	0	5,103	150,125
Denver-Aurora-Broomfield, CO	19740	Diversified	1	143,914	2,506,626
Detroit-Warren-Livonia, MI	19820	Diversified	1	200,742	4,425,110
Harrisonburg, VA *	25500	Industry	0	5,222	118,409
Jefferson City, MO *	27620	Other	0	5,396	146,363
Kennewick-Pasco-Richland, WA **	28420	Service	0	8,171	235,841
Los Angeles-Long Beach-Santa Ana, CA	31100	Service	1	699,773	12,872,808
Memphis, TN-MS-AR	32820	Diversified	1	62,953	1,285,732
Minneapolis-St. Paul-Bloomington, MN-WI	33460	Diversified	1	186,738	3,229,878
Nashville-Davidson-Murfreesboro-Franklin, TN	34980	Diversified	1	76,294	1,550,733
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	37980	Service	1	322,325	5,838,471
Pittsburgh, PA	38300	Service	1	110,489	2,351,192

MSA	FIPS Code	Economic Class.	POPN >1m (1=yes)	MSA GMP ($M)	Population
Port St. Lucie, FL **	38940	Diversified	1	11,652	2,207,462
Providence-New Bedford-Fall River, RI-MA	39300	Service	1	63,906	1,596,611
Raleigh-Cary, NC	39580	Service	1	51,341	1,088,765
Riverside-San Bernardino-Ontario, CA	40140	Multi-Sector	1	111,916	4,115,871
Salt Lake City, UT	41620	Service	1	60,594	4,274,531
San Antonio, TX	41700	Multi-Sector	0	76,785	265,297
Santa Cruz-Watsonville, CA	42100	Diversified	0	9,799	549,150
St. George, UT *	41100	Industry	0	3,459	408,238
Tampa-St. Petersburg-Clearwater, FL	45300	Service	1	110,743	2,733,761
Tucson, AZ	46060	Multi-Sector	1	30,913	1,012,018
Winchester, VA-WV *	49020	Trade	0	4,776	122,369

* did not meet MSA definition in 2000; hence, only 2007 data is used in this Stage. **2000 data not used in this Stage

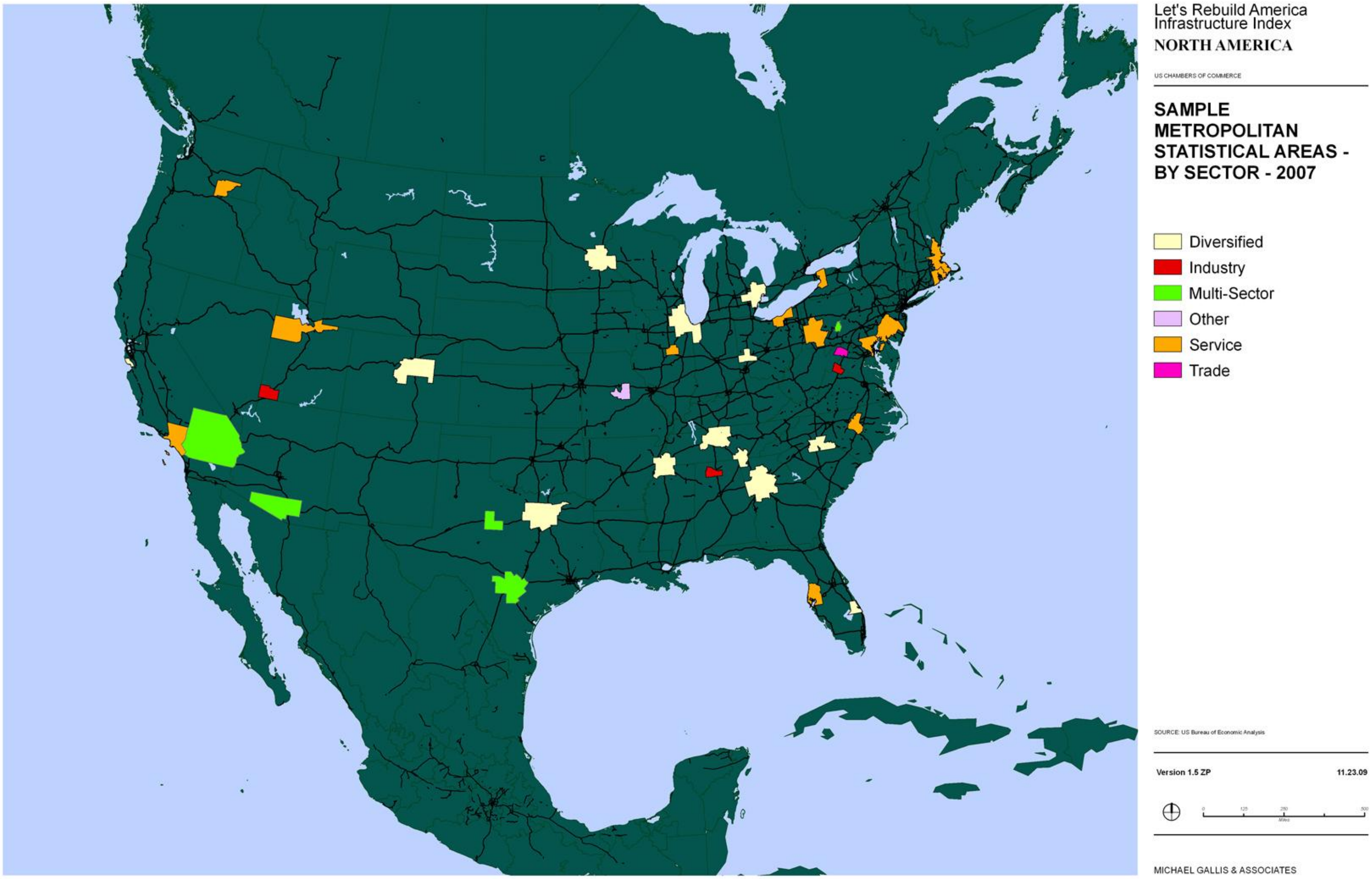


Figure 2: Geographic Area for Sampled MSAs

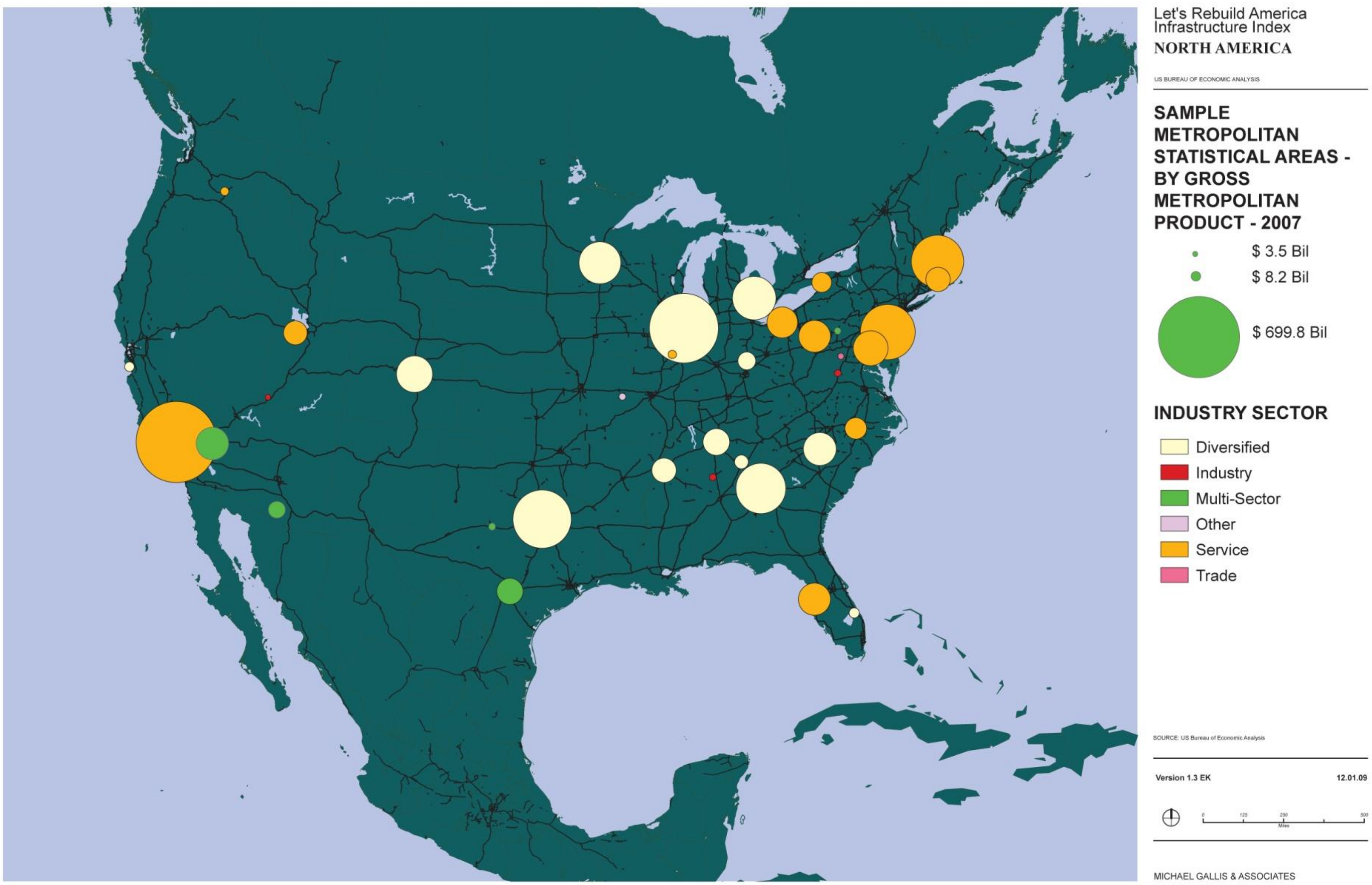


Figure 3: Relative Size of Economy for Sampled MSAs

Checking the Sample

Our sample provides the following coverage: 34.5 percent of U.S. MSA Population (34.7 percent of total U.S. population) and 34.7 percent of U.S. MSA economic output.

This sample may appear to cover less of the U.S. economy than it really does. There are instances where MSA level data by industry will not sum to the total contribution of all MSAs to national GDP. There are two reasons for this, both of which are explained in the footnotes to the BEA tables. BEA does not report a number if either the industry's contribution to GMP is less than $500,000 (marked "L") or if the industry contained so few companies that giving the GMP would allow one to identify the output of a private company (marked "D"). For this reason, some MSAs will show $0 even after aggregating industries into our Economic Sector level. These BEA conventions result in the loss of about 23 percent of total U.S. Metropolitan Portion of GDP in analyses using MSA-Industry level data for 2007.[2] There are no very good options for changing this while achieving the representative nature of the sampling matrix. For example, the only "Industrial" economic classification number reported at any industry sub-level in 2007 for the Philadelphia-Camden-Wilmington MSA is "693" ($million) in "Crops and animal production (Farms)." Every other sub-line for our industrial economic classification is marked (D) (too few companies).

Representativeness is evaluated in terms of the following standards:

- *Share of GDP by industry types (Table 9):*
  The table shows the percentage of U.S. GDP that is in the sample, with breakout by Economic Classifications. Our sample shows somewhat more representation in large MSAs with diversified or multi-sector economies than the overall U.S., while the economic classification of the smaller MSAs is very similar to All MSAs. At the total level, however, representation is more balanced.
- *Geographic distribution (regions) (Table 10):*
  To check the representativeness of the sample, each MSA was coded by region using the table of BEA states and regions (see Appendix B). Generally, we find that our sample is well balanced across the cells (i.e., across location and population). We note that our sample has somewhat more representation in the Southwest than the population of all U.S. MSAs, but we find this is balanced by somewhat less representation in the Far West.
- *State coverage (Table 11):*
  Nineteen states plus the District of Columbia are not represented in the

[2] This is not unusual. The additive total of GDP by state differs by about 1 percent from national GDP (BEA, 2006).

selected sample of MSAs. The largest state without a sampled MSA is Connecticut, which ranks 23rd among all states for GDP. The smallest state – Vermont, (measured by GDP) -- is also not included.

Two other attributes of the sample may also be important. One is capturing connectivity, both nationally and globally. The other is checking for contiguous MSAs, which is only important if they are located in the same cell for the sampling process. These two attributes, and any others that are identified in the on-going development of the infrastructure Component Indices, will be addressed in the next stage of the project.

Table 9. Share of GDP in Population and Sample

All MSAs			
Economic Classification	Popn < 1 million	Popn > 1 million	Total
Diversified	19.9%	43.0%	34.9%
Industry	21.4%	0.6%	7.9%
Multi-Sector	25.9%	8.6%	14.7%
Other	11.1%	0.9%	4.5%
Service	15.9%	45.9%	35.4%
Trade	5.9%	1.0%	2.7%
Grand Total	100.0%	100.0%	100.0%
Sample MSAs			
Economic Classification	Popn < 1 million	Popn > 1 million	Total
Diversified	33.6%	47.7%	47.1%
Industry	7.3%	0.0%	0.3%
Multi-Sector	45.3%	3.5%	5.4%
Other	2.8%	0.0%	0.1%
Service	8.5%	48.8%	47.0%
Trade	2.5%	0.0%	0.1%
Grand Total	100.0%	100.0%	100.0%

Table 10 Percent of GDP in Population and Sample by Region

		Population < 1m		Population > 1m	
	Region	**Sample**	**Population**	**Sample**	**Population**
1	New England	0.0%	5.9%	8.7%	5.3%
2	Mideast	2.2%	7.5%	14.9%	28.0%
3	Great Lakes	21.9%	11.8%	20.0%	14.7%
4	Plains	2.8%	6.7%	4.6%	5.1%
5	Southeast	18.7%	23.9%	17.1%	17.9%
6	Southwest	43.2%	8.4%	9.7%	13.7%
7	Rocky Mountain	1.8%	3.7%	5.0%	2.6%
8	Far West	9.5%	32.0%	20.0%	12.7%
	Grand Total	100.0%	100.0%	100.0%	100.0%

Table 11. States Not Included in the Sample

State	GDP Ranking
Alaska	46
Connecticut	23
District of Columbia	35
Hawaii	39
Idaho	43
Iowa	30
Kansas	32
Kentucky	27
Louisiana	24
Maine	44
Montana	48
Nebraska	37
Nevada	31
New Mexico	38
North Dakota	50
Oklahoma	29
Oregon	26
South Dakota	47
Vermont	51
Wyoming	49

What the Sample Does Not Include

Early discussions indicate that the data sources for infrastructure will be available by MSA or state, but not specifically for either non-MSA or rural geographic areas. There are two ways to think about geography with regard to our purpose of measuring infrastructure performance: the placement of infrastructure in MSAs and the contribution of MSAs to the economy. Clearly, surface transportation vectors between, say, Los Angeles and San Antonio will cross through non-MSA geography. This point leads us to look at the contribution of the support of infrastructure to non-MSA economies. For example, about 13 percent of jobs in Transportation, Communication (including Broadband) and Utilities (including Water and Energy) are in non-MSA economies (SBA 1999). Though GDP data is not available separately for non-MSA geographic areas, the data in Table 12, which we obtained from a report done by the Small Business Administration, gives the share of firms and jobs in rural areas.

The key infrastructure issues for non-MSA geographic areas, as described by media and political discourse, are high energy costs, the need for broadband access, sources of water (locks, dams and reservoirs), locations for renewable energy (solar, wind, biofuels) and the need for roads and bridges associated with the national transportation that passes through these areas.

We draw data for the sample strategy from the Bureau of Economic Analysis and the Census Bureau, which use parallel definitions for "MSA." An MSA is a geographic area with at least one urbanized area, a central county and adjacent counties that have "a high degree of social and economic integration with the central county as measured through commuting." 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.

For these reasons we elected to base our sample on MSAs, which capture sufficient representation of the characteristics important to our analysis.

Table 12. Non-MSA Contribution for Selected Industries

Industry Title	Jobs	Firms
Gross domestic product	15.3%	19.1%
Agriculture, forestry, fishing, and hunting	n.a.	20.0%
Mining	n.a.	50.0%
Construction	14.8%	21.4%
Manufacturing	22.5%	0.0%
Transportation, Communications, Utility	12.6%	0.0%
Wholesale trade	11.5%	0.0%
Retail trade	16.9%	22.0%
Finance, insurance, real estate, rental, and leasing	9.0%	16.0%
Services	12.2%	16.8%

Source: SBA 1999

PROPOSED TRANSPORTATION INDICATORS

Introduction

Transportation indicators serve as the building blocks for the Transportation Index. The objective is to identify a set of indicators that reflects the performance of the transportation infrastructure and its relationship to economic health and growth. The indicators are selected based on the following definitions of transportation infrastructure:

- **General Definition:** Moving people and goods by air, water, road and rail
- **Technical Definition:** The fixed facilities (roadway segments, railway tracks, transit terminals, harbors, and airports), flow entities (people, vehicles, container units, railroad cars) and control systems that permit people and goods to traverse geographical space efficiently and in a timely manner and for the intended purpose. Transportation modes include highway, rail, air, waterway, and pipeline.

Following the methodology described in the chapter *Building an Infrastructure Index*, we define criteria for selecting broad classes of performance indicators, establish a hierarchical structure through which the Index is developed, explore specific indicators and review the available data.

Criteria

Criteria or classes of indicators group like indicators that reflect a key concept of performance. Classes of indicators or measures have been used in earlier studies, although they have not been applied in a consistent or comprehensive manner. For example, the National Council on Public Works Improvement in *"Fragile Foundations: A Report on America's Public Works"* categorizes eight different public works sectors: highways, airports, transit, water supply, waste water treatment, water resources, public works and solid waste. (NCPWI 1988) The report then identified the following classes of performance measures each category:

- Availability of physical assets (capital investment)
- Service delivery
    - Physical capacity
    - Quality of operation and maintenance
    - Level of demand
- Quality of service (accessibility, reliability, safety, health effects and congestion)
    - Physical size and condition

  - Product being delivered
  - Operating priorities
- Economic
  - Efficiency
  - Cost effectiveness

Another model is provided by the National Research Council's study on performance measures (NRC 1995). The classes of performance measures established by the study committee as part of the study framework are effectiveness, reliability and cost. The framework assumes that the boundaries of the system, as well as the inventory of facilities, are clearly defined. The study focused on four broad categories of infrastructure: (1) transportation, including highways, mass transit, and aviation; (2) water, including water resources and water supply; (3) wastewater (both sanitary sewage and storm water runoff); and (4) municipal waste, including both solid and hazardous wastes. These classes are further broken down as follows:

- Effectiveness
  - Service delivery/Capacity
  - Quality of service of users
  - Regulatory concerns
  - Community concerns/ Community-wide impacts/ Externalities
- Reliability
- Cost

It is worth noting that both reports offer hundreds of measures in each of the classes.

To develop our Infrastructure Index, we defined four broad classes of performance indicators or criteria:

- Supply, which captures availability and coverage (What geographical area is covered?)
- Efficiency, which captures the cost of service (What is the price charged for services?)
- Quality of service, which captures inconvenience, cost of disruption and reliability (How well service is provided?)
- Utilization, which captures whether growth can be accommodated (How fully the existing facilities are used?)

A Hierarchy for Transportation Infrastructure

The hierarchical structure for developing the Transportation Index (see Figure 1 above) is made up of several levels of detail:

- The geographic area level is broken down into three groups based on population: large metropolitan, other metropolitan, and micropolitan. In order to ensure that these areas are a representative sample of U.S. economic activity, the MSAs are weighted based on their contributions to the U.S. economy. In the prototype Transportation Index, the micropolitan areas are not included.
- The category level is unique to each infrastructure component. For example, road, rail, transit, air and water are the categories of transportation infrastructure that we want to measure.
- The next level includes the four overarching criteria which are applied to assessing each aspect of transportation: supply, efficiency, quality of service and utilization.
- Within each criterion, indicators are identified to measure the productivity of the system. The data used to measure the indicators represents the final level within the hierarchy.

Originally, the hierarchy included two additional levels. One represented the two users of transportation: freight versus passenger. The other represented the different service and infrastructure providers (supply side) of transportation -- road, rail, air, and water as options for freight mobility; and auto, transit (including bus, rail, light rail, and ferry), and air as forms of passenger mobility. Given the shared facilities and common indicators, these levels were eliminated from the hierarchy.

Transportation Indicators

As the nation becomes dependent on a more interconnected network, problems or slowdowns at any single point turn into system-wide disruptions. This interdependence presents challenges for defining appropriate indicators. Examples include:

(1) Shared infrastructure: capturing the interactions between passenger and freight transportation in the case of auto and truck, or commuter rail and freight rail;

(2) Inter-regional: measuring the impact of bottlenecks in one metropolitan area on adjacent metropolitan areas;

(3) National: comparing indicator measures for metropolitan areas with ports to those without ports;

(4) Regional variation: measuring the influence of the size of a metropolitan area with the relative importance of transportation indicators.

It is important to remember that the indicators in the Project Initiation Stage apply to a representative sample of metropolitan areas and when aggregated across the U.S., regional, national and international influences should be captured.

Table 13 is a list of 22 potential indicators of the performance of passenger and freight transportation infrastructure. Table 14 shows the 13 proposed indicators that we used to develop the prototype Transportation Index. Note that there are no indicators for the "efficiency" criteria; we were unable to fill the data needs at this time to fill in those indicators. In order to continue work on developing the process and methodology, we moved forward without this data so we could still provide this demonstration. A complete description of each of the 13 proposed indicators, along with some average values for 2000 and 2007, are included as Appendix C of this report.

Table 13. Potential Indicators of the Performance of Transportation Infrastructure

Criteria	Mode/ User	Indicator	Possible Source
Supply	Highway – Passenger OR Highway - Freight	Lane-miles per 1,000 population Lane-miles per square mile	Use GIS from Bureau of Transportation Statistics (BTS, 2009)
	Transit – Passenger	% population within 0.5 miles of public transportation	Use GIS from BTS
	Air – Passenger	% population within 50 miles of major airport	Use GIS from BTS
	Air - Passenger	# of airline seats per day per 1000 population	Using GIS from BTS
	Rail - Freight	Track miles per square mile	Using GIS from BTS
	Air	Average distance to airport	Using GIS from BTS
	Water	Miles of inland waterway per square mile	Using GIS from BTS
	Ports	Distance from the center of MSA to the closest international port	Using GIS from BTS
Efficiency	Auto	% of household expenditure in transportation	Consumer Expenditure Survey http://www.bls.gov/cex/ (only 17 metro areas) (Bureau of Labor Statistics, 2010)
	Transit	Base transit fare divided by average hourly income	
	Air	Average fare per mile	
Quality of Service	Highway – passenger and freight	Travel time index OR Congestion index	BTS OR Texas Transportation Institute (TTI)
		Fatalities per million VMT	Fatal Accident Reporting System (FARS)
		% of lane miles with IRI greater than 170 in/mile	Highway Performance Monitoring System (HPMS)
		% of lane miles at LOS C or better	Highway Performance Monitoring System (HPMS)
		% of bridges structurally deficient or functionally obsolete OR % of bridges with a sufficiency rating < 70	National Bridge Inventory (NBI)
	Rail – freight	Rail delay	FRA and computed using (Adams, 2005)
	Waterway – freight	Lock delay and processing times (waterway)	(U.S. Army Corps of Engineers, 1999)
	Port	Average ship turnaround time (port)	U.S. Army Corps of Engineers
Utilization	Port	Containers Per Acre Per Year	U.S. Maritime Administration and Port Authorities
	Air	# passengers per year per gate	FAA and Phone Survey of Airports
	Air	# days/year that airport closed	BTS

Table 14 Proposed Indicators of the Performance of Transportation Infrastructure for the Prototype Transportation Index

Criteria	Mode/ User	Indicator
Supply	Highway - Freight	Highway Density
	Air – Passenger	Airport Access
	Rail - freight	Rail Density
	Air – freight	Airport Proximity
	Water – freight	Inland Waterway Density
	Ports – freight	Port Access
Quality of Service	Highway – passenger and freight	Travel Time Reliability
		Safety
		Road Roughness
		Road Congestion
		Bridge Integrity
Utilization	Port	Port Congestion
	Air	Air Passenger Congestion

BUILDING THE TRANSPORTATION INDEX

Introduction

The prototype Transportation Index is intended to illustrate the process, provide an opportunity for in-depth exploration of data sources and limitations and provide a sense of the effort required to develop and maintain a national Infrastructure Index. As defined in earlier chapters, the transportation indicators and index in this demonstration are based on the following parameters:

- **Time frame**: Data for the prototype Transportation Index was collected for 2000 and 2007 for generating information about changes in infrastructure performance.
- **Sample** – Where possible, we use the full sample of geographic areas for the prototype Transportation Index. Six MSAs in our sample (see Sampling Strategy) did not exist in 2000. Those six MSAs are marked with * signs in Table 8. We worked with 30 MSAs for 2000 and 36 for 2007.

This chapter details the process used to normalize the data so that the wide range of values can be compiled into one index value. The following sections then describe the process used to obtain the relative weights both for the data and the sampled MSAs. Finally, we explain the calculation of the Component Index and discuss the preliminary results.

Normalizing (Standardizing) the Data

Each indicator uses a different scale. To convert all the indicators to a common scale, we normalize the data using a common base year. Furthermore, for some measures larger is better (for example, highway density), where for other measures, smaller is better (for example, safety measured in terms of fatalities). The normalization for this characteristic of the data requires using the difference of the measure from some objective base, and we determined that the best value for the measure across all MSAs in the base year. For the demonstration, we use 2000 – our earliest observation – as the base year. Finally, some measures are in the thousands while others are in percentages (or decimals). Our method of normalization (known as the range index method) also accommodates a wide range of data values for inclusion in one Transportation Index.

Each indicator is normalized as follows:

N_{ij} = Normalized Measure for MSA i and indicator j in year t

For indicators that should be minimized

$$N_{ijt} = \left(I_{ijt} - \max_{i}(I_{ij,2000})\right) / \left(\min_{i}(I_{ij,2000}) - \max_{i}(I_{ij,2000})\right)$$

For indicators that should be maximized

$$N_{ij} = \left(I_{ijt} - \min_{i}(I_{ij,2000}))\right) / \left(\max_{i}(I_{ij,2000}) - \min_{i}(I_{ij,2000})\right)$$

Where

I_{ijt} = measure for indicator *j* in MSA *i* in year *t*

The idea is that we want to track the indicators over time so we need to anchor them to a point (in this case 2000). The Index is 0 if all indicators for all MSAs performed as badly as the worst MSAs in 2000. Similarly, the Index is 100 if all indicators for all MSAs performed as well as the best MSAs in 2000. This means that the Infrastructure Index or any Component Index could actually be negative or greater than 100 at any point in time. In practice, this is unlikely to occur.

Here is an illustration. The values for the indicator "Percent of Lane Miles with IRI greater than 170 in/mi" for one MSA are 11.26% in 2000 and 24.88% in 2007. The maximum and minimum values for this indicator in 2000 for all MSAs in the sample are 57.73% and 0 respectively. This indicator is to be minimized. Therefore, we calculate the normalized value of the indicator for this one MSA as:

N_{2000} = (11.26 – 57.73) / (0 – 57.73) = 0.8050
N_{2007} = (24.88 – 57.73) / (0 – 57.73) = 0.5690

Notice that the "normalized indicator" generates a higher value in 2000 when the measure is lower. Since the goal is to minimize this measure, we are generating a higher value for the Infrastructure Index as the indicator moves in the goal direction.

Similarly, the values for the "Percentage of Lane Miles at Level of Service C or Better" (Uncongested Road, UR) indicator for one MSA are 94.84% in 2000 and 98% in 2007. The maximum and minimum values for this indicator in 2000 for all MSAs are 99.58% and 74.33% respectively. Higher indicator values are better, so we normalize this indicator as:

$N_{i,\mathrm{UR},2000}$ = (94.84 – 74.33) / (99.58 – 74.33) = = 0.8123
$N_{i,\mathrm{UR},2007}$ = (98 – 74.33) / (99.58 – 74.33) = 0.9374

Here, the indicator generates a higher value in 2007, when the measure is higher. Since the goal is to maximize this measure, we are generating a higher value contribution to the Index when the measure moves in the goal direction.

The goals to minimize or maximize each indicator are given in Table 15.

Before moving on, we present a final illustration of how the normalization process works to standardize disparate values. The range of values in the demonstration sample for "Fatalities per million VMT" (FVMT) is from 0.001 to 0.031, while the range of values for "Number of airline passengers per year per gate" (PPG) is from 15,678 to 228,359. The particular values for MSA Chicago in 2000 are: 0.014102 FVMT and 196,661 PPG. We would generate the normalized values for use in the remainder of the process of building the Transportation Index for the year 2000 as follows:

$N_{Chicago,\ FVMT,2000} =$

$$(0.014102 - 0.031) / (0.001 - 0.031) = -0.0168980 / -0.03 = 0.563;$$

and

$N_{Chicago,\ PPG,2000} =$

$$(196{,}661 - 15{,}678) / (228{,}359 - 15{,}678) = 180{,}983 / 212{,}681 = 0.851$$

Therefore, this process provides for a wide range of values to be considered simultaneously without allowing their relative scales to interfere in the analysis.

Weighting the Indicators

Following the work of Bossel and using the Analytical Hierarchy Process (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. AHP uses a pairwise comparison to develop relative weights for each of the indicators. The pairwise comparison can be a group consensus or the inputs of team members. For the demonstration, we used the survey found in Appendix D completed by the U.S. Chamber's staff. Before applying the weights, we need to make one more adjustment to reflect the fact that not every MSA will have every type of transportation infrastructure.

Defining MSA Types

We classify our MSAs based on population (over 1 million or under 1 million), with or without an airport, and with or without a port. There are no MSAs with

- population of over 1 million that
  - do not have an airport and do not have a port; or
  - do not have an airport, but have a port; or
- population under 1 million that do not have an airport but have a port.

In our sample there are also no MSAs with population under 1 million that have both a port and an airport. Nationally, these MSAs not included in the sample represent less than 1% of the economy.

We define four “types” of MSAs using the following codes:

a. 111 – MSA over 1million with one or more airports and a port
b. 110 – MSA over 1 million with one or more airports but no port
c. 010 – MSA under 1 million with one or more airports but no port
d. 000 – MSA under 1 million with no airports and no port

Based on these “types” it is clear that every MSA in the sample does not have data for every indicator. For example, an MSA with fewer than 1 million people without an airport or port (type 000) only has 8 indicators (highway density, rail density, inland waterway density, port access, safety, road roughness, road congestion, and bridge integrity); moreover, there are no values for the five transportation infrastructure performance indicators related to airports, ports and large metropolitan areas.

Table 15 lists the weights assigned to each of the indicators used in the prototype Transportation Index for each of the MSA types. Shaded cells represent indicators that are not relevant for that type of MSA.

Expanding MSA Types

The index for each MSA needs to be weighted by its contribution to the U.S. economy so that a national representative value is obtained. This step assures that several small MSAs or several large MSAs won’t dominate the national values. Each MSA type is weighted by the percent of the U.S. economy that *all* MSAs in that category contribute divided by the contribution of the MSAs in our sample.

We describe this process as generating an expansion factor so that a national representative value is obtained. For example, for MSAs with populations greater than 1 million and an airport and a port, our sample represented 11.88% of the economy in 2000. All MSAs of this type represented 33.02% of the economy. Therefore our expansion factor for this type of MSA for 2000 is 2.78 (33.02/11.88). The expansion weights for 2000 and 2007 for the MSA types represented in the Transportation Index are shown in Table 16.

Calculating the Transportation Index

Complete data sets for each MSA in the same type were assembled. Utilizing these data sets, we constructed an index that is representative of the performance of the transportation component of infrastructure for benchmarking and measuring change (improvement or decline). Below are the technical specifications used to calculate the Transportation 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

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

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

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

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

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

Preliminary Results

Our preliminary Transportation Indexes for 2000 and 2007were intended to demonstrate the process for developing the index, and to help us understand the effort involved in and the data available for creating the index. Both the absolute and relative value of the numbers themselves are otherwise of limited usefulness at this time, as just two values of the index (for 2000 and 2007) are not sufficient data to show a trend or change. Furthermore, these indexes are based on limited data, attributed by two factors. First, we used only a limited sample of indicators and measures from three of the four criteria (Supply, Quality of Service and Utilization) to fit the project within the allotted timeframe.

Second, the weighting for the indicators relied on a test survey of a small number of the Chamber’s staff to give us an idea of how our process design was working, without the full survey necessary to decide the weights as an input for the final product, the Infrastructure Index.

Discussion

Despite the preliminary nature of the statistical results at this time, the project team remains highly confident that the process is correctly designed and that it can be successfully executed given additional time. Our finding is that identifying the broadest scope of indicators for each infrastructure component's performance is key to the success of this effort. Identifying and gathering the best possible measures (data) for those indicators is our primary goal for the Project Development Stage. Furthermore, we are satisfied that the revised process design for the surveys will provide realistic weights for the relative importance of these indicators. We intend to use that survey design to weight the infrastructure components in the final Infrastructure Index, too.

The remainder of the report describes the results of our efforts to date with regard to defining the other infrastructure Component Indices (water, energy and broadband), and how we can best measure their indicators of performance. Before outlining the steps for the next stage of the project, we include a final section on the role of infrastructure in economic prosperity. The results of this review of prior economic research on the subject guided our methodology that builds a fully inclusive Infrastructure Index focused on performance.

Table 15. Normalization Process and Weights for Demonstration Indicators

Criteria	Min/ Max?	MSA Size	> 1 million		≤ 1 million	
		Type	Airport and Port	Airport and No Port	Airport and No Port	No Airport and No Port
		MSA Code	111	110	010	000
Supply	Max	Highway Density	0.056	0.063	0.116	0.133
Supply	Max	Airport Access	0.019	0.021	0.039	
Supply	Max	Rail Density	0.004	0.005	0.008	0.010
Supply	Min	Airport Proximity	0.020	0.023	0.041	
Supply	Max	Inland Waterway Density	0.004	0.005	0.008	0.010
Supply	Min	Port Access	0.019	0.021	0.039	0.045
Quality	Min	Travel Time Reliability	0.401	0.454		
Quality	Min	Safety	0.185	0.209	0.383	0.439
Quality	Min	Road Roughness	0.021	0.024	0.043	0.050
Quality	Max	Uncongested Roads	0.084	0.095	0.174	0.200
Quality	Min	Bridge Integrity	0.049	0.055	0.101	0.116
Utilization	Min	Port Utilization	0.116			
Utilization	Min	Air Passenger Congestion	0.023	0.026	0.048	
Total *			1.001	1.001	1.002	1.002

*Totals do not sum to 1 due to rounding errors.

Table 16. Expansion Factors for MSA Types

	MSA Type			
Year	000	010	110	111
2000	40.69	25.81	1.77	2.78
2007	29.29	24.96	1.80	2.85

Key: MSA Types

000 – MSA under 1 million with no airports and no port

010 – MSA under 1 million with one or more airports but no port

110 – MSA over 1 million with one or more airports but no port

111 – MSA over 1million with one or more airports and a port

POTENTIAL SAMPLING, CATEGORIES AND INDICATORS: WATER, ENERGY AND BROADBAND

Introduction

Based on experience with developing a prototype Transportation Index and discussions with experts regarding water, energy and broadband infrastructure, this chapter summarizes the concepts relating to the remaining infrastructure components: broadband, energy, and water. These Component Indices will be built using a common methodology similar to that used for the Transportation Index prototype. All four Component Indices will then be aggregated into a single, national Infrastructure Index, based on indicators of infrastructure performance. This chapter describes and documents the potential indicators for water, energy and broadband.

Sampling by Component

The sampling geographies for the Transportation Index were based on MSAs that provided both data on each of the four categories of transportation (air, water, rail and roads) and corresponding economic data. For each of the other Component Indices, sampling strategies must reflect each component's functional geographies and the ability to find available economic data in the same geography.

Creating the sampling geography for the Transportation Index used large and small metropolitan areas as the geographic areas, as airports, seaports, rail yards and truck terminals are largely concentrated in urban centers. Preliminary discussion suggests, however, that MSAs may not be the appropriate sampling unit for broadband, energy and water. Consideration has been given to sampling utilities for energy and water and then attempting to match the geographic coverage of the utility to jurisdictional units with relevant economic data. On the other hand, geographic boundaries have little meaning for electric energy, thus national measures, similar to those used for the energy security index, may be appropriate. Sampling for broadband may be even more problematic due to data issues.

Categories by Component

The categories for water, energy and broadband will have to be unique to their components. The categories for transportation were based on the primary modes (air, water, rail, transit and road). Preliminary discussions for broadband categories have focused on service levels (or speeds), energy categories could be focused on the end user (i.e. business, industry, agriculture and residential) and categories for water include potable, non-potable and storm water. Each component's categories will be finalized with the input of area experts from each component area in the Project Completion Stage.

Indicators by Component

The inputs reflected in Tables 17-19 are intended to illustrate the concept. They will be refined and modified in the Project Development Stage. The quantitative measures will be supplemented with graphics and qualitative assessments. Where appropriate, measures will be normalized to reflect scale and context to make sure that we are capturing performance on comparable scales (Office of Management and Budget, 2008).

Broadband

- **General Definition**: Moving information (voice, data, images etc.) at high speed over the Internet and other networks

- **Technical Definition**: Broadband is a specific segment of the total communications infrastructure. It is the advanced communications systems capable of providing high-speed (at least 768 Kbps) transmission of services, such as voice, data, images, etc., over the Internet and other networks. Transmission is provided by a wide range of technologies, including digital subscriber line and fiber optic cable, coaxial cable, wireless technology and satellite. Broadband platforms make possible the convergence of voice, data and images services onto a single network. (FCC, 2008; FCC, 2009a; FCC 2009b; Kruger, 2009)

The ways that broadband is being used are growing. Communication devices are not stationary, but increasingly mobile. Cell phones are no longer simply phones but multi-function communication and information devices. A special class of problems in measuring changes across time arises as a result of "leapfrog technology" where some users will switch, for example, to satellite communications without passing through earlier generation cable communications.

Across America, the capacity of broadband as well as the types of usage exhibits a wide differential affecting the quality and capacity of service levels. This is a critical issue in the *Obama-Biden 2008 Blueprint for America* for rural areas. The MSA/non-MSA division does not completely capture the distinction. According to the Office of Management and Budget, "The Metropolitan and Micropolitan Statistical Area Standards do not equate to an urban-rural classification; many counties are included in Metropolitan and Micropolitan Statistical Areas, and many other counties contain both urban and rural territory and populations."

Other data could include maps of cellular coverage, maps of broadband coverage, and charts of the growth of bandwidth usage. Candidate indicators are shown in Table 17. A complete diagram of the hierarchy for the Broadband Index is shown in Figure 4.

Table 17. Candidate Broadband Indicators

Criteria	Indicator
Supply	% of time some acceptable level of broadband access is available % of households with access to community based Wi-Fi % area receiving access to some acceptable level of broadband access
Efficiency	annual cost of individual broadband access as a % of average annual income
Quality of service	% of time data is lost
Utilization	maximum transmission rate outside the area (gigabytes per nanosecond) per unit of population

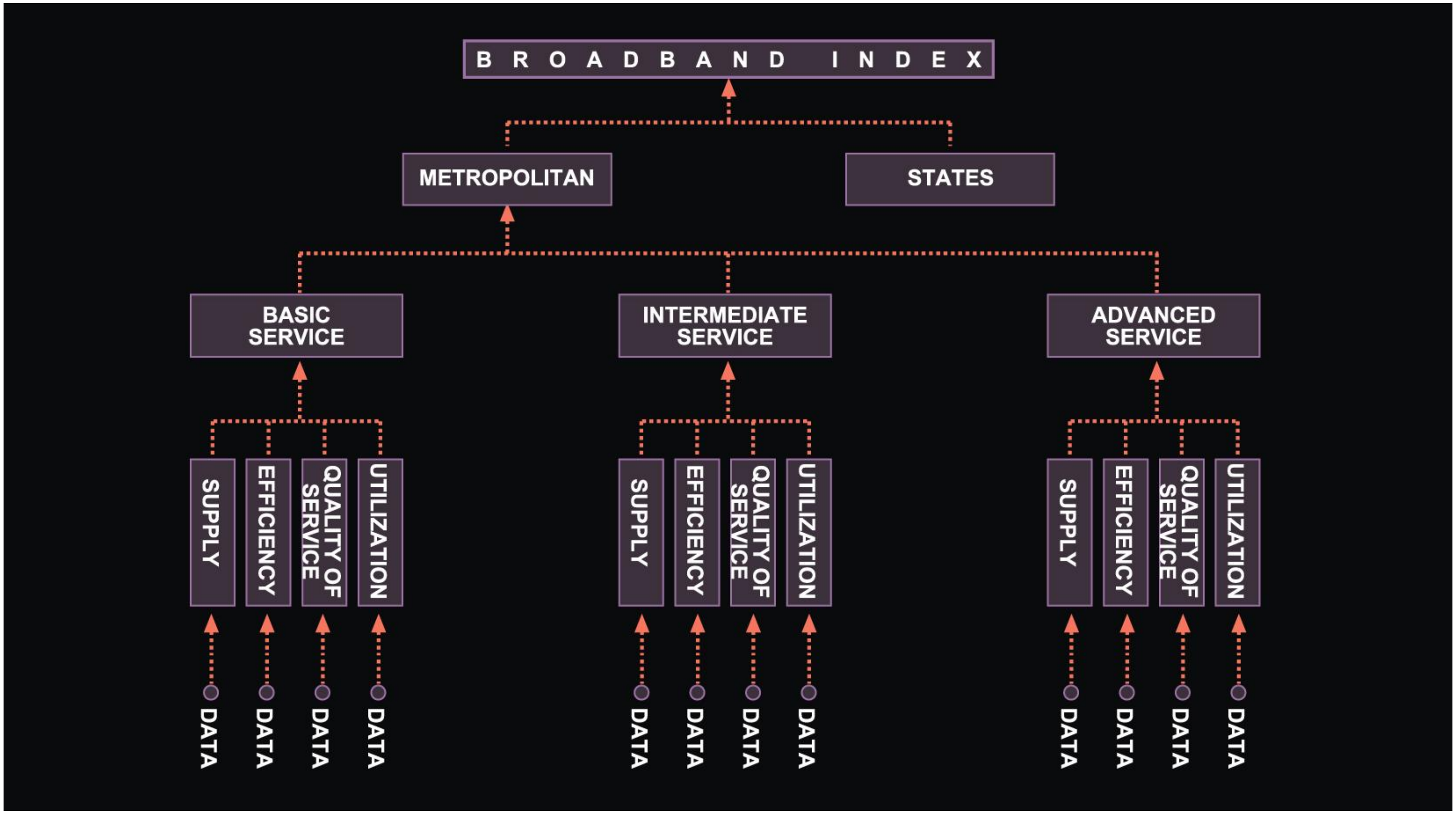


Figure 4. Broadband Hierarchy

Energy

- **General Definition**: Providing power and fuels for business, residential, industry, transportation and agriculture

- **Technical Definition**: Energy infrastructure includes: (1) networks that produce or import raw energy materials and distribute them to conversion infrastructure, such as pipes for oil and natural gas; (2) facilities that convert raw energy materials to useful forms of energy resources (fuels and electricity), such as refineries and power plants; and (3) networks that deliver refined fuels and electricity to end users in households, businesses, industry, mining, agriculture and other activities, such as electricity transmission lines and other means of transportation. (Whitehouse, 2001)

Energy drives the world. Energy generation and distribution vary by sector and by source. The vulnerability to disruptions in the supply of energy is exacerbated by high demand, but the electric grid supports our ability to share energy among regions. All analyses can be conducted by sector and by source (domestic / imported).

Other resources include Electric Power Research Industry (EPRI) maps of generating capacity, as well as transmission and distribution networks. Also of value would be a graphical representation of the location of growth in alternative fuels. Candidate indicators are shown in Table 18. A complete diagram of the hierarchy for the Energy Index is shown in Figure 5.

Table 18. Candidate Energy Indicators

Criteria	Transportation	Industrial/ Manufacturing	Commercial	Agricultural
Supply	% area receiving reliable supply (e.g., 99% availability) Circuit miles of transmission lines per gigawatt of peak demand			
Efficiency	$/gal/ average annual income	$/kw hr		
Quality of Service	# days/ year with rationing of capacity limitations	Number of blackouts per year/ mile of transmission Number of blackouts per kw hr of generation capacity % Generating capacity from alternative energy Diversity of sources		
		Number of brownouts per year/ mile of transmission Number of brownouts per kw hr of generation capacity		
Utilization	Regional oil refinery capacity in gal/day	KJ of energy consumer per capita per year KW hr of generation capacity available at peak demand		

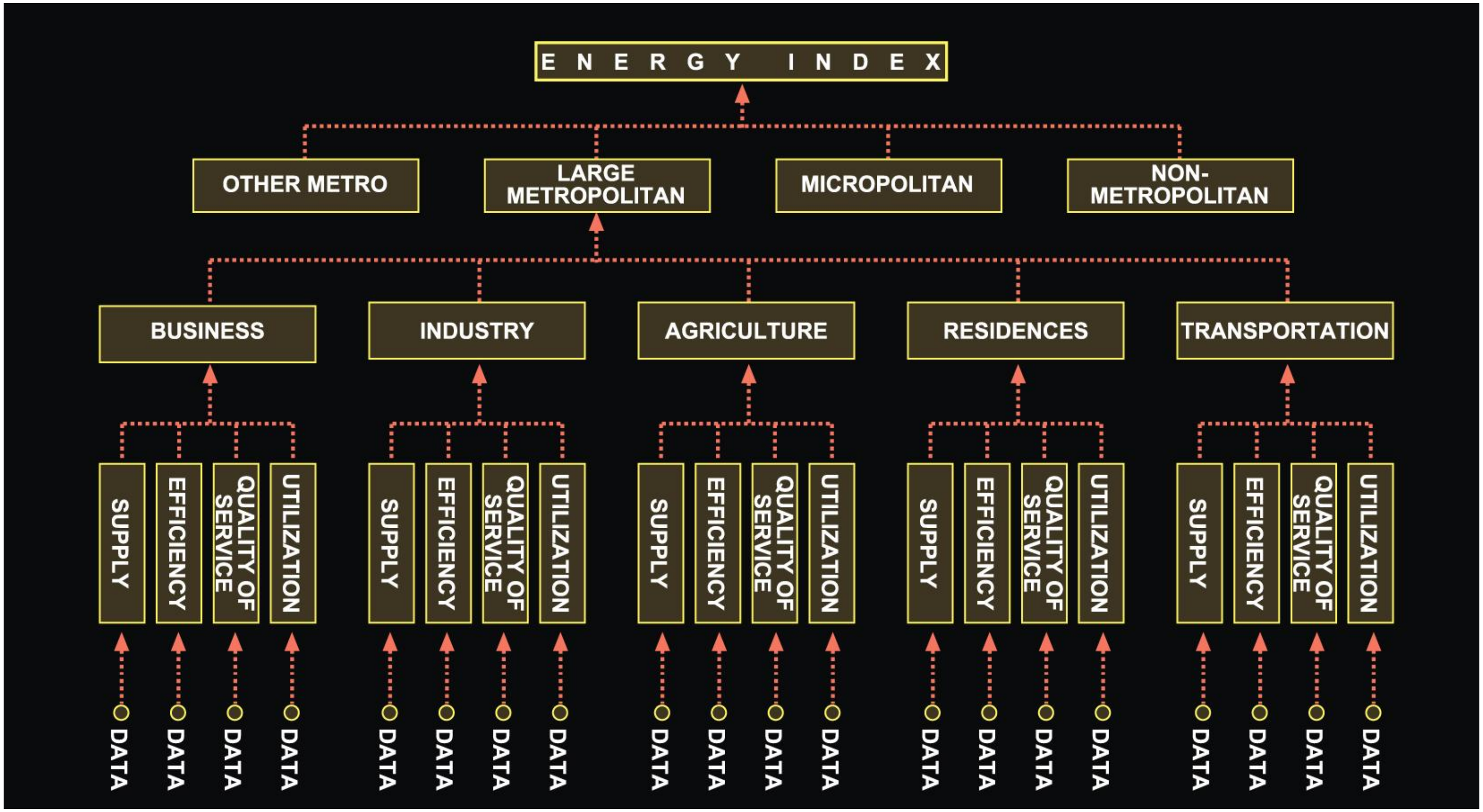


Figure 5. Energy Hierarchy

Water

- **General Definition**: Supplying water for communities, economies and agriculture, and removing wastewater and storm water from those same locations

- **Technical Definition**: The part of the total water system – which includes rivers, lakes, rainfall, etc. – that is the man-made portion (the controllable portions) as infrastructure to supply water for communities, economies, and agriculture. The facilities, such as the reservoirs, towers, pipes, pumps, sewers, treatment plants and drainage systems that we rely on every day to store, transport and treat our water are commonly divided into drinking (potable) water, wastewater and storm water infrastructure. Watersheds and water resources are important for flood control, reducing the impact of droughts and supporting both agriculture and recreation. (Infrastructure Canada, 2004; Hyman et al, 1998)

Three subsectors are relevant to the water sector: potable water, wastewater (both sewage and storm water), and water resources. The performance of our potable water is subject to shifting climate patterns (the pattern of rainfall and snow across the U.S. resulting in some regions being flooded on a more regular basis, other regions suffering though prolonged droughts, etc.) and degradation of our water treatment plants and our water distribution systems. Our wastewater system is often under capacity, with integrated storm water and sewage. Intense rainfall events often overload plants, and imposing environmental pressures on natural bodies of water.

Some consideration may be given to using different weighting schemes in different regions of the country. For example, the focus may be on potable water in the West and Southwest but on sewage and storm water in the Northeast.

Supplemental data serves to capture the performance of our water resources. Maps include a drought map of the U.S., as well as key water resource facilities such as Lake Meade in the West (Colorado River Commission). The lake level has dropped more than 100' in the last decade, and a further drop of 45' to a surface elevation of 1050' would shut down power generated from the Hoover Dam to 22 western states. Issues like this cross the line between environment (rainfall) and infrastructure. Candidate water indicators are shown in Table 19. A complete diagram of the hierarchy for the Water Index is shown in Figure 6.

Table 19. Candidate Water Indicators

Criteria	Potable Water		Wastewater (Sewage and Storm water)	
	Treatment	Distribution	Treatment	Distribution
Supply	% area served		% waste treated	% area served
Affordability	$ per 1000 gals		$ per 1000 gals	
Quality of Service	% water consumed meeting treatment standards	# breaks/ year	Treatment level (using standard definitions)	# breaks/ year
	Health events/year Demand/Capacity ratio	% losses	# overflow events/ year	# sewer backups reported/year
Utilization	Millions of gals/ day		Millions of gals/ day	
	Potential reuse (% of usage)			

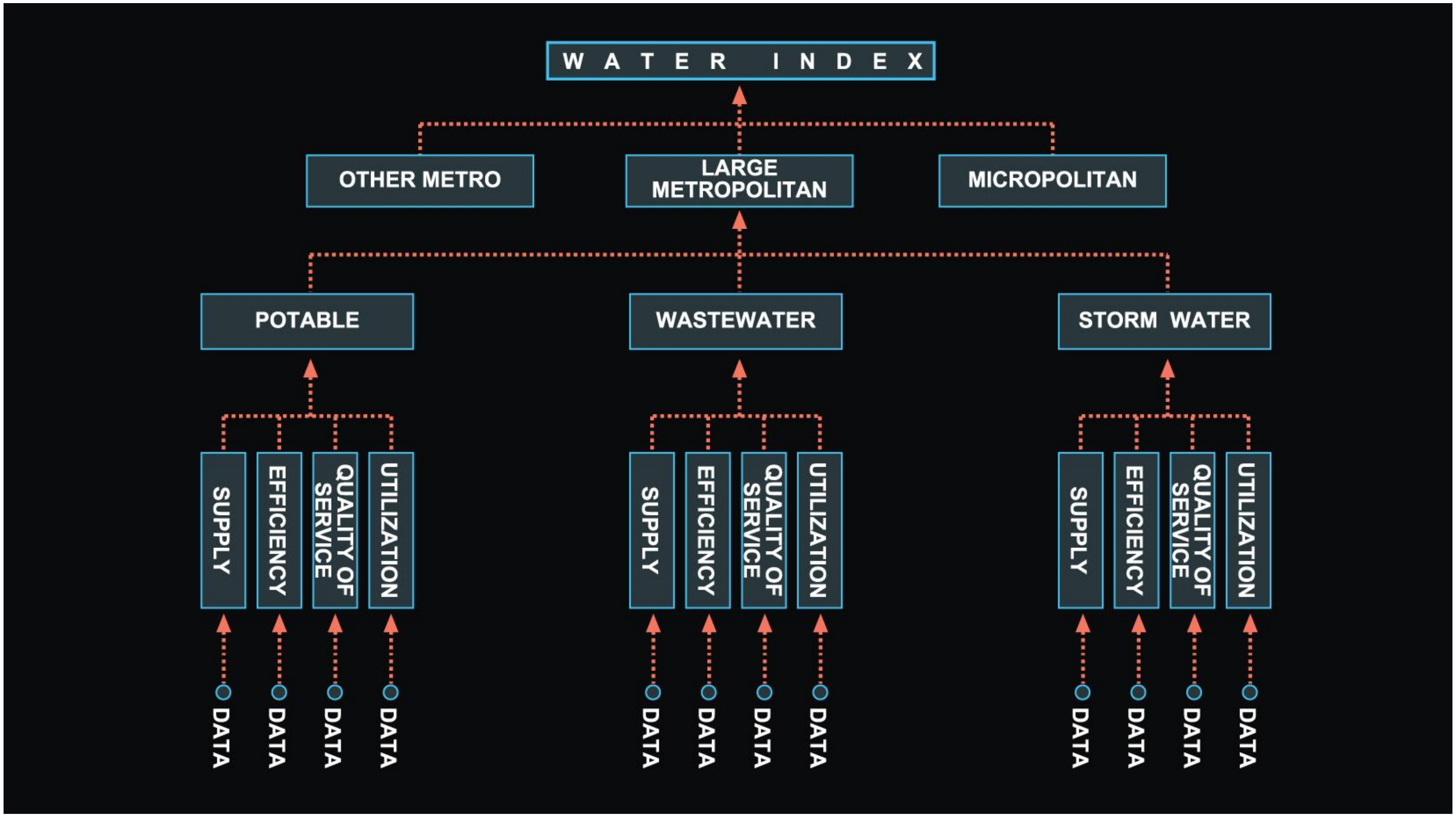


Figure 6. Water Hierarchy

NEXT STEPS

Project Development Stage

The Initiation Stage of the Infrastructure Index Project created the foundation for building each of the other three component indices and for creating the Infrastructure Index representing all four components. The second stage will involve the completion of the specific tasks as outlined below. We recognize that additional tasks may become necessary during the year-long duration of the project.

The first tasks are focused on completing the technical framework necessary to refine and complete the Transportation Index, develop the other three Component Indices for energy, water and broadband and completing the Infrastructure Index. This includes finalizing the sampling strategy for each Component Index, finalizing the categories and indicators, gathering the data for each indicator from each sample geography, assembling the input for the weighting and developing the model that serves as the calculator for each of the Component Indices and the Infrastructure Index.

The methodology will follow a similar approach to that used for the demonstration Transportation Index with some recognition that the sampling strategy will be modified to reflect the organizational structure of the component infrastructure and data, and the specific types of data may vary.

In a separate task, we will establish the correlation between U.S. economic and infrastructure performance. The description of advisory services is provided in a separate section below.

The Project Development Stage is projected to take 12 months beginning in February 2010 through February 2011. This stage will require continued interaction with the U.S. Chamber of Commerce staff and the project team in the form of meetings and regular conference calls. The meetings will also include stakeholder input.

Technical Framework

To create the Infrastructure Index, the following tasks will be completed in the Project Development Stage.

Task 1: Finalize the sampling strategy (by geographic units) for each Component Index.

- Revisit and evaluate the sampling strategy for each of the indicators.
    - While only minor changes to the sampling strategy for the Transportation Index are expected, each of the other three Component Indices will require significant research and inputs from

users, providers and area experts to make a final determination of which geographic sampling strategy will be used for each.
    - Consider the impact of the geographic sampling strategy for each sector on the development of state-by-state as well as national level indices.
- Establish economic categories for sampling relevant to each of the three other Component Indices to determine an appropriate sample size by economic strata.

Task 2: Complete the Transportation Index

- While a demonstration version of the Transportation Index has been completed, it is not yet fully developed and capable of fully revealing the performance characteristics of this infrastructure system. To make it fully functional require revisions of the indicators used in the demonstration and additional indicators based on Chamber member feedback, and associated data collection for all final transportation indicators.
- The demonstration Transportation Index used only data from 2 different years to demonstrate the ability of the Index to show differences in performance and thereby trends in performance over time. In this stage the data for additional years will be researched and integrated into the model.
- The prototype Index developed in the Initiation Stage used only past data to show previous trends. However, in this stage a detailed methodology will be developed for consistently extrapolating indicators for future years. The Transportation Index will cover the period 1990-2007 and extrapolate the index to 2015. However, it should be noted that some of the earlier data (particularly 1990-1994) may not be available and historical data may have to be estimated using interpolation and extrapolation methods.
- The process used to create the Transportation Index will be employed to develop state-by-state Transportation Indices. The intent is to use the same indicators, but these indicators will be adjusted to account for the different scales relative to the size (e.g., economic output, population, etc.) of each state.
- The trend line for the state-by-state indices will use three reference points: 1995, 2000, and 2007.

Task 3: Develop the Energy Index

- While a conceptual model of the Energy Index has been developed, a review of the initial categories and indicators will be used in the building of this Index. This will also involve a review of the indicators used in ongoing energy work for the US Chamber to identify possible conceptual gaps in both the categories and indicators used in creating the Index. Following this analysis a list of categories and indicators will be finalized.
- Once the categories and indicators are finalized the required data sources will be indentified and the necessary data collected.

- Appropriate weights and expansion factors will be developed to reflect the relative importance of different indicators and the differences between the sample and the U.S. as a whole.
- Once the data has been assembled and organized, completing the Index will require reviews by the U.S. Chamber staff and area experts and a review by stakeholders including telephone presentations, meetings and surveys to properly weight the indicators prior to entering it into the computational model.
- The final step in the creating the Energy Index will be to calculate the Index (including normalizing the data and generating expansion factors).
- We will develop the Energy Index for the period 1990-2007 and extrapolate the index to 2015.
- The trend line for the state-by-state Energy Indices will use the reference points of 1995, 2000, and 2007.

Task 4: Develop the Water Index

- The process for creating the Water Index will follow the same steps as the Energy Index. The conceptual model of the Water Index will be reviewed. This will involve analyzing, evaluating and then finalizing the categories and indicators to be used in the building of this index.
- Once the categories and indicators are finalized, the required data sources will be indentified and the necessary data collected.
- Appropriate weights and expansion factors will be developed to reflect the relative importance of different indicators and the differences between the sample and the US as a whole.
- Once the data has been assembled and organized, completing the Water Index will require reviews by the U.S. Chamber staff and area experts and a review by stakeholders including telephone presentations, meetings and surveys to properly weight the indicators prior to entering it into the computational model.
- The final step in the creating the Water Index will be to calculate the Index (including normalizing the data and generating expansion factors).
- We will develop the Water Index for the period 1990-2007 and extrapolate the index to 2015.
- The trend line for the state-by-state Water Indices will use the reference points of 1995, 2000, and 2007.

Task 5: Develop the Broadband Index

- Based on the decision to move forward with this Component Index, the process for creating it will follow the same steps as the Water and Energy Indices.
- The conceptual model of the initial Broadband Index will be reviewed. This will involve analyzing, evaluating and then finalizing the categories and indicators to be used in the building of this Index.

- Once the categories and indicators are finalized the required data sources will be indentified and the necessary data collected.
- Appropriate weights and expansion factors will be developed to reflect the relative importance of different indicators and the differences between the sample and the U.S. as a whole.
- Once the data has been assembled and organized, completing the Broadband Index will require reviews by the U.S. Chamber staff and area experts and a review by stakeholders via telephone presentations, meetings and surveys to properly weight the indicators prior to entering it into the computational model.
- The final step in the creating the Component Index will be to calculate the Index (including normalizing the data and generating expansion factors).
- We will develop the Broadband Index for the period 1990-2007 and extrapolate the index to 2015.
- The trend line for the state-by-state Broadband Indices will use the reference points of 1995, 2000, and 2007.

Task 6: Develop the Infrastructure Index

- The Infrastructure Index will be created by integrating the outputs of the four Component Indices.
- Integrating the four Component Indices will require weights to be given to each Component Index to establish their relative importance in determining U.S. infrastructure performance. Weighting the Component Indices will involve a short survey of an extensive list of individuals representing a broad range of stakeholders. Once the survey is complete, the weightings from the stakeholders will be averaged.
- The final step in the creating the Infrastructure Index will be to calculate the Index.
- We will develop the Infrastructure Index for the period 1990-2007 and extrapolate the index to 2015.

Task 7: Develop and execute a model for the relationship of the Infrastructure Index to economic prosperity.

- Complete literature search and bibliography on economic relevance of Energy, Water and Broadband systems. In addition, search literature on the use of complex indices in economic models and produce bibliography.
- Produce literature review and write literature summary. Review with U.S. Chamber economist and select modeling technique (technology).
- Identify and select and gather data variables to represent economy.
- Generate Economic model with Index.
- Run and test models with Infrastructure Index. Analyze results and revise as necessary to establish correlation between U.S. economy and infrastructure performance.

- Produce report for results of statistical analysis of Infrastructure Index with economic data.
- Generate economic analysis with Component Indices.
- Produce economic report for Component Indices.

Task 8: Document the process

- Draft report to document the methodology, indicators and data used to produce the Infrastructure Index and all of the elements and Component Indices used to create it.
- The final report will document the consultations with Chamber members and experts and explain how performance measures suggested were translated to actual indicators.
- Produce final report for publication that includes project documentation plus sufficient explanatory material to make the Infrastructure Index documentation function as a "stand-alone" report for use by the Chamber.

Advisory Services

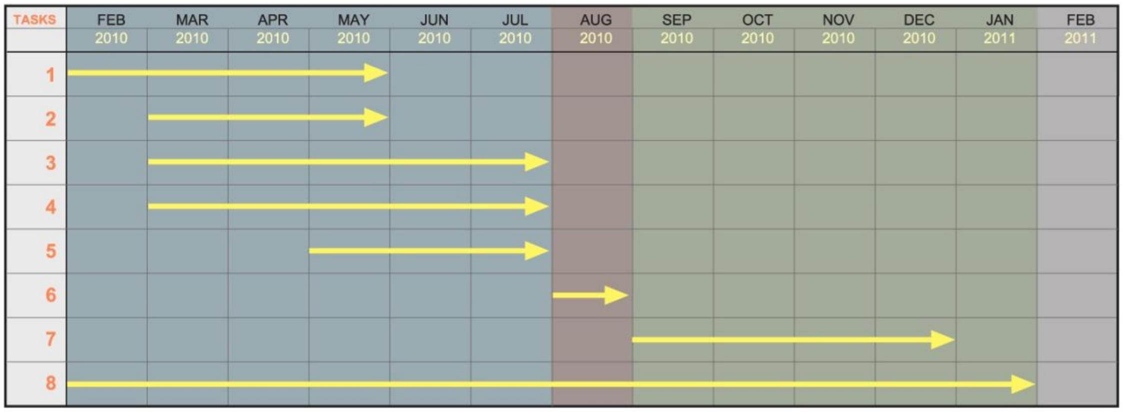
Engaging the Corporate Community

Drawing from its several policy committees and the *Let's Rebuild America* Leadership Council, the U.S. Chamber will develop an oversight group for the project that will be involved in reviewing the project as it progresses and ideally supporting the project financially. The consulting team may assist in a review of the oversight group membership to identify gaps in participation and potential project supporters among businesses and corporations that should be involved in the Infrastructure Index project. In addition to support of the Infrastructure Index, this activity should build broader and stronger involvement among the business community for *Let's Rebuild America.*

Communications

Communicating the progress and final results of the Infrastructure Index will be an important element of the Project Development Stage. As each component of the Infrastructure Index is created, including the identification of indicators and models, the communications strategy will evolve in parallel. In the Project Completion Stage, the Consulting Team will work closely with the U.S. Chamber staff to ensure that messages and positioning related to the project are technically accurate while achieving high levels of impact.

Figure 7. Timeline for Task Completion



Task 1 Finalize Sampling Strategy and Geographic Units

Task 2. Enhance the Transportation Index

Task 3. Develop the Energy Index

Task 4. Develop the Water Index

Task 5. Develop the Broadband Index

Task 6. Develop the Infrastructure Index

Task 7. Economic Correlation

Task 8. Documentation

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APPENDIX A – AN OVERVIEW OF SOME EXISTING INDICES

This appendix will briefly review the construction of some existing indices.

The Consumer Price Index

The Consumer Price Index (CPI) is a measure of the average change over time in the prices paid by urban consumers for a representative market basket of consumer goods and services (Bureau of Labor Statistics, 2010). The CPI reflects spending patterns for each of two population groups: all urban consumers and urban wage earners and clerical workers representing about 87 percent of the total U.S. population, from which samples are selected. The CPI market basket is developed from detailed expenditure information provided by families and individuals on what they actually bought. The CPI represents all goods and services purchased for consumption by the reference population, arranged into eight major groups: food and beverages (breakfast cereal, milk, coffee, chicken, wine, full service meals, snacks), housing (rent of primary residence, owners' equivalent rent, fuel oil, bedroom furniture), apparel (men's shirts and sweaters, women's dresses, jewelry), transportation (new vehicles, airline fares, gasoline, motor vehicle insurance), medical care (prescription drugs and medical supplies, physicians' services, eyeglasses and eye care, hospital services), recreation (televisions, toys, pets and pet products, sports equipment, admissions), education and communication (college tuition, postage, telephone services, computer software and accessories), and other goods and services (tobacco and smoking products, haircuts and other personal services, funeral expenses). The Consumer Price Indices (CPI) program (http://www.bls.gov/CPI/) produces monthly data.

The Dow Jones Industrial Average

The Dow Jones Industrial Average (DJIA) is an index that shows how certain large, publicly-owned U.S. companies (covers all industries with the exception of Transportation and Utilities) have traded during a standard trading session in the stock market, so as to gauge the performance of the industrial sector within the American economy (Dow Jones Indices, 2010). The value of the Dow is the sum of all the component prices divided by a divisor, which adjusts whenever one of the component stocks has a stock split or stock dividend. The individual components of the DJIA, currently 30 companies, are occasionally changed as market conditions warrant. When companies are replaced, the scale factor used to calculate the index is also adjusted so that the value of the average is not directly affected by the change. An interactive online database can be accessed through the Dow Jones Industrial Average website (http://www.djaverages.com/).

The Capital Access Index

The Capital Access Index (CAI), compiled by the Milken Institute, identifies quantitative and qualitative measures of the ability of an entrepreneur to gain access to capital in a wide range of countries. The CAI ranks countries according to the ability of businesses and entrepreneurs to finance their strategies and investments for job creation and capital formation. The index aims to measure the depth and breadth of each country's financial system, covering the macroeconomic environment, the strength of economic institutions, financial and banking institutions, equity and bond markets, availability of capital and ability to access funds internationally (Miliken Institute Online, 2008). A fundamental assumption underlying the CAI is that access to capital will tend to enliven and infuse a country's real economy with the on-the-ground competition necessary for innovation, profitability and long-run growth. Such access should permit all individuals to acquire wealth, not just to select ensconced elite. Countries that promote access to capital will possess more competitive markets and will in the long run achieve superior economic performance (Yago et al., 2001).

Using a benchmarking system, the CAI is generated by determining which values would achieve scores from 1 to 7, with a score of 1 indicating poor conditions of capital access and a score of 7 indicating excellent conditions. Vast quantities of data on international economic conditions and activity exist, many with direct or indirect bearing on "capital access" broadly construed, each of which is composed of a number of specific quantitative and qualitative components. The general economic environment creates the conditions for entrepreneurial activity. Macroeconomic measures reflect important variables relating to inflation, interest rates and fiscal policy. Institutional measures reflect the fact that if legal contracts are not enforced, or either private or government agents can expropriate assets or earnings with no recourse, capital access will be constrained. The second set of variables for capital access concerns the ease of securing bank lending. A third set of variables is meant to capture an additional avenue of capital access: equity and bond market development. More sophisticated instruments such as securitization are included in the measure of advanced capital market development.
The annual CAI is published by Milken Institute Online (milkeninstitute.org).

RepuTex Energy Index

The RepuTex Future Energy Index series tracks the performance of stocks deriving primary revenue from alternative energy activities. The series seeks to provide investors with exposure to a range of future energy themes, providing not only access to stocks involved in the direct generation and delivery of nuclear, water and alternative energy products, but also exposure to stocks engaged in the upstream supply of components, benefiting from a surge in supply as demand grows. The RepuTex Future Energy Index Series is made up of seven indices (RepuTex, 2009):

1. **RepuTex Future Energy 100 Index**
   Derived from global stocks engaged in alternative energy, nuclear and water activities, selected stocks are active in direct production and distribution of alternative energy, as well as related upstream supply services (RepuTex, 2009).

2. **RepuTex Alternative Energy Index**
   A subset index of the Future Energy 100 Index that does not include water, nuclear stocks and diversified utilities stocks, instead focusing solely on global stocks engaged in pure play alternative energy production and distribution, as well as related upstream component supply (RepuTex, 2009).

3. **RepuTex Alternative Energy (Upstream Supply) Index**
   A subset index of the RepuTex Alternative Energy Index that focuses solely on global stocks engaged in upstream component supply (RepuTex, 2009).

4. **RepuTex Alternative Energy (Asia) Index**
   This index is derived from global stocks engaged in alternative energy, nuclear and water activities deriving primary revenue from operations in China, India, Korea, Japan and Taiwan. Selected stocks are active in production and distribution of alternative energy, as well as related upstream component supply (RepuTex, 2009).

5. **RepuTex Solar Index**
   A subset index of the RepuTex Future Energy 100 Index, its purpose is to provide exposure solely to companies engaged in pure play solar energy production or upstream component supply, including distribution, technology, components, materials, equipment and services (RepuTex, 2009).

6. **RepuTex Nuclear Index**
   This index is derived from global stocks engaged in pure play nuclear energy production, distribution or upstream supply, including uranium mining, conversion plants, enrichment, fuel fabrication, reactors and equipment (RepuTex, 2009).

7. **RepuTex Water Index**
   Derived from global stocks engaged in pure play water related businesses, its focus includes water utilities and infrastructure, water equipment, desalination, materials and services (RepuTex, 2009).

LEED Rating System

LEED, developed by the United States Green Building Council (USGBC), is currently made up of nine programs each referencing a different type of green building infrastructure. The following programs are currently available: New Construction, Existing Buildings, Schools, Homes, Retail, Neighborhood Development, Core and Shell, Commercial Interiors, and Healthcare. Each of these programs is a third party certification process providing owners, engineers and planners with the tools necessary to have immediate and measurable impacts on their building/neighborhood performance (United States Green Building Council, 2008).

The information required by the rating systems is gathered by committees that adhere to the USGBC policies and procedures used to guide development (U.S. Green Building Council, 2007). The rating systems are market-driven and formulated using accepted energy and environmental principles that encompass both established and innovative practices (U.S. Green Building Council, 2007). Each rating system consists of mandatory prerequisites as well as credits that can be achieved in order to obtain certification. In order for a project to be certified, the minimum point total for that rating system must be achieved, and, if exceeded, additional points may apply to silver, gold or platinum certification.

Living Planet Index

The Living Planet Index monitors biodiversity throughout the world by tracking trends in a large number of populations of species. It is based on trends from approximately 5,000 populations of 1,686 species of reptile, mammal, bird, fish and amphibian across the world. The changes in species populations are averaged and compared to 1970 (which is given a value of 1.0) (World Wildlife Fund (WWF), 2008).

The global Living Planet Index aggregates two indices: temperate and tropical. The temperate index includes terrestrial and freshwater species from the Palearctic, Nearctic, and marine species north or south of the tropics (WWF, 2008). The tropical index includes terrestrial and freshwater species found in Afrotropical, Neotropical, and marine species from the zone between the Tropics of Cancer and Capricorn (WWF, 2008).

Environmental Sustainability Index

The Environmental Sustainability Index (ESI) is a composite index that tracks socioeconomic, environmental and institutional indicators that influence environmental sustainability nationwide (Yale Center for Environmental Law and Policy and Columbia University Center for International Earth Science Information Network, 2005). It integrates 76 data sets into 21 indicators in order to assess past and present pollution levels, environmental management efforts, the capacity of a society to improve its environmental performance and natural resource endowments (Yale Center for Environmental Law and Policy and Columbia University Center for International Earth Science Information Network, 2005). The indicators allow for comparison across five broad categories: Environmental Systems, Reducing Environmental Stresses, Global Stewardship, Reducing Human Vulnerability to Environmental Stresses and Societal and Institutional Capacity to Respond to Environmental Challenges (Yale Center for Environmental Law and Policy and Columbia University Center for International Earth Science Information Network, 2005).

Opacity Index

The Opacity Index is used to measure economic and financial risk across the world. It measures individual countries based on five components related to "negative social capital." These five components include Corruption, Legal System Inadequacies, Economic Enforcement Policies, Accounting Standards and Corporate Governance, plus Regulation (CLEAR) (Kurtzman and Yago, 2009). The index is based entirely on empirical observations and is updated every five years. The index represents over 70 variable inputs per country and the next update will be completed in 2011 (Kurtzman and Yago, 2009). In addition to the major update every five years, the developers of the index conduct a "light update" to encompass fast changing data such as accounting standards. The Opacity Index allows government leaders to compare their economic and financial status to other countries throughout the world (Kurtzman and Yago, 2009).

APPENDIX B - STATES IN REGIONS FOR SAMPLING STRATEGY

Table 20 shows the states in each of the eight regions defined by the Bureau of Economic Analysis (BEA, 2006).

Table 20. Region Codes and States

Code	State or Region name	Abbr	Code	State or Region name	Abbr
91	**New England Region (1)**	NENG	95	**Southeast Region (5)**	SEST
9	Connecticut	CT	1	Alabama	AL
23	Maine	ME	5	Arkansas	AR
25	Massachusetts	MA	12	Florida	FL
33	New Hampshire	NH	13	Georgia	GA
44	Rhode Island	RI	21	Kentucky	KY
50	Vermont	VT	22	Louisiana	LA
92	**Mideast Region (2)**	MEST	28	Mississippi	MS
10	Delaware	DE	37	North Carolina	NC
11	District of Columbia	DC	45	South Carolina	SC
24	Maryland	MD	47	Tennessee	TN
34	New Jersey	NJ	51	Virginia	VA
36	New York	NY	96	**Southwest Region (6)**	SWST
42	Pennsylvania	PA	4	Arizona	AZ
93	**Great Lakes Region (3)**	GLAK	35	New Mexico	NM
17	Illinois	IL	40	Oklahoma	OK
18	Indiana	IN	48	Texas	TX
26	Michigan	MI	97	**Rocky Mountain Region(7)**	RKMT
39	Ohio	OH	8	Colorado	CO
55	Wisconsin	WI	16	Idaho	ID
94	**Plains Region (4)**	PLNS	30	Montana	MT
19	Iowa	IA	49	Utah	UT
20	Kansas	KS	56	Wyoming	WY
27	Minnesota	MN	98	**Far West Region (8)**	FWST
29	Missouri	MO	2	Alaska	AK
31	Nebraska	NE	6	California	CA
38	North Dakota	ND	15	Hawaii	HI
46	South Dakota	SD	32	Nevada	NV
			41	Oregon	OR
			53	Washington	WA

APPENDIX C – TRANSPORTATION INDICATORS

This appendix summarizes each of the following transportation indicators used in the prototype:

- Highway Density
- Airport Access
- Rail Density
- Airport Proximity
- Inland Waterway Density
- Port Access
- Travel Time Reliability
- Safety
- Road Roughness
- Uncongested Roads
- Bridge Integrity
- Port Congestion
- Air Passenger Congestion

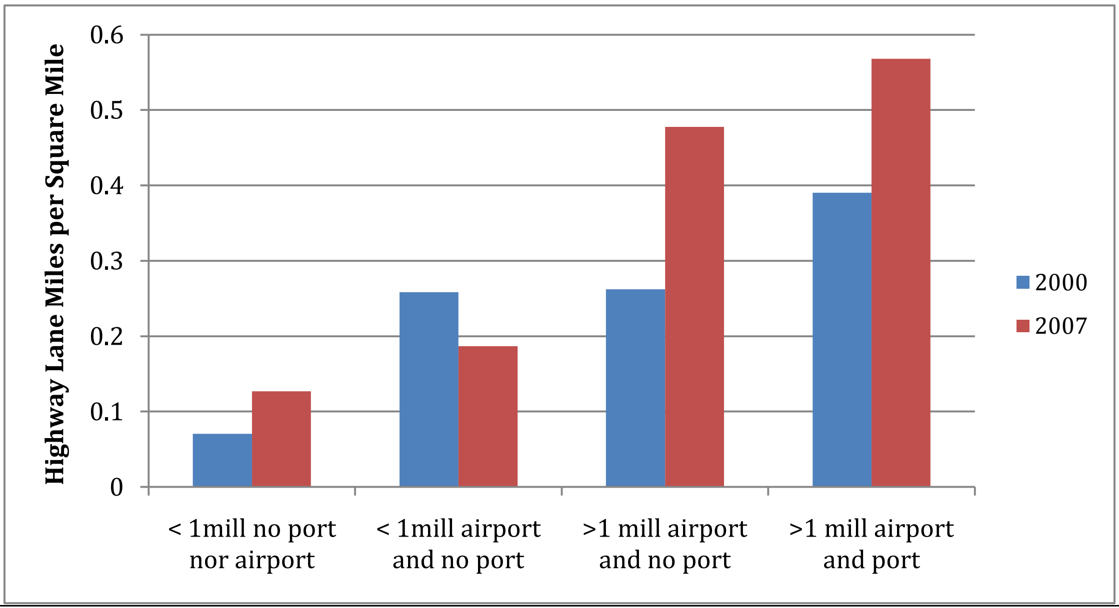
For each indicator the following data are provided:

- Definition
- Why it's important
- Criteria metric
- Historical and projected values (limited to 2000 and 2007)
- Observations
- Contribution to the transportation sub-index
- Primary data sources
- Data issues and opportunities

After the tables for the thirteen indicators used for the prototype index, we list some additional data sources that could be exploited in the Project Development Stage to fulfill the full list of potential indicators of Transportation infrastructure performance (see Table 13 for the complete list).

Indicator #1	Highway Density
Definition:	Highway lane miles per square mile within the statistical area
Why it's important:	Highway density indicates the supply of highway mobility and interconnectivity for roadway travelers. The highway density is an indicator of the development of the highway system.
Criteria metric:	Supply

2000 and 2007 Values:



Observations:

- Highway density from 2000 to 2007 increases at the national level.
- Highway density tends to be higher in large cities.

Contribution to Index:

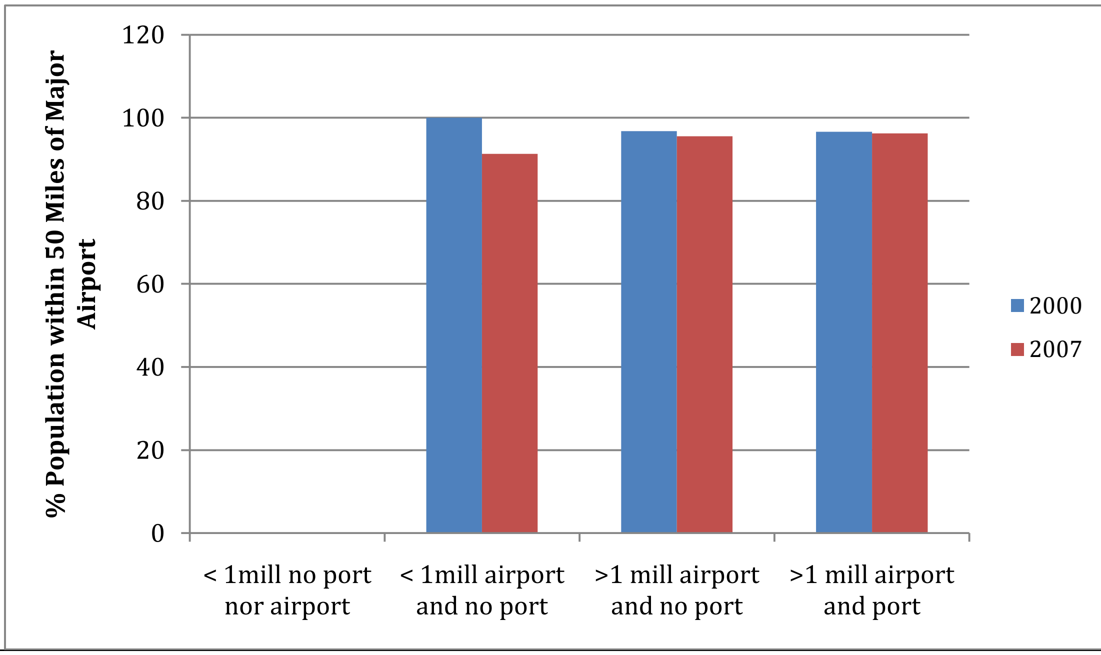
MSA (population under 1 million) without airport or port-0.133
MSA (population under 1 million) with airport and no port- 0.116
MSA (population over 1 million) with airport and no port- 0.063
MSA (population over 1 million) with airport and port- 0.056

The weight factors are determined and calculated from Analytical Hierarchical Process.

Primary data sources:	Bureau of Transportation Statistics: Highway Performance Monitoring System (highway lane miles) available at http://www.bts.gov/programs/geographic_information_services/ and U.S. Census Bureau (square miles)
Data issues & opportunities	

Indicator #2	Proximity of Airport
Definition:	Percent of population in statistical area within a fifty mile radius of a major airport
Why it's important:	The airport access indicates the supply of air transportation facilities available to the population in the statistical area.
Criteria metric	Supply

2000 and 2007 Values:



Observations:
Airport facilities remained fairly constant from 2000 to 2007. Therefore, the airport access for population that lives within a fifty miles radius from a major airport remained fairly constant as well.

Contribution to Index:

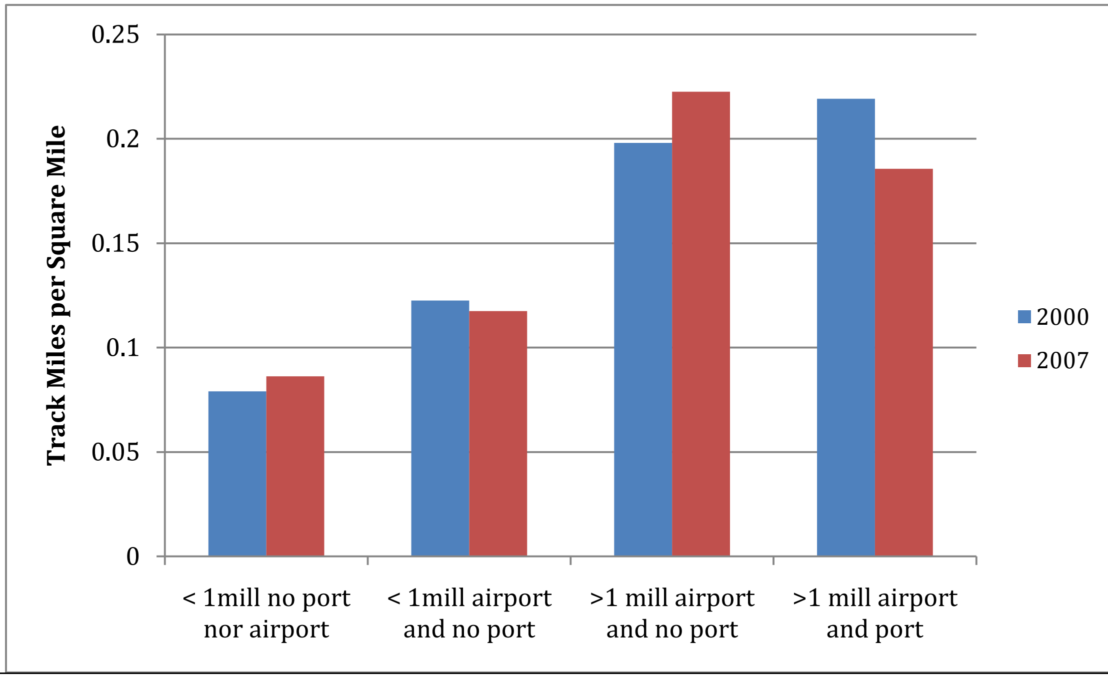
MSA (population under 1 million) without airport or port-0.000
MSA (population under 1 million) with airport and no port- 0.039
MSA (population over 1 million) with airport and no port- 0.021
MSA (population over 1 million) with airport and port- 0.019

The weight factors are determined and calculated from Analytical Hierarchical Process.

Primary data sources:	Bureau of Transportation Statistics (airport location) available at http://www.bts.gov/programs/geographic_information_services/.
Data issues & opportunities	MSAs without airports are included in the data analyses.

Indicator #3	Rail Density
Definition:	Track miles per square mile within the statistical area
Why it's important:	The rail density indicates the supply of rail services for transit riders. The rail density is an indicator of the development of the rail system.
Criteria metric	Supply

2000 and 2007 Values:



Observations:
The rail track miles per square miles slightly increased from 2000 to 2007, except for the largest MSAs with both airports and ports.

Contribution to Index:

MSA (population under 1 million) without airport or port-0.010
MSA (population under 1 million) with airport and no port- 0.008
MSA (population over 1 million) with airport and no port- 0.005
MSA (population over 1 million) with airport and port- 0.004

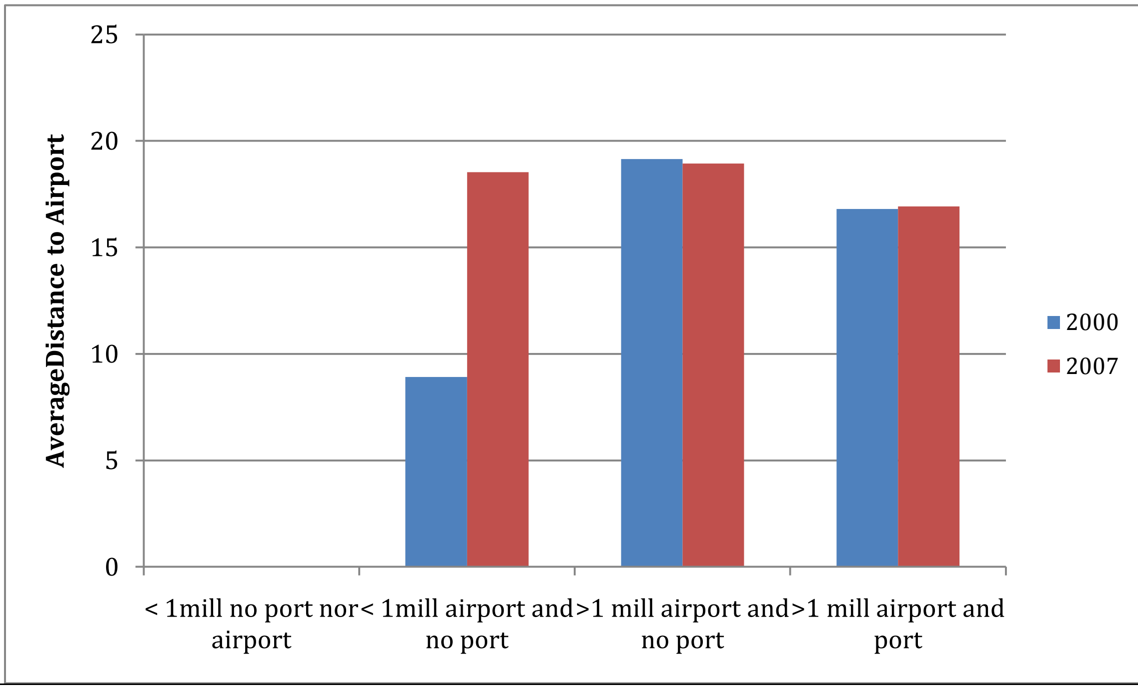
The weight factors are determined and calculated from Analytical Hierarchical Process.

Primary data sources:	Federal Railroad Administration (rail miles) available at http://www.fra.dot.gov/, Bureau of Transportation Statistics available at http://www.bts.gov/programs/geographic_information_services/ and U.S. Census Bureau (square miles)
Data issues & opportunities	2007 Rail data not available online so access by ordering CD from BTS website

Indicator #4	Airport Proximity
Definition:	Average distance to airport within the statistical area
Why it's important:	The airport proximity indicates the accessibility and location of airport facilities.

Criteria metric: Supply

2000 and 2007 Values:



Observations:
Airport facilities remained fairly constant from 2000 to 2007, therefore airport proximity remained fairly constant (with a slight increase in smaller MSAs with no ports) from 2000 to 2007.

Contribution to Index:

MSA (population under 1 million) without airport or port-0.000
MSA (population under 1 million) with airport and no port- 0.041
MSA (population over 1 million) with airport and no port- 0.023
MSA (population over 1 million) with airport and port- 0.020

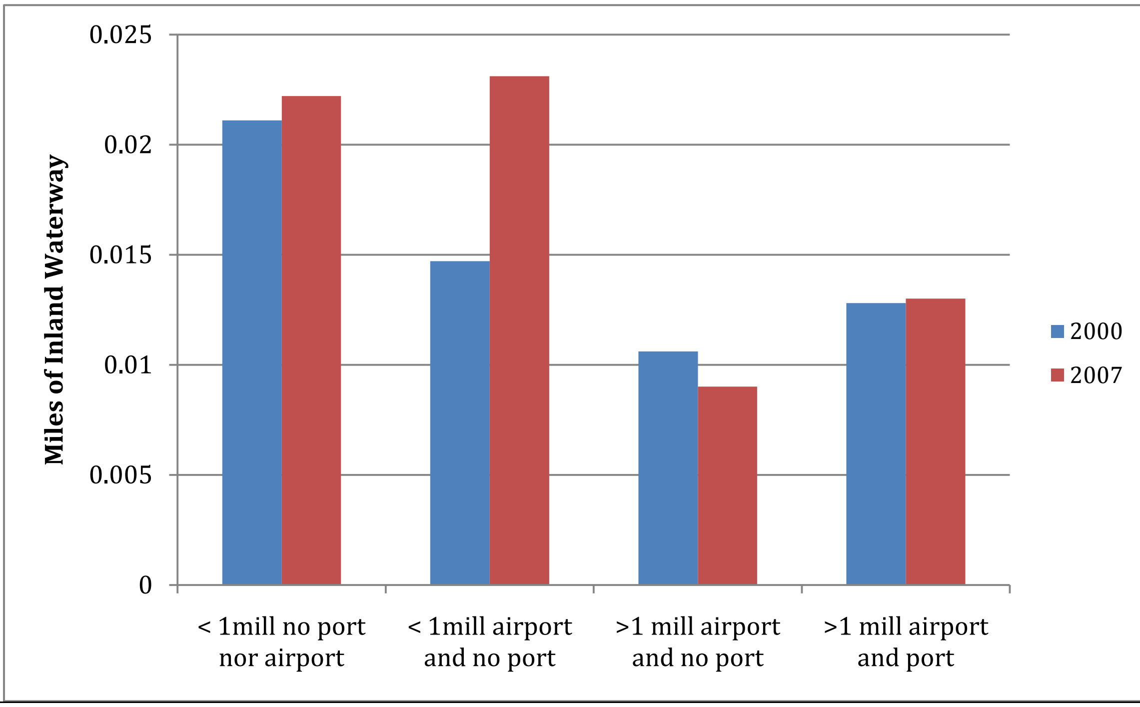
The weight factors are determined and calculated from Analytical Hierarchical Process.

Primary data sources:	Bureau of Transportation Statistics (airport location) available at http://www.bts.gov/programs/geographic_information_services/
Data issues & opportunities	MSAs without airports are included in the data analyses.

Indicator #5	**Inland Waterway Density**
Definition:	Miles of inland waterway per square mile
Why it's important:	The inland waterway density indicates the supply of inland waterway services.

Criteria metric: Supply

2000 and 2007 Values:



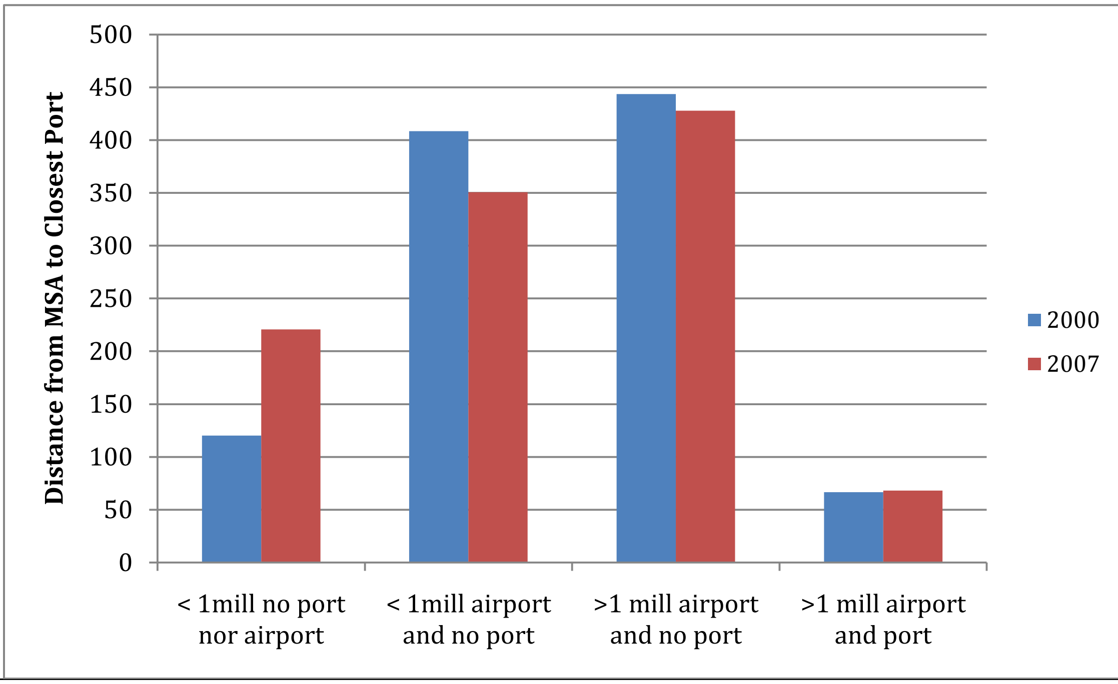
Observations:
Miles of inland waterway remained fairly constant from 2000 to 2007.
The changes in miles of inland waterway per square mile from 2000 to 2007 were primarily a result in changes in the MSA boundaries during that time period.

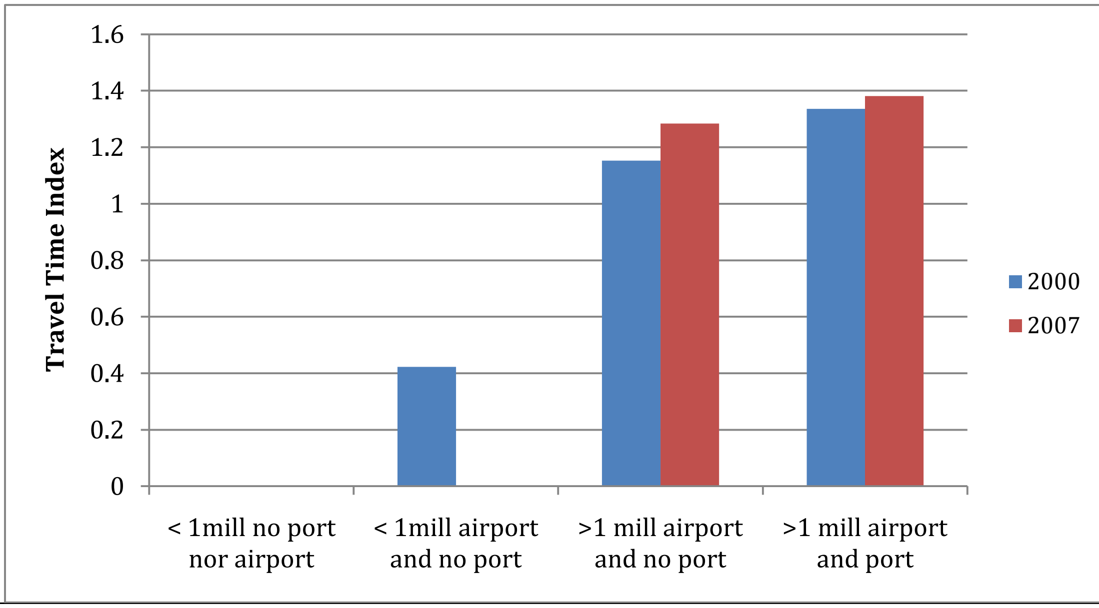
Contribution to Index:

MSA (population under 1 million) without airport or port-0.010
MSA (population under 1 million) with airport and no port- 0.008
MSA (population over 1 million) with airport and no port- 0.005
MSA (population over 1 million) with airport and port- 0.004

The weight factors are determined and calculated from Analytical Hierarchical Process.

Primary data source:	Bureau of Transportation Statistics: United States Army Corps of Engineers Navigation Data Center (waterway miles) available at http://www.iwr.usace.army.mil/NDC/, and U.S. Census Bureau (square miles)
Data issues & opportunities	2007 data not available online so 2009 was used based on the assumption that miles of inland waterway remained constant from 2007 to 2009.

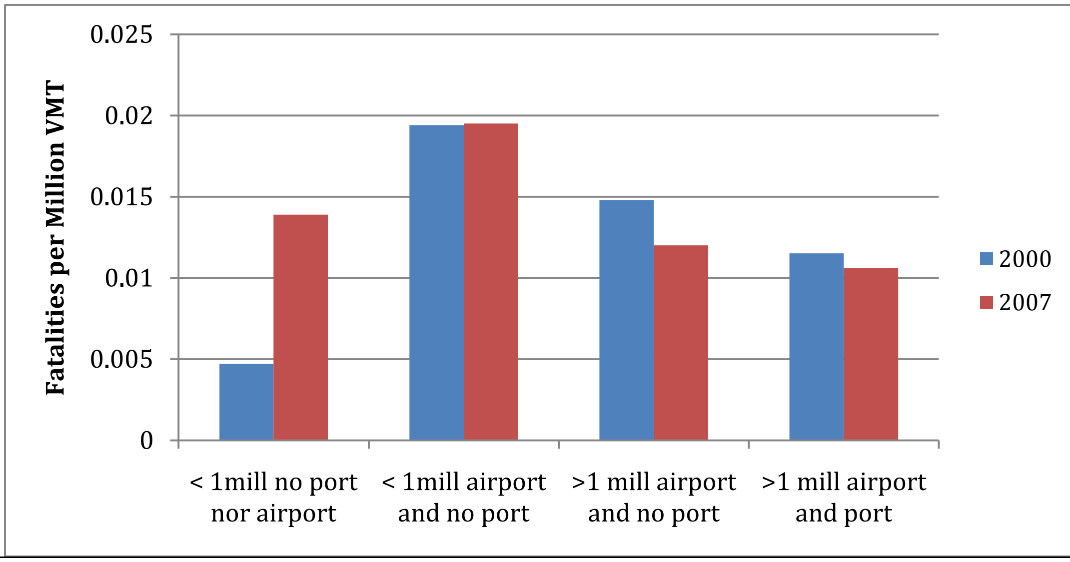
Indicator #6	Port Access
Definition:	Distance from statistical area to the closest international port
Why it's important:	Port access indicates the accessibility of port services within the statistical area.
Criteria metric: Supply	
2000 and 2007 Values: 	
Observations: Port access slightly decreased from 2000 to 2007 in all but the smallest MSAs.	
Contribution to Index: *MSA (population under 1 million) without airport or port-0.045* *MSA (population under 1 million) with airport and no port- 0.039* *MSA (population over 1 million) with airport and no port- 0.021* *MSA (population over 1 million) with airport and port- 0.019* The weight factors are determined and calculated from Analytical Hierarchical Process.	
Primary data sources:	Bureau of Transportation Statistics (port location) available at http://www.bts.gov/programs/geographic_information_services/.
Data issues & opportunities	MSAs without ports are included in the data analyses. Port addresses had to be geocoded into GIS manually.

<table>
<tr><td>Indicator #7</td><td>Travel Time Reliability</td></tr>
<tr><td>Definition:</td><td>The travel time reliability is measured by the Travel Time Index (TTI) which is the ratio of peak period travel time to free flow travel time.</td></tr>
<tr><td>Why it's important:</td><td>The TTI expresses the average amount of extra time it takes to travel during peak hours relative to free-flow travel. A TTI of 1.3, for example, indicates a 20-minute free-flow trip will take 26 minutes during the peak travel times, a 6-minute (30 percent) travel time penalty.</td></tr>
<tr><td colspan="2">Criteria metric: Quality of Service</td></tr>
<tr><td colspan="2">2000 and 2007 Values:

</td></tr>
<tr><td colspan="2">Observations:
Congestion problems tended to be more severe in 2007. The average increase in the travel time penalty was less than 20 percent between 2000 and 2007.</td></tr>
<tr><td colspan="2">Contribution to Index:
MSA (population under 1 million) without airport or port-0.000
MSA (population under 1 million) with airport and no port- 0.000
MSA (population over 1 million) with airport and no port- 0.454
MSA (population over 1 million) with airport and port- 0.401
The weight factors are determined and calculated from Analytical Hierarchical Process.</td></tr>
<tr><td>Primary data sources:</td><td>Texas Transportation Institute, The Annual Urban Mobility Report, available at http://mobility.tamu.edu, currently available from 1982 to 2007. The data are also cited in U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, National Transportation Statistics, table 1-64 at: http://www.bts.gov/publications/national_transportation_statistics/.</td></tr>
<tr><td>Data issues & opportunities</td><td>Detailed data are available for most areas over 1 million population. However, for smaller MSAs, the TTI data are generally aggregated into one number for this group.</td></tr>
</table>

Indicator #8	Safety
Definition:	Safety is measured by the total number of fatalities on a traffic way customarily open to the public in an MSA for a specific year divided by the total Vehicle Miles Traveled (VMT) (in 100 million) in this area during the same period.
Why it's important:	It provides an overall measure of highway safety.

Criteria metric: Quality of Service

2000 and 2007 Values:



Observations:
The number of deaths due to motor vehicle crashes dropped from 2000 to 2007.

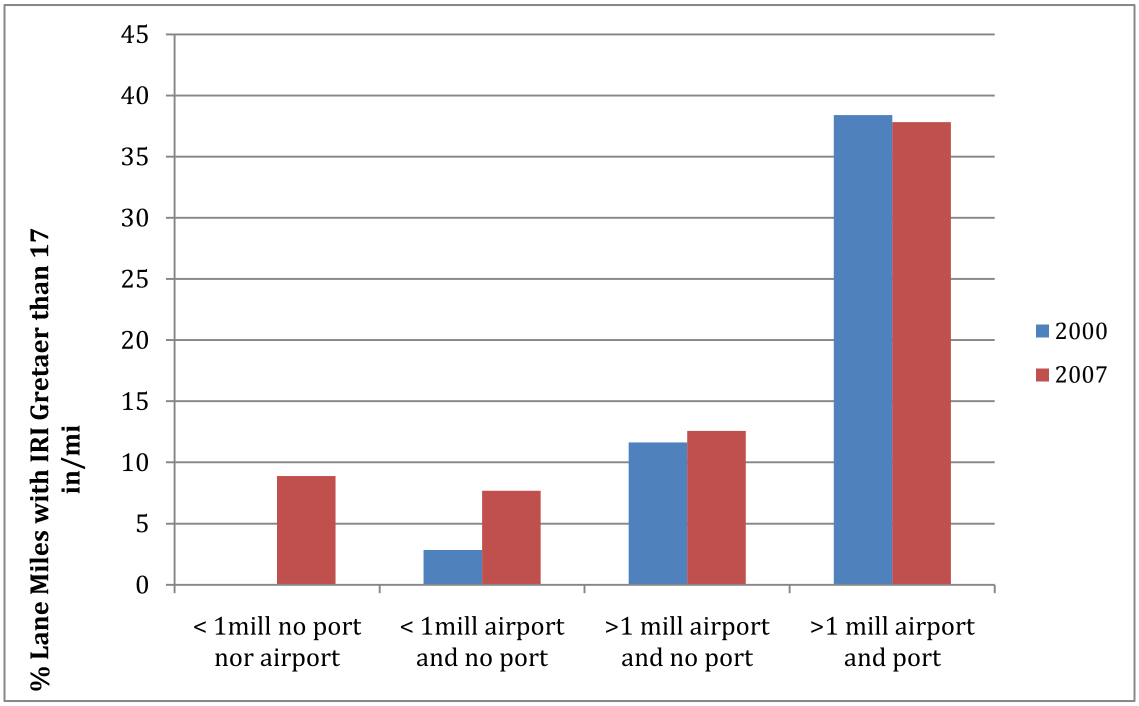
Contribution to Index:
MSA (population under 1 million) without airport or port-0.439
MSA (population under 1 million) with airport and no port- 0.383
MSA (population over 1 million) with airport and no port- 0.209
MSA (population over 1 million) with airport and port- 0.185

The weight factors are determined and calculated from Analytical Hierarchical Process.

Primary data sources:	The number of fatalities data is from the Fatality Analysis Reporting System (FARS): http://www-fars.nhtsa.dot.gov/Main/index.aspx. The data are available from 1994 to 2008 by state and county (U.S. Department of Transportation, 2010). More data (from 1975 to 2008) are also available at the NHTSA ftp: ftp://ftp.nhtsa.dot.gov/FARS/. VMT data can be derived from the annual Highway Performance Monitoring System (*HPMS*) data.
Data issues & opportunities	

Indicator #9	Road Roughness
Definition:	Road roughness is measured by the percentage of lane miles that have IRI roughness values greater than 170 in/mi.
Why it's important:	International Roughness Index (IRI) is a dimensionless quantity used for measuring road roughness (ride quality) and proposed as a world standard by the World Bank.
Criteria metric: Quality of Service	

2000 and 2007 Values:



Observations:

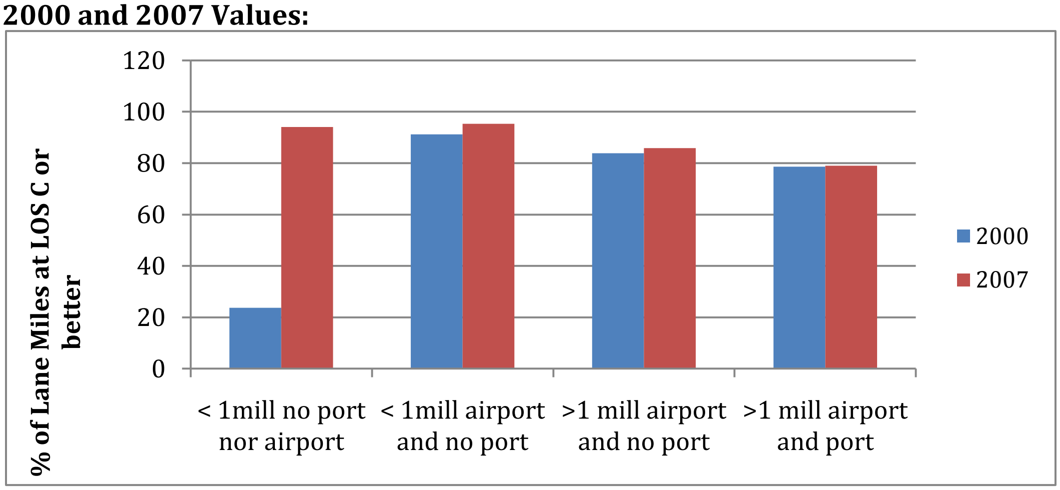
Road roughness tended to increase from 2000 to 2007.

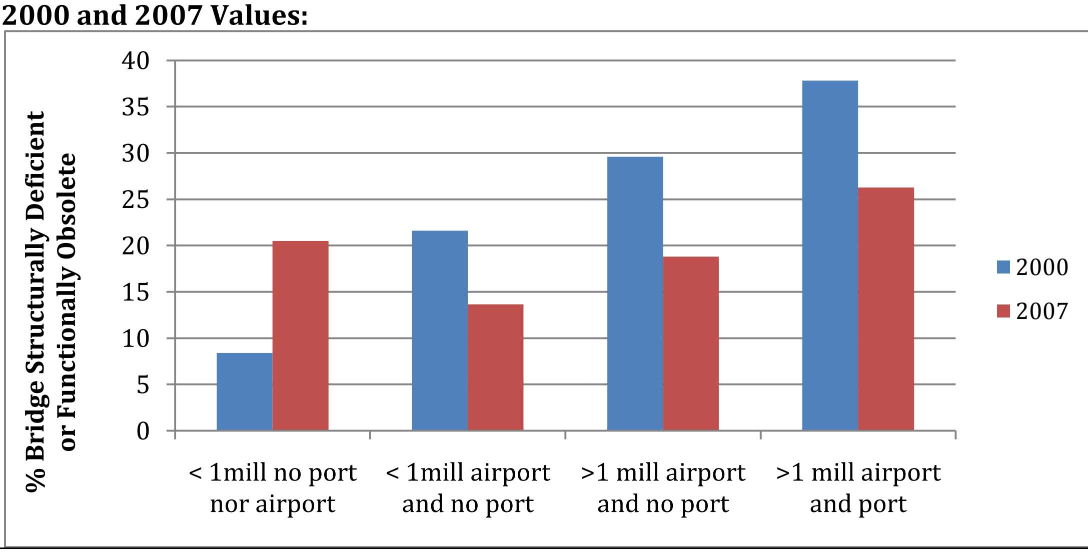
Contribution to the comprehensive transportation index:

MSA (population under 1 million) without airport or port-0.050
MSA (population under 1 million) with airport and no port- 0.043
MSA (population over 1 million) with airport and no port- 0.024
MSA (population over 1 million) with airport and port- 0.021

The weight factors are determined and calculated from Analytical Hierarchical Process.

Primary data sources:	The IRI data can be derived from the annual Highway Performance Monitoring System (HPMS) data. The threshold for "Acceptable" ride quality used in this report is the 170 in/mi. IRI value as set by the FHWA Performance Plan for the NHS available from (http://www.fhwa.dot.gov/reports/2003plan/index.htm).
Data issues & opportunities	

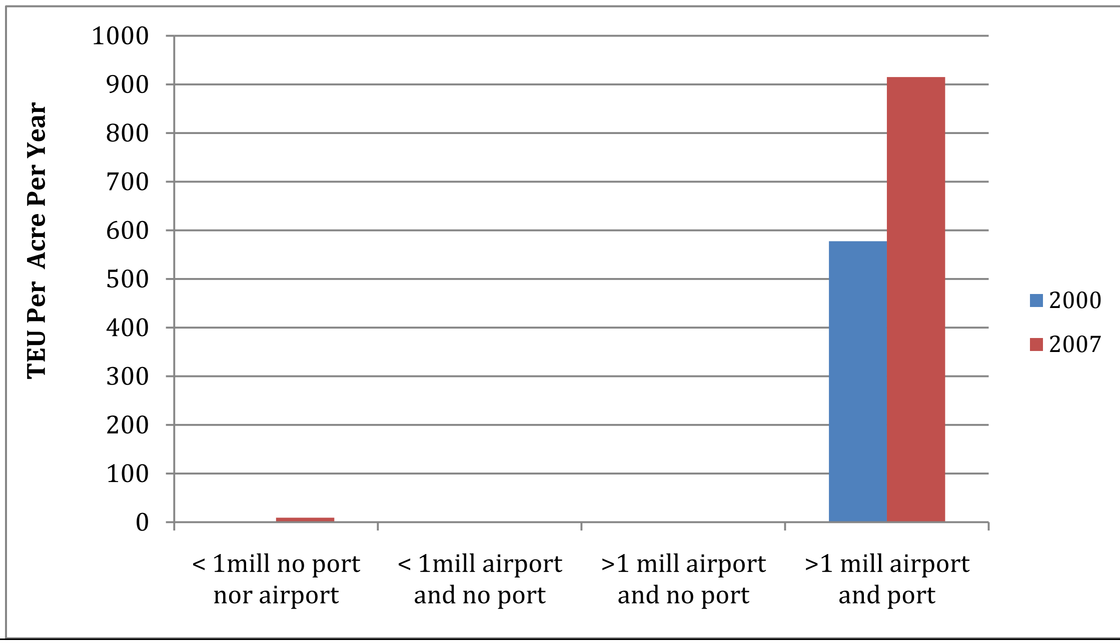
<table>
<tr><td>Indicator #10</td><td>Uncongested Roads</td></tr>
<tr><td>Definition:</td><td>Road congestion is measured by the percentage of lane miles with Level of Service (LOS) at C or better.</td></tr>
<tr><td>Why it's important:</td><td>The Highway Capacity Manual (HCM) and AASHTO Geometric Design of Highways and Streets ("Green Book") classify the transportation LOS system into five levels, using the letters A through F, with A being best and F being worst. It is a measure of roadway congestion. At LOS C, the ability to pass or change lanes is not always assured. LOS C is the target for urban highways in some places, and for rural highways in many places. At LOS C most experienced drivers are comfortable, roads remain safely below but efficiently close to capacity, and the posted speed is maintained.</td></tr>
<tr><td colspan="2">Criteria metric: Quality of Service</td></tr>
<tr><td colspan="2">2000 and 2007 Values:

</td></tr>
<tr><td colspan="2">Observations:
Roads tended to become less congested.</td></tr>
<tr><td colspan="2">Contribution to the comprehensive transportation index:
MSA (population under 1 million) without airport or port-0.200
MSA (population under 1 million) with airport and no port- 0.174
MSA (population over 1 million) with airport and no port- 0.095
MSA (population over 1 million) with airport and port- 0.084
The weight factors are determined and calculated from Analytical Hierarchical Process.</td></tr>
<tr><td>Primary data sources:</td><td>The Volume-to-service flow (V/SF) ratio data can be derived from the annual Highway Performance Monitoring System (HPMS) data. The V/SF ratio compares the number of vehicles (V) traveling in a single lane in 1 hour with the theoretical service flow (SF). A level of 0.80 is frequently used as a threshold for classifying highways as "congested," while a level of 0.95 is frequently described as "severely congested."
http://www.fhwa.dot.gov/policy/2006cpr/chap4.htm)</td></tr>
<tr><td>Data issues & opportunities</td><td></td></tr>
</table>

Indicator #11	**Bridge Integrity**
Definition:	Bridge integrity is measured by the percent of bridges (out of total) which are functionally obsolete or structurally deficient.
Why it's important:	Structurally deficient means there are elements of the bridge that need to be monitored and/or repaired. The fact that a bridge is "structurally deficient" *does not* imply that it is likely to collapse or that it is unsafe. It means the bridge must be monitored, inspected and repaired/replaced at an appropriate time to maintain its structural integrity. A functionally obsolete bridge is one that was built to standards that are not used today. These bridges are not automatically rated as structurally deficient, nor are they inherently unsafe. Functionally obsolete bridges are those that do not have adequate lane widths, shoulder widths, or vertical clearances to serve current traffic demand or to meet current geometric standards, or those that may be occasionally flooded.
Criteria metric: Quality of Service	
2000 and 2007 Values: 	
Observations: The percentage of deficient bridges has declined since 2000.	
Contribution to Index: *MSA (population under 1 million) without airport or port-0.116* *MSA (population under 1 million) with airport and no port- 0.101* *MSA (population over 1 million) with airport and no port- 0.055* *MSA (population over 1 million) with airport and port- 0.049* The weight factors are determined and calculated from Analytical Hierarchical Process.	
Primary data sources:	The ascII files, the record layout, the coding guide and notes on downloading and using the National Bridge Inventory (NBI) data can be found at: http://www.fhwa.dot.gov/bridge/nbi/ascii.cfm.
Data issues & opportunities	

Indicator #12	Port Congestion
Definition:	The number of cargo containers (TEUs) per land acre of port per year. One TEU (twenty foot equivalent unit) is based on the volume of a 20-foot (6.1 m) long and 8 feet (2.4 m) wide intermodal container. TEUs have become shipping's standard unit of measure.
Why it's important:	TEUAY measures the number of containers handled per acre of land for a port in one year. This metric provides a measure of the utilization of U.S ports. One limiting factor in vertical stacking of containers at ports is the underlying geology's load bearing capacity.

Criteria metric: Utilization

2000 and 2007 Values:



Observations:
Containers Per Acre Per Year has increased from 2000 to 2007.

Contribution to Index:
MSA (population under 1 million) without airport or port-0.000
MSA (population under 1 million) with airport and no port- 0.000
MSA (population over 1 million) with airport and no port- 0.000
MSA (population over 1 million) with airport and port- 0.116

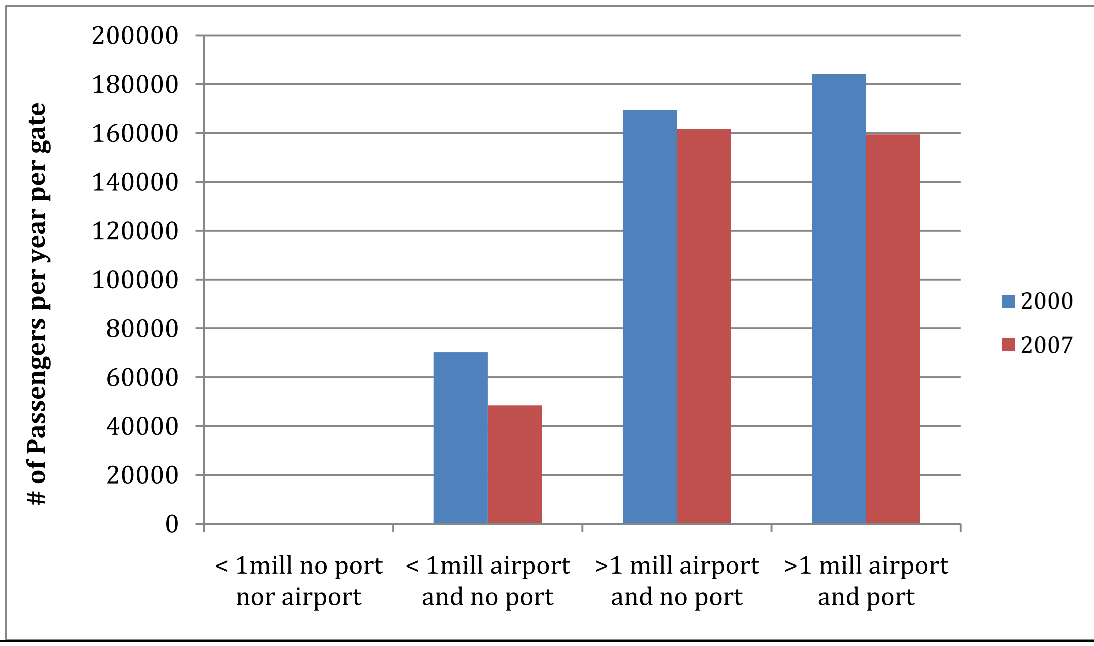
The weight factors are determined and calculated from Analytical Hierarchical Process.

Primary data sources:	Acres: Phone survey of individual port terminals or authorities, and port websites Number of TEUs: U.S. Dept. of Transportation, Maritime Administration: Port Import Export Reporting Service (PIERS); data collected from Vessel Manifests and Bills of Lading
Data issues & opportunities	

Metric #13	**Air Passenger Congestion**
Definition:	Air passenger congestion is measured by the number of passengers per year per gate.
Why it's important:	Air Passenger Congestion indicates the utilization of the airport facility and congestion that may be occurring at an airport facility that is in high demand.

Criteria metric: Utilization

2000 and 2007 Values:



Observations:
Airports added gates at a faster rate than passengers increased between 2000 and 2007, lowering the ratio of passengers per year per gate.

Contribution to the comprehensive transportation index:
MSA (population under 1 million) without airport nor port-0.000
MSA (population under 1 million) with airport and no port- 0.048
MSA (population over 1 million) with airport and no port- 0.026
MSA (population over 1 million) with airport and port- 0.023

The weight factors are determined and calculated from Analytical Hierarchical Process.

Primary data sources:	Enplanements: Federal Aviation Administration Number of Gates: Phone survey of airports and Jonathan Williams, Univ. of Georgia, Economics Federico Ciliberto, Univ. of Virginia, Economics Individual airport Competition Plans required by law beginning in 2000
Data issues & opportunities	Individual airport Competition Plans required by law beginning in 2000

Public Data Sources

National Highway Planning Network (NHPN): The NHPN is a geospatial dataset for planning that is consistent with other datasets such as the Highway Performance Monitoring System. The NHPN is a 1:100,000 scale network database that contains line features representing just over 450,000 miles of current and planned highways in the U.S. The NHPN consists of interstates, principal arterials and rural minor arterials. (FHWA 2009c)

Highway Performance Monitoring System (HPMS): The HPMS is a national level highway information system developed by the Federal Highway Administration (FHWA) in 1978 to support decision-making within FHWA, U.S. Department of Transportation (DOT) and Congress (FHWA 2009b). The database includes data on the extent, condition, performance, use and operating characteristics of the nation's highways. The data are reported to FHWA by state DOTs and include comprehensive data for the national highway systems and sample data for arterial and collector systems. Data fields appropriate for use in this project included AADT and percentage trucks.

National Bridge Inventory (NBI): The NBI is a database, compiled by the Federal Highway Administration, with information on all bridges and tunnels in the United States that have roads passing above or below. This bridge information includes the design, the dimensions of the usable portion and the conditions of the bridge. The bridge inventory was developed with the purpose of having a unified database for bridges, including identification information, bridge types and specifications, operational conditions, bridge data including geometric data and functional description, inspection data, etc. The data are available from the FHWA website since 1994.

National Transportation Atlas Database (NTAD): The U.S Department of Transportation Bureau of Transportation Statistics (BTS) initiated the NTAD in 1996 in the framework of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. The mission was to consolidate "all of the department's transportation network and facility databases on one CD-ROM." It can be used "to produce high quality, up-to-date maps and conduct national transportation analyses." The NTAD is a set of about 34 transportation-related geospatial datasets gathered, processed, documented, reviewed and released by BTS. BTS distributes the data as shapefiles through an annual CD released in the summer and also through a web-based download application.

GeoFreight: GeoFreight is an intermodal freight decision support and display tool developed by the Oak Ridge National Laboratory and the Bureau of Transportation Statistics. It is widely available on CD. The tool uses a routing model to assign freight flows to the transportation network (ORNL 2009).

Freight Analysis Framework (FAF): The FAF integrates data from a variety of sources to estimate commodity flows and related freight transportation activity among states, regions and major international gateways (FHWA 2009a). FAF estimates and forecasts are available for 1998, 2010, and 2020. The FAF's main products are (FHWA 2009a):

- Freight Origin-Destination Database: commodity flows among and within regions, benchmarked every five years and updated annually
- Freight Network Flow Database: commodity movements assigned to corridors centered on major transportation facilities connecting regions with forecasts and updates
- Commodity Flow Disaggregation Tool: a method for disaggregating the Freight Origin-Destination Database to more detailed geography

Fatality Analysis Reporting System (FARS): FARS was created by the National Highway Traffic Safety Administration to collect data on a census of fatal traffic crashes within the 50 states, the District of Columbia, and Puerto Rico. FARS has been operational since 1975 and has collected information on over 989,451 motor vehicle fatalities, including information on over 100 different coded data elements that characterize the crash, the vehicle and the people involved.

Lock Performance Monitoring System (LPMS): The LPMS provides data for all locks owned and operated by the U.S. Army Corps of Engineers. The lock characteristics report includes information on the physical characteristics of each lock chamber, usage and closure data (U.S. Army Corps of Engineers, 1999).

APPENDIX D – SURVEY

The following survey was used to complete the pairwise comparisons of the performance criteria and the thirteen indicators for the Analytic Hierarchy Process (AHP) used for the prototype Transportation Index. Each of the proposed indicators for transportation was compared, as well as the three criteria, using the standard AHP scale from 1-9. For the demonstration, team members completed the survey to understand the effort and the nuances involved in interpreting the questions. U.S. Chamber staff also completed the survey and their responses were used to develop the weights. The weights were tabulated using AHP software Expert Choice. These weights were then normalized on a scale from 0 (low) - 1 (high).

Infrastructure Index Project

The U.S. Chamber of Commerce is working with Michael Gallis & Associates and the University of Delaware to quantify how important infrastructure is to U.S. businesses. The project is developing an Infrastructure Index to serve as a yard stick to quantify the relationship between infrastructure performance and economic performance. In this brief survey we are asking you to assist us by making comparisons between various indicators of transportation infrastructure. Your opinions will serve as inputs to the index. The survey is voluntary and anonymous (no identifying information is collected that links your response to you as an individual).

We would like to know which sector best describes your business. Please check one of the following:

	Agriculture, forestry, fishing, and hunting		Information		Educational services
	Mining		Government		Health care and social assistance
	Construction		Finance and insurance		Arts, entertainment, and recreation
	Manufacturing		Real estate and rental and leasing		Accommodation and food services
	Utilities		Professional and technical services		Other services, except government
	Transportation and warehousing, excl Postal Service		Management of companies and enterprises		Wholesale trade
			Administrative and waste services		Retail trade

The survey consists of a series of pairwise comparisons. For example, for a Metropolitan Statistical Area (MSA) the survey asks: With respect to the SUPPLY of transportation infrastructure, which is more important and to what degree: A. Density of Highways (Highway Lane-Miles per Square Mile) or B. Airport Availability (% of population within 50 miles of an airport)? Table 1 displays the sample comparison.

Table 1: Pairwise Comparison Example:

			A is more important than B				OR	B is more important than A			
Criteria	Indicator A	Indicator B	Extreme	Very Strong	Strong	Moderate	Equal	Moderate	Strong	Very Strong	Extreme
SUPPLY	**Highway Density** (Highway Lane-Miles per Square Mile)	**Airport Access** (% Population within 50 Miles of Maj	9	7	5	3	1	3	5	7	9

In Table 1, number "3" is circled under the column of "moderate" where "A is more important than B," which means with respect to the criteria of "Supply," indicator A (Highway Density) holds "moderate" importance over indicator B (Airport Access).

Please do similar pairwise comparisons for each of the indicators and criteria. Please refer to the **description** of each indicator under the Indicator A column. The order of the indicators listed under the Indicator B column is reflective of the order of the indicator in Indicator A column and the attachment. In each row of any table, please only circle **ONE** score.

Definitions

- Transportation – Moving people and goods by air, water, road and rail
- Metropolitan Statistical Area (MSA) – Urban area containing a core urban area of 50,000 or greater population (Center for Business and Economic Research, 2007; Office of Management and Budget, 2008)
- Criteria – Broad classes of infrastructure performance
- Supply – Criterion that captures availability
- Quality of service – Criterion that captures reliability
- Utilization – Criterion that captures the potential to accommodate growth

Questions?

If you have questions or concerns please contact:

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Professor
University of Delaware
302 831 0760
Email: smcneil@udel.edu

Section 1 - Criteria

With respect to transportation infrastructure in a large region (defined by a Metropolitan Statistical Area), please complete the following table of pairwise comparisons with respect to criteria. Circle the appropriate score – only circle one rating per row.

		A is more important than B				OR	B is more important than A			
Criteria A	**Criteria B**	**Extreme**	**Very Strong**	**Strong**	**Moderate**	**Equal**	**Moderate**	**Strong**	**Very Strong**	**Extreme**
SUPPLY	QUALITY OF SERVICE	9	7	5	3	1	3	5	7	9
SUPPLY	UTILIZATION	9	7	5	3	1	3	5	7	9
QUALITY OF SERVICE	UTILIZATION	9	7	5	3	1	3	5	7	9

Section 2 - Indicators

Considering transportation infrastructure in a region (defined by a Metropolitan Statistical Area), please complete the following table of indicator pairwise comparisons with respect to the indicators. Circle the appropriate score – only circle one rating per row.

			A is more important than B				OR	B is more important than A			
Criteria	**Indicator A**	**Indicator B**	**Extreme**	**Very Strong**	**Strong**	**Moderate**	**Equal**	**Moderate**	**Strong**	**Very Strong**	**Extreme**
SUPPLY	**Highway Density** (Highway Lane-Miles per Square Mile)	**Airport Access**	9	7	5	3	1	3	5	7	9
		Rail Density	9	7	5	3	1	3	5	7	9
		Airport Proximity	9	7	5	3	1	3	5	7	9
		Inland Waterway Density	9	7	5	3	1	3	5	7	9
		Port Access (Distance from MSA to the closest International port)	9	7	5	3	1	3	5	7	9
SUPPLY	**Airport Access** (% Population within 50 Miles of Major Airport)	**Rail Density**	9	7	5	3	1	3	5	7	9
		Airport Proximity	9	7	5	3	1	3	5	7	9
		Inland Waterway Density	9	7	5	3	1	3	5	7	9
		Port Access (Distance from MSA to the closest International port)	9	7	5	3	1	3	5	7	9
SUPPLY	**Rail Density** (Track miles per square mile)	**Airport Proximity**	9	7	5	3	1	3	5	7	9
		Inland Waterway Density	9	7	5	3	1	3	5	7	9
		Port Access (Distance from MSA to the closest International port)	9	7	5	3	1	3	5	7	9
SUPPLY	**Airport Proximity** (Average distance to airport)	**Inland Waterway Density**	9	7	5	3	1	3	5	7	9
		Port Access (Distance from MSA to the closest International port)	9	7	5	3	1	3	5	7	9
SUPPLY	**Inland Waterway Density** (Miles of inland waterway per square mile)	**Port Access** (Distance from MSA to the closest International port)	9	7	5	3	1	3	5	7	9
QUALITY OF SERVICE	**Travel Time Reliability** (Travel Time Index -MSAs popn>1million only)	**Safety**	9	7	5	3	1	3	5	7	9
		Road Roughness	9	7	5	3	1	3	5	7	9
		Road Congestion	9	7	5	3	1	3	5	7	9
		Bridge Integrity (% of bridges with a sufficiency rating < 70)	9	7	5	3	1	3	5	7	9
QUALITY OF SERVICE	**Safety** (Fatalities per million VMT)	**Road Roughness**	9	7	5	3	1	3	5	7	9
		Road Congestion	9	7	5	3	1	3	5	7	9
		Bridge Integrity (% of bridges with a sufficiency rating < 70)	9	7	5	3	1	3	5	7	9
QUALITY OF SERVICE	**Road Roughness** (% of road section with IRI greater than 168 in/mile)	**Road Congestion**	9	7	5	3	1	3	5	7	9
		Bridge Integrity (% of bridges with a sufficiency rating < 70)	9	7	5	3	1	3	5	7	9
QUALITY OF SERVICE	**Road Congestion** (% of lane miles at LOS C or better)	**Bridge Integrity** (% of bridges with a sufficiency rating < 70)	9	7	5	3	1	3	5	7	9
UTILIZATION	**Port Utilization** (Average berth utilization rate (%))	**Air Passenger Congestion** (# passengers per day per gate)	9	7	5	3	1	3	5	7	9