TRANSPORTATION PERFORMANCE INDEX: COMPLETE TECHNICAL REPORT

Measuring and Benchmarking Infrastructure Performance

TRANSPORTATION **INDEX**

LET'S REBUILD

AMERICA

US Chamber of Commerce

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ABSTRACT

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 – an Infrastructure Index -- to communicate effectively the need to improve the condition and performance of U.S. infrastructure. The Index measures the performance of infrastructure as it meets the needs of productive businesses working toward economic prosperity.

This report documents the process developed to create one element of the Infrastructure Index, the Transportation Index and reports the values of the national Transportation Index from 1990 to 2008, and the values of state-by-state Transportation Indices for 1995, 2000 and 2007. Forecast values for the national and state-by-state indices for 2015 are also reported.

The report also documents an economic analysis that demonstrates the usefulness of the Index for exploring the contribution of infrastructure to keeping American businesses competitive.

The Transportation Index is generated from publicly available data using a completely transparent process that can be replicated by any interested party and used to benchmark and measure the improvement or decline of the performance of U.S. transportation infrastructure over time.

GLOSSARY

Accessibility – ability of people and businesses to reach desired goods, services and activities (Litman, 2009)

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

Broadband – moving information (voice, data, images, etc.) at high speed over the Internet and other networks.

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: highways, transit, aviation, rail, and marine.

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).

Energy - providing power and fuels for business, residential, industry, transportation, and agriculture.

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 used for this analysis are a set of accounts that present the contribution of each private industry and government industry 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 that are also used. 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 the purpose of the Infrastructure Index, 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.

Normalization – the process of transforming indicators from the raw measures to a common scale.

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.

Sampling – process for selecting a set of observations that are representative of the population.

Transportation – moving people and goods by air, water, road, and rail.

Water – supplying water for communities, economies, and agriculture, and removing wastewater and storm water from those same locations.

INTRODUCTION

Infrastructure systems are the foundation for productive business and commerce. Without major infrastructure, such as roadways, waterways, pipelines, electricity lines, and broadband connections, businesses are not able to function or flourish. Everyday business decisions are made based on infrastructure performance. For example, firms choose to co-locate with desirable infrastructure and they leave areas where infrastructure is deteriorating or inadequate (U.S. Chamber of Commerce, 2010). Strong infrastructure performance can ultimately support economic efficiency, which allows U.S. businesses to remain competitive. Increased costs and decreased efficiency for U.S. businesses can be attributed to deteriorating infrastructure (Cambridge Systematics, 2008).

Existing infrastructure performance assessments fail to use a rigorous, quantitative, and repeatable methodology. Studies that relate the provision of infrastructure with economic growth and prosperity have largely relied on infrastructure expenditures rather than infrastructure performance (U.S. Chamber of Commerce, 2010). Therefore, an index that is based on a well-defined methodology, uses existing publicly available data, and incorporates the major infrastructure sectors is essential. The U.S. Chamber of Commerce (2010) recognizes transportation, water, broadband, and energy as the major infrastructure sectors that influence business health. Therefore, the methodology develops a sub-index for each sector that is then used to construct a composite index for the nation. The sub-indices and the composite index also support comparisons of infrastructure over time.

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

This report documents the methodology used to create a Transportation Index to track U.S. transportation infrastructure performance over time.

Defining and Addressing the Infrastructure Problem

Recognizing that effectiveness of policies and investments can be better assessed using performance measures and outcomes as illustrated in several recent papers (Dowall & Ried, 2009; Pisano et al, 2010), the U.S. Chamber of Commerce developed a methodology that constructs a national composite infrastructure index.

The methodology for constructing a national infrastructure index that is correlated to economic performance relies on a broad base of research that includes the following elements:

- A literature review focusing on infrastructure indices and decision support tools
- A sampling strategy to ensure representation of all sectors of the economy and regions of the country
- Integration of the Analytic Hierarchy Process into the index development
- A rigorous, repeatable, and universal methodology for determining a number that represents the nation's infrastructure performance

The application of the methodology to developing a transportation index requires:

- Identification of appropriate indicators
- Data collection
- Pairwise comparison of indicators to develop weights
- Weighting of sample data to represent the nation

Given limited resources for gathering all the data necessary to measure and benchmark the performance of every piece of infrastructure in the entire United States, a sampling strategy was designed. Since data on the measurements is needed by geographic area, sample selection criteria are identified. The criteria 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.

The Role of Infrastructure in Economic Prosperity

Development of the analytic framework for an infrastructure index that demonstrates the connection to the economy began approximately thirty years ago with studies of government spending on public infrastructure projects. The goal of these studies is to analyze the impact of economic growth, economic productivity, and social welfare (U.S. Chamber of Commerce, 2010). Prior to the 1990's, research on infrastructure was primarily kept separate from economic growth studies (Holtz-Eakin and Schwartz, 1995). By the early 1990's, the analytic framework was extended to evaluate economic growth specifically in relation to private spending on infrastructure. Between 1990-1995, empirical modeling began based on the correlation of infrastructure development and economic growth and productivity (Calderon, et al., 2008). Since then, research has been devoted to assessing the effects of infrastructure not only on growth and productivity, but also on poverty and development. The results vary as much as the number of measurements gathered (U.S. Chamber of Commerce, 2010). Rather than focusing on the ways of measuring the economy, this research focuses on ways to measure infrastructure, which is reflected in the proposed methodological process.

Prior research, including national and global studies, typically resulted in contradictory findings. A major cause of this contradiction is that "infrastructure" is measured as "spending" rather than performance (Straub, 2007). These results are flawed for many reasons (U.S. Chamber of Commerce, 2010). First, there is an inconsistency in the quality and quantity of infrastructure funding. For example, there are differences in the efficiency of infrastructure funding in Africa compared to the United States. Sanchez-Robles (1998) completed a study that showed that there is no relationship between infrastructure development and the economy when spending is used to measure infrastructure. Second, when spending is used, it typically includes only public investments, which ignores the contribution of private infrastructure investments (U.S. Chamber of Commerce, 2010). Finally, "bi-directional results" are likely because there is a positive statistical correlation that a growing economy can afford more infrastructure (U.S. Chamber of Commerce, 2010). Therefore, by removing the notion of spending a measure of infrastructure performance can more directly capture the important factors that influence economic growth.

Currently, national infrastructure measures exist in specific areas of infrastructure performance. The most well-known comprehensive assessment of national infrastructure is the American Society of Civil Engineers' Infrastructure Report Card, which provides a qualitative assessment (American Society Civil Engineers, 2010). There is no quantitative methodology used to measure infrastructure performance, nor to correlate infrastructure performance with economic performance. Therefore, developing a step-by-step methodology to construct a U.S. infrastructure index is essential for understanding economic trends and promoting prosperity throughout the business sector.

Infrastructure Index – An Overview

In order to construct a well-defined national infrastructure index, a rigorous methodology is needed with the goal of being universal and repeatable. To capture infrastructure performance, the methodology is based on quantitative data that are publicly available. This supports the idea that the index is replicable and repeatable, both over time and applicable for a broad range of users.

The first step in constructing the methodology involved researching background literature on index development, specifically indicator identification. Given the attributes of the methodology for developing an infrastructure index, there are many different ways to develop the index. A review of a selection of indices used in economics, finance, ecology, health, green building, and sustainability and past experience suggest the need for a step-by-step process (U.S. Chamber of Commerce, 2010). According to Bossel (1999), a four step process should be used in the development of an index:

1. Understand, conceptually, the entire system
2. Identify representative indicators
3. Quantify the degree to which the needs of business are met

4. Conduct a participative process

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

Oswald and McNeil (2010) expanded Bossel's methodology to a seven step process as a way to universalize measuring infrastructure projects or sites using a rating scale. These seven steps can be directly applied to this research and are described below:

1. Define criteria for selecting the infrastructure under investigation
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

This revised methodology serves as a basis for constructing the methodology specific to the national infrastructure index. This methodology relies on a set of indicators to quantify objective measures. Principles for developing good indicators have been identified by Litman (2008) and are listed below:

- *Comprehensive*- indicators should reflect various economic, social, and environmental impacts and various transport activities
- *Data quality*- data collection practices should reflect high standards to ensure that information is accurate and consistent
- *Comparable*- data collection should be standardized so the results are suitable for comparison between various jurisdictions, timeframes, and groups

- *Easy to understand*- indicators must be useful to decision-makers and comprehensible to the general public
- *Accessible and Transparent*- indicators and analysis details should be available to all stakeholders
- *Cost effective*- the suite of indicators should be cost effective to collect, and the value of the indicators to decision-making must outweigh the cost of collecting them
- *Net Effects*- indicators should differentiate between net (total) impacts and shifts of impacts to different locations and times
- *Performance targets*- indicators should be suitable for establishing usable performance targets

Building Infrastructure Indices

Based on the literature review of existing index methodologies, a comprehensive step-by-step process is developed for the purposes of constructing a national composite infrastructure index. The methodology consists of seven steps:

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

These seven steps map to Bossel's (1999) four steps and Oswald and McNeil's (2010) seven steps as shown in Table 1.

There are four sub-indices representing individual sectors: energy, water, broadband, and transportation. These sectors are defined as the following (U.S. Chamber of Commerce, 2010):

- *Energy*- Providing power and fuel for business, residential, industry, transportation, and agriculture.
- *Water*- Supplying water for communities, economies, and agriculture and removing wastewater and storm water from those same locations.
- *Broadband*- Moving information (voice, data, and images) at high speed over the Internet and other networks.
- *Transportation*- Moving people and goods by air, water, road, and rail.

These sub-indices are then weighted in order to determine the results for a composite infrastructure index using AHP. In order to visualize the methodology, a conceptual model is developed and displayed in Figure 1. To illustrate the application of the methodology, the computation of the transportation index is described.

Outline of the Report

This report documents the development of the Transportation Index and the analysis of the results. The report is organized as follows:

- The following chapter documents the process used for developing the Transportation Index.
- The subsequent chapter reports the results and analyses the changes in values over time and compares the results to other students.
- The following chapter reports on the state-by-state Transportation Indices.
- The next chapter documents the economic analysis.

Six appendices include summaries of meetings with the stakeholder community and transportation experts, document the data sources and alternative measures for the national index and state-by-state indices, describe the survey uses to determine the relative weights of the indicators, and document other rankings of transportation infrastructure.

Table 1. Comparison of Index Methodologies

Infrastructure Index Methodology	Bossel (1999) Methodology	Oswald & McNeil (2010) Methodology
1. Define infrastructure sectors	1. Understand, conceptually, the entire system	1. Define criteria for selecting the infrastructure under investigation
2. Identify representative samples based on geography and economy		
3. Create hierarchy models for each sector		2. Develop indicator categories
4. Identify indicators for each sector	2. Identify representative indicators	3. Develop indicators
5. Explore data sources and collect indicator data		4. Transform indicators into measures by identifying data associated with each indicator
6. Weight the indicators using AHP pairwise comparisons	3. Quantify the degree to which business needs are met. 4. Conduct a participative process	5. Prioritize indicators by assigning weights
7. Compute the index based on normalized indicators, relative weighting, and economic relevance		6. Allocate points 7. Develop a measurement scale

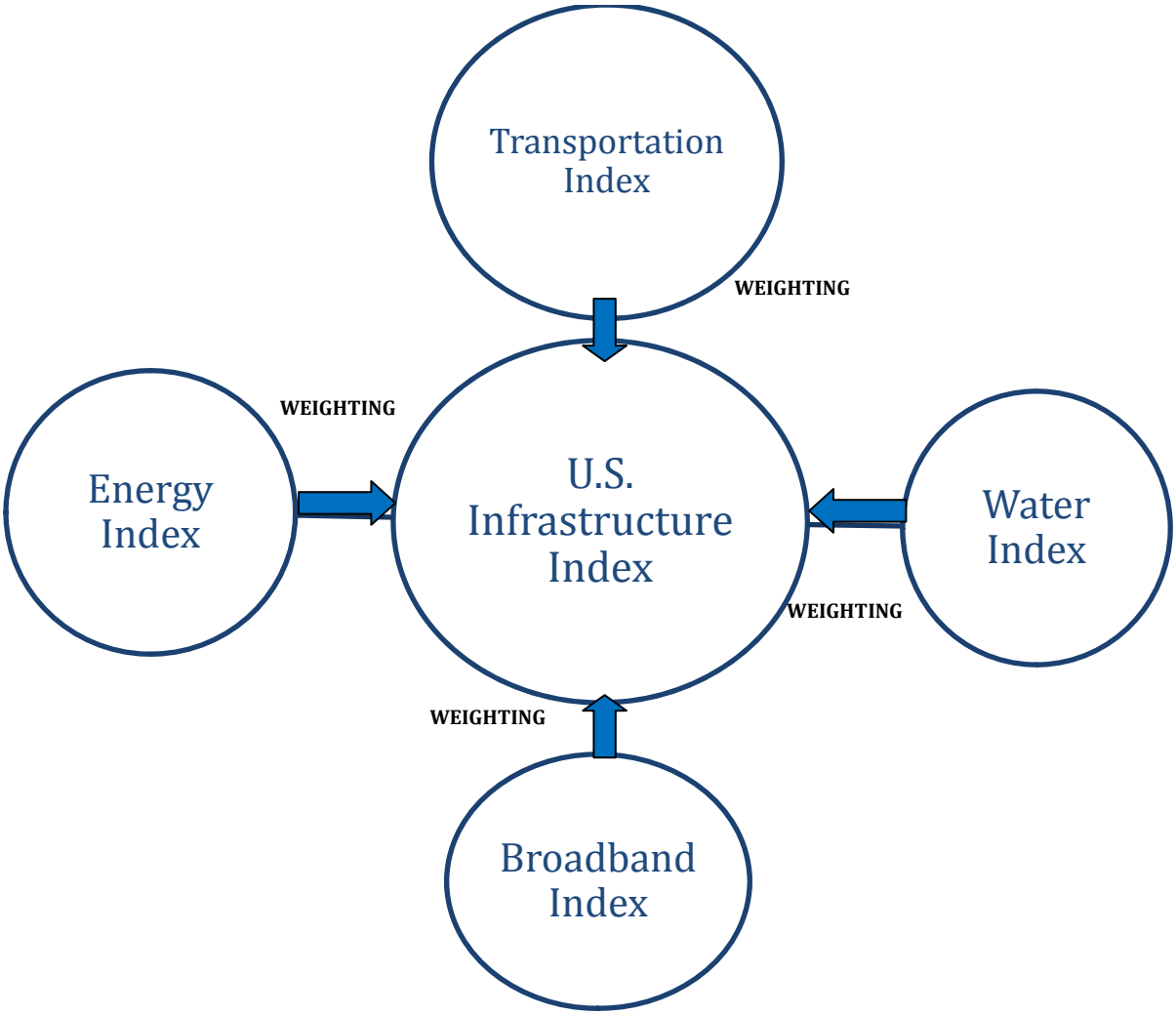


Figure 1. Conceptual Model of Index Methodology

BUILDING THE TRANSPORTATION INDEX

The transportation index relies on a representative sample of transportation infrastructure. Since data on the measurements are collected by geographic area, sample selection criteria are identified to ensure a representative sample with attributes that demonstrate sufficient variability to capture all the factors that influence 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.

Definition: 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, and marine.

Structure

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 two groups based on population: large Metropolitan Statistical Areas (MSAs), and other MSAs. The MSAs were selected to ensure that these areas are a representative sample of U.S. economic activity. The MSAs are then weighted in the index based on their contributions to the U.S. economy. Originally, micropolitan areas and rural areas were also considered but the lack of data prevented their inclusion in the index.
- The category level is unique to each infrastructure component. For example, road, rail, transit, air, and marine are the categories of transportation infrastructure measured.
- The next level includes the four overarching criteria that are applied to assessing each aspect of transportation: supply, efficiency, quality of service, and utilization.
- Within each criterion, indicators are identified to measure the performance of the system. The data used to measure the indicators represent 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.

Following the methodology described in the *Infrastructure Performance Index: Initiation Phase Report* (U.S. Chamber, 2010), criteria for selecting broad classes of performance indicators are defined, a hierarchical structure through which the Index is developed, specific indicators are explored, and the available data are reviewed. The criteria used are:

- 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 are the existing facilities used?)

Where possible indicators representing Highway, Air, Rail, Marine, Intermodal, Port, and Transit infrastructure are included to capture all modes and both passenger and freight transportation.

Sampling

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 makes use of infrastructure. The initial set of geographic areas consists of the 366 metropolitan statistical areas (MSAs) for which the Department of Commerce's Bureau of Economic Analysis reports industry level economic data (BEA, 2006).

The stratified sampling strategy ensures the selection of infrastructure sectors within important geographic locations. Thirty six MSAs were selected based on the 2003 definitions of MSAs. The sampled MSAs are listed in Table 2 and shown in Figure 2. The determination of the sample size and the selection of the sample are documented in the *Infrastructure Performance Index: Initiation Phase Report* (U.S. Chamber, 2010). The economic classifications MSAs are used:

- Service : All services, including business, and education
- Trade: Wholesale and retail trade
- Industrial: Agriculture, mining, manufacturing
- Other: All infrastructure (water, utilities, etc.) industries plus government
- Multi- Sector: more than one dominant industry (service, trade, industrial or other)
- Diversified: no dominant industry

The thirty-six MSAs are grouped into three types of MSA:

- Population over 1 million (all MSAs have airports) – 23 MSAs; Type 11,
- Population under 1 million with a primary airport – 7 MSAs; Type 01, and

- Population under 1 million without a primary airport – 6 MSAs; Type 00.

Checking the Sample

The sample provides coverage of 34.5% of the U.S. MSA Population (29.3% of the total U.S. population) and 34.7% of the country's MSA economic output (30.3% of the U.S. economic output) based on 2007 data.

Representativeness is evaluated in terms of the following standards:

- Share of GDP by industry types
- Geographic distribution (regions)
- State coverage

Further details are included in the *Infrastructure Performance Index: Initiation Phase Report* (U.S. Chamber, 2010).

What the Sample Does Not Include

The Transportation Index used data from MSAs to capture the variability across the US. These samples tell us very little about transportation infrastructure across rural America and notions of connectivity and accessibility that require us to capture the network of different models and services.

The key transportation infrastructure issues for non-MSA geographic areas include the ability to meet local transportation needs while servicing the "through" traffic, access to alternative modes, particularly when catastrophic events limit services provided by commonly used modes, and weight restrictions.

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, the sample is based on MSAs, which capture sufficient representation of the characteristics important to the analysis.

Table 2. MSA Sample

MSA	FIPS Code	Economic Classification	Population>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
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

MSA	FIPS Code	Economic Classification	Population>1m (1=yes)	MSA GMP ($M)	Population
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

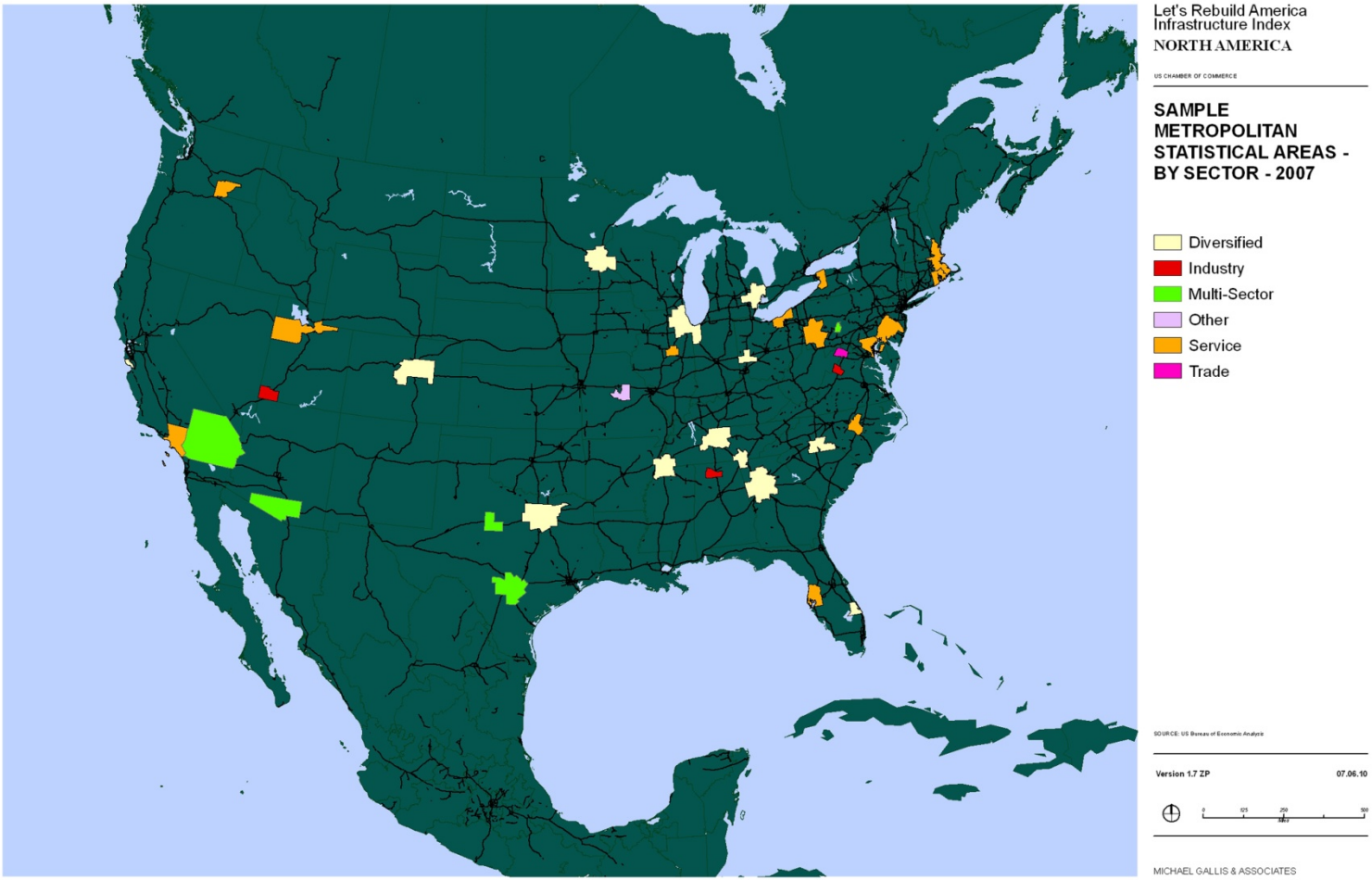


Figure 2. Sample MSAs

Indicators

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 definitions of transportation infrastructure. Building on literature reviews and web searches, the project participated in meetings with representatives of businesses in the Chicago, Atlanta, Houston and San Jose areas, and academic experts. These meetings are documented in Appendix A and Appendix B of this report.

The list of indicators evolved over the course of the project. The initial candidates for indicators included indicators such as port delay, which might be measured as delay per TEU (twenty foot equivalent unit – a unit of measure for containers), and measures of delay on rail to reflect quality of service. Interactions with the transportation experts and stakeholders also suggested several interesting indicators such as channel depth for inland waterways and runway incursions for air safety. In some cases, data are available to measure these indicators and in other cases not. In most cases the concerns voiced at the stakeholder meetings are captured by the indicators. However, addressing the issues identified by the experts from the business community is more challenging. For example, the railroad industry suggested several indicators that were previously explored and rejected. These include quality of service data on Average Train Speed, Terminal Dwell Time, and Cars On Line (measure of congestion). This is excellent data but is available only for the most recent 53 weeks (http://www.railroadpm.org/). Using this data in the future will require timely downloading of the data and developing a strategy to aggregate data across railroads. A more complete discussion of missing and alternative indicators is included in Appendix C of this report.

The final list of indicators is shown in Table 3. In total, twenty-one (21) indicators are selected: eight (8) for Supply, nine (9) for Quality of Service, and four (4) for Utilization. Data for indicators were not available for all modes and all criteria. For example, there is no indicator for Utilization of Marine transportation.

Data Sources

The ground rules are that the indicator should reflect infrastructure performance, the data should be publicly available, and the data can be obtained back to 1990. To meet these requirements, extensive reviews were conducted to identify the appropriate databases. Many sources, including Bureau of Transportation Statistics (BTS), National Transportation Atlas Data (NTAD), Highway Performance Monitoring Systems (HPMS), National Bridge Inventory (NBI), National Transit Database (NTD), Aviation System Performance Metrics (ASPM), Federal Aviation Administration's (FAA) Runway Safety Database, Terminal Area Forecast (TAF), Fatal Accident Reporting System (FARS), Federal Railroad Administration (FRA), and U.S. Army Corps of Engineers, are used for gathering data. In addition, the U.S. Census data is used to obtain population data. Table 4 and Table 5 list the databases

explored for this project. The tables include a general description of the database, the data agency, and their major usage.

Where possible, data for each indicator are assembled from 1990 to 2007. Missing data are added using extrapolation or interpolation. The 10,440 pieces of data are assembled from approximately 10 Gigabytes of raw data from the abovementioned databases using spreadsheet, database, and Geographic Information System (GIS) tools. The indicator description, its data source and year availability, and whether the data can be obtained at MSA level or national level (indicated in the column "Geography") are summarized in Table 6. The table also designates which indicators are maximized and which are minimized.

As mentioned, connectivity and accessibility are not captured in the sample. These performance attributes are also not captured in the indicators. Related issues arise because passenger and freight transportation share the same infrastructure, and not all MSAs have all types of infrastructure (port, airports, transit systems, and intermodal facilities). However, the indicators used are, in fact, just that – indicators - and as a whole are representative of infrastructure performance.

Complete descriptions of each of the 21 indicators, along with the average values for 1990 through to 2008 for each type of MSA, are included as Appendix C of this report.

Table 3. Indicators Selected

Criteria	Mode	Description	Measure
Supply	Highway	Highway Density (Availability of highways)	Route-miles per 10,000 population
	Transit	Density (Availability of transit)	Miles of transit per 10,000 population
	Air	Access (Proximity of airports)	Percent of population within 50 miles of major airport(s)
		Capacity (Availability of airport service)	Airport arrival rate and departure rate per hour
	Rail	Density (Availability of railroads)	Route-miles per 10,000 population
	Marine	Density (Availability of marine)	Miles of waterways per 10,000 population
		Port Access (Proximity of ports)	Distance from the center of MSA to the closest international container port
	Intermodal	Freight Access (Proximity of intermodal facilities)	Number of facilities per 10,000 population
Quality of Service	Highway	Travel Time Reliability (Variability in travel time due to congestion)	Travel Time Index
		Safety (Fatal highway crashes)	Fatalities per 100 million Vehicle Miles Traveled
		Road Roughness (Highway ride comfort)	Percent of lane miles in poor or fair condition (based on an International Roughness Index greater than 170 in/mi)
		Bridge Integrity (Ability of bridges to meet the needs of the users)	Percent of bridges structurally deficient or functionally obsolete

Criteria	Mode	Description	Measure
Quality of Service	Transit	Safety (Transit incidents)	Number of incidents per million Passenger Miles Traveled
	Aviation	Congestion (Airport congestion)	Percent of on-time performance for departures
		Safety (Chances of crashes)	Runway incursions per million operations
	Rail	Safety (Railroad incidents)	Number of incidents per million train miles
	Marine	Congestion (Delays on inland waterway)	Average lock delay per tow
Utilization	Highway	Reserve capacity	Percent of lane miles uncongested defined as Level of Service C or better
	Transit	Reserve capacity	Passenger miles traveled per capacity (standing and seating)
	Aviation	Reserve capacity	Percent of capacity used between 7 am and 9 pm
	Rail	Reserve capacity	Ton-miles per track mile

Table 4. Inventory of Transportation Database Sources Explored

Mode	Database Name	Description	Data Agency	Major Usage/Note
Highway	Highway Performance Monitoring System (HPMS)	Provides the extent, condition, performance, use, and operating characteristics of U.S. highways	Federal Highway Administration (FHWA)	● To analyze highway system condition, performance, and investment needs
	National Bridge Inventory (NBI)	A collection of designs and operational conditions for more than 600,000 Nation's bridges	Federal Highway Administration (FHWA)	● To analyze bridges and judge their conditions
	Fatality Analysis Reporting System (FARS)	Contains information on all fatal motor vehicle crashes	National Highway Traffic Safety Administration (NHTSA)	
	Highway Congestion (Urban Mobility Study)	Provides information on levels of mobility and congestion in 68 urban areas	Texas Transportation Institute	● Urban areas chosen based on the availability of data provided
Transit	National Transit Database (NTD)	Consists of financial and operating transit data	Federal Transit Administration (FTA)	● Safety Management Information System (SAMIS) reported under NTD
Air	Aviation System Performance Metrics (ASPM)	Provides IFR flights performance data only for ASPM airports and carriers	Federal Aviation Administration (FAA)	● To monitor airport efficiency and system performances, etc.
	On-Time Performance	Contains scheduled and actual departure and arrival times	Bureau of Transportation Statistics (BTS)	● Reported by major air carriers
	Aviation Safety Information Analysis and Sharing (ASIAS) System	Collections of safety databases across the industry	Federal Aviation Administration (FAA)	● Includes Accident /Incident Data System (AIDS), Runway Incursion, etc.
	Terminal Area Forecast (TAF) system	The official forecast of aviation activity at FAA facilities	Federal Aviation Administration (FAA)	
Rail	FRA Office of Safety Analysis	Makes railroad safety information readily available to a broad constituency	Federal Railroad Administration (FRA)	
	Railroad Performance Measures	Six major freight railroads report the Cars On Line, Train Speed, and Terminal Dwell	http://www.railroadpm.org/	● Updates every week, but keeps only 53 weeks historical data
Marine	Navigation Data Center (NDC)	Provides information on waterborne commerce, vessel characteristics, port facilities, dredging, and lock performance	U.S. Army Corps of Engineers	● Includes Lock Performance Monitoring System (LPMS), port facilities, etc.
	Waterborne Commerce	Provides summaries of waterborne freight flows, commodity tonnage, ton miles, and freight traffic	Maritime Administration	

Table 5. Inventory of Other Databases Explored

Database Name	Description	Data Agency	Major Usage/Note
U.S. Census	Population data	U.S. Census Bureau	● Decennially ● Estimates updated annually
National Transportation Atlas Database (NTAD)	GIS data for transportation networks, facilities, and other geographic reference data	Bureau of Transportation Statistics (BTS)	
National Transportation Statistics	Presents national and state wide information on the U.S. transportation system	Bureau of Transportation Statistics (BTS)	● Annually
TRANSTATS	A searchable index of over 100 transportation-related databases	Research and Innovative Technology Administration (RITA)	

Table 6. Data Sources and Availability

Criteria	Mode	Indicator Identification	Description	Source	Availability	Geography	MAX/ MIN
Supply	Highway	ID1	Density	NTAD	1996-2009	All MSA Types	MAX
	Transit	ID2	Density	NTAD	1996-2009	All MSA Types	MAX
	Aviation	ID3	Access	NTAD and 1990 and 2000 census tracts	1996-2009	MSA type 01 and 11	MAX
		ID4	Capacity	ASPM	2000-2010	MSA Type 11	MAX
	Rail	ID5	Density	NTAD	1996-2009	All MSA Types	MAX
	Marine	ID6	Density	NTAD	1996-2009	All MSA Types	MAX
		ID7	Port Access	NTAD	1996-2009	All MSA Types	MIN
	Intermodal	ID8	Freight Access	NTAD	1996-2009	All MSA Types	MAX
Quality of Service	Highway	ID9	Travel Time Reliability	TTI	1982-2007	MSA Type 11	MIN
		ID10	Safety	FARS	1994-2009	All MSA Types	MIN
		ID11	Road Roughness	HPMS	1990-2009	All MSA Types	MIN
		ID12	Bridge Integrity	NBI	1992-2009	All MSA Types	MIN
	Transit	ID17	Safety	NTD	2002-2009	All MSA Types	MIN
	Aviation	ID 13	Congestion	BTS	1987-2010	MSA type 01 and 11	MAX
		ID14	Safety	FAA ASIAS	2001-2009	MSA type 01 and 11	MIN
	Rail	ID15	Safety	BTS	1990-2009	National	MIN
	Marine	ID16	Congestion	Army Corps NDC LPMS	1990-2009	National	MIN
Utilization	Highway	ID18	Reserve capacity	HPMS	1990-2009	All MSA Types	MAX
	Transit	ID20	Reserve capacity	NTD	1997-2009	All MSA Types	MIN
	Aviation	ID19	Reserve capacity	ASPM	2000-2010	MSA Type 11	MIN
	Rail	ID21	Reserve capacity	BTS	1990-2009	National	MIN

MSA type: 00 = population under 1 million without airport, 01 = population under 1 million with one or more airports, 11 = population greater than 1 million with one or more airports

Normalizing the Data

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

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. The survey found in Appendix E and the Comparion tool, a web-based interface for administering Expert Choice surveys, are used to solicit responses to an internet survey. The distribution list was generated by the U.S. Chamber's staff and included participants in the workshops and members who had indicated an interest in the project.

The survey went out to 447 participants. Twenty one (21) responses were received, a 4.7% response rate. The responses generated a consistency ratio of 0.01 where anything under 0.10 is considered satisfactory. The weights are shown in Figure 3.

Before applying the weights, two more adjustments are needed. The first adjustment reflects the different types of MSAs. For example, MSAs without a primary airport (Type 00) will not have airport related indicators. Therefore, the number of indicators is slightly different for the three types of MSAs:

- Population over 1 million (all MSAs have airports) – 23 MSAs; 18 indicators (Type 11),
- Population under 1 million with a primary airport – 7 MSAs; 15 indicators (Type 01), and
- Population under 1 million without a primary airport – 6 MSAs; 12 indicators (Type 00).

Table 7 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.

The second adjustment reflects the contribution of each MSA to the U.S. economy so that a national representative value is obtained. This step assures that several small MSAs or several large MSAs 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 the sample.

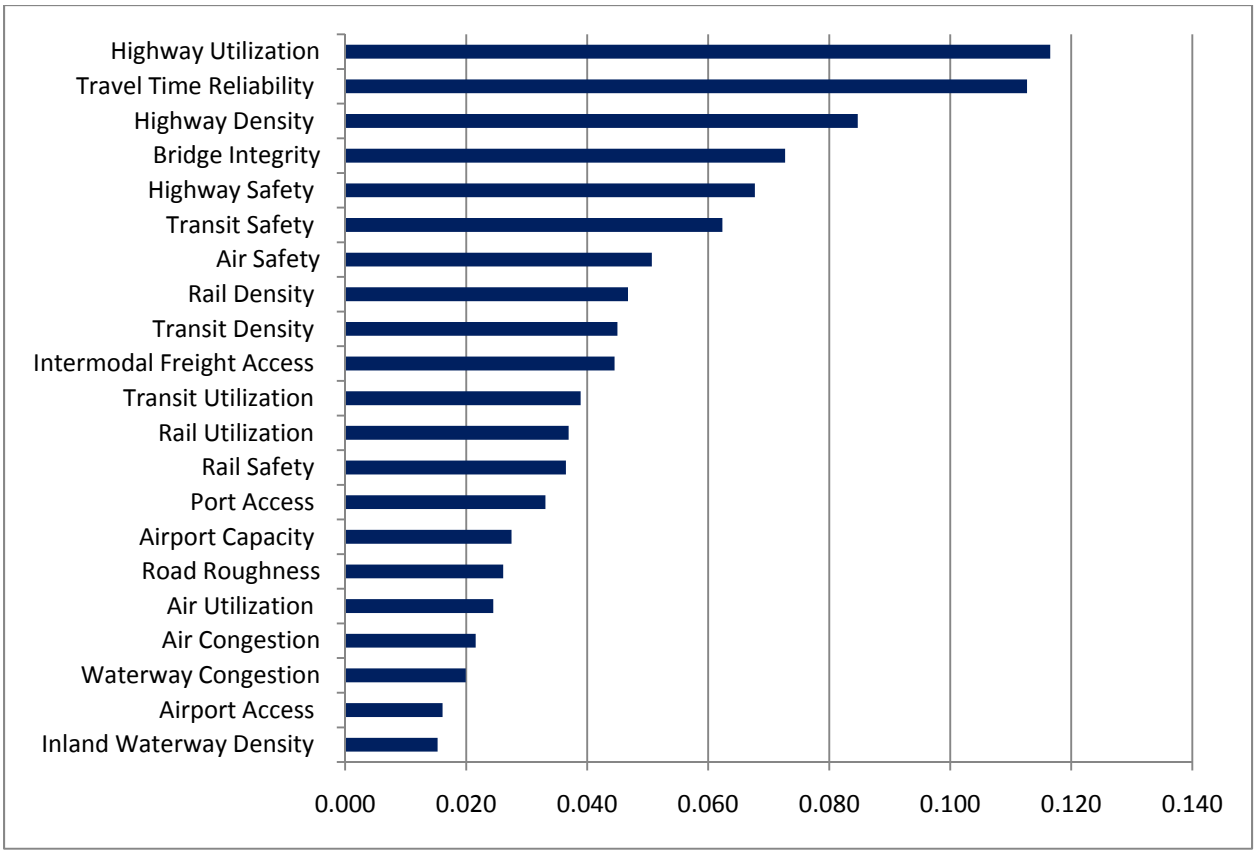


Figure 3. AHP Weights Derived from Comparion Survey

Table 7. Weights by MSA Type and Indicator

Indicator Identification	Description	MSA Type		
		11 From AHP	00 Calculated	01 Calculated
ID1	Density	0.085	0.099	0.093
ID2	Density	0.045	0.052	0.049
ID3	Access	0.016		0.018
ID4	Capacity	0.028		
ID5	Density	0.047	0.055	0.052
ID6	Density	0.015	0.017	0.016
ID7	Port Access	0.033	0.038	0.036
ID8	Freight Access	0.045	0.052	0.049
ID9	Travel Time Reliability	0.113		
ID10	Safety	0.068	0.112	0.089
ID11	Road Roughness	0.026	0.043	0.034
ID12	Bridge Integrity	0.073	0.121	0.096
ID 13	Congestion	0.022		0.029
ID14	Safety	0.051		0.067
ID15	Safety	0.036	0.059	0.047
ID16	Congestion	0.02	0.033	0.026
ID17	Safety	0.062	0.102	0.082
ID18	Reserve capacity	0.117	0.132	0.132
ID19	Reserve capacity	0.024		
ID20	Reserve capacity	0.039	0.044	0.044
ID21	Reserve capacity	0.037	0.042	0.042

Calculating the Index

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

For each year, the Transportation Index is defined as:

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

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

Where

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

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

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

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

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

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

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

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

Data Collection

The process for extracting the relevant data for each measure is documented in the summary for each indicator included in Appendix C. The following data are included in each summary:

- Definition: an explanation of the short name used in the text and tables
- Why it is important: relevance to transportation infrastructure performance
- Criteria metric: relevant criterion (supply, quality of service, or utilization)
- Historical and current values: average data by MSA type
- Observations: relevant notes related to the data
- Contribution to the transportation sub-index: relative weight
- Primary data sources: URLs for websites, where applicable
- Data issues and opportunities: descriptions of problems, solutions, and ideas for improvements in source data

Assessment and evaluation

In addition to the review by industry and academic experts that was part of the iterative process for identifying indicators, a logical evaluation was undertaken. This logical evaluation included:

- Review of the type of data and the range of the data, which allows screening the most obvious problematic data sets.
- Visual examination of graphs of indicators (by MSA and over time) to check for consistency.

Graphs for each MSA type are included in the summary of each indicator. In addition, graphs such as Figure 4 are plotted for each sampled MSA to check the data consistency over the years. For illustrative purposes, Figure 4includes the "Highway Density" and "Airport Capacity" indicators for seven (7) selected MSAs. If there is an abrupt change in one year, there might be an error in the data processing and a review for that year in the MSA is conducted. Through this mechanism, some calculation errors are identified. However, the graphs also showed that for some MSAs, the reported data are inconsistent in

nature over the years. For the two indicators shown in Figure 4, no huge variations within an MSA are expected. It can be seen from the figure that some MSAs produce better quality data than others. This phenomenon is also observed in the National Bridge Inventory (NBI), and transit data.

There are four barriers to developing a set of comprehensive, repeatable, measurable indicators of transportation infrastructure performance. The barriers are: varying levels of data aggregation, missing and erroneous data, prediction, and institutional issues. Each barrier and how that barrier was remediated or managed are discussed below.

Barrier 1: Scale and Level of Aggregation

Data are often available at different scales, and therefore, the data may be too disaggregated or too aggregate. Where possible, MSAs are used as the unit of geography. The MSA was chosen to ensure a representative sample of different economies. However, not all data are available for this sampling geography. For example, the data on rail safety, waterway congestion, and rail utilization required for the analysis are available only at the national level. While lock delay data (the measure of waterway congestion) are available from the Lock Performance Monitoring System by River and U.S. Army Corps of Engineers Division or District, mapping this data to MSAs is not possible. This underscores the fact that many of the intercity and freight transportation facilities are not confined to MSAs and will be included in the study only if they pass through an MSA.

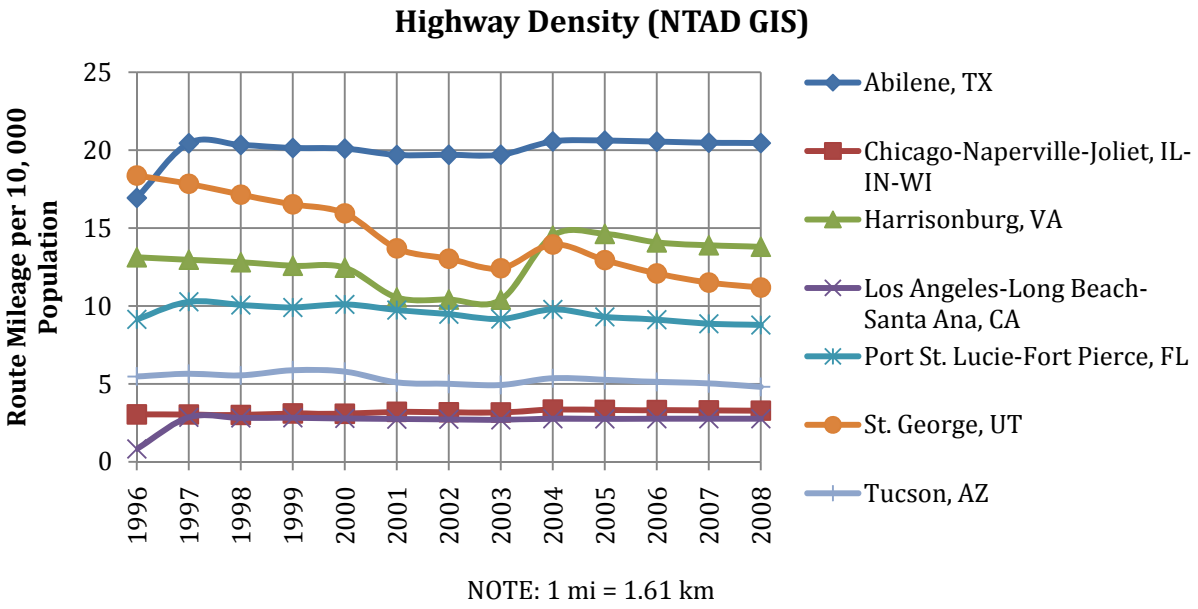
Similarly, reports by trade organizations, individual states and metropolitan planning organizations often provide good local data that are not available for all regions. There are also rich sources of national data. For example, the Bureau of Transportation Statistics compiles Key Performance Indicators that are appropriate aggregate measures but do not capture regional changes. Furthermore, these indicators changed in 2002 and are not available prior to 2000.

Tools such as Geographic Information Systems (GIS) go a long way to help assemble data at an appropriate level of aggregation and offer many different ways to look at disaggregate data recognizing jurisdictional boundaries.

Barrier 2: Missing and Erroneous Data

In terms of missing and erroneous data, 4,674 of the 10,440 pieces of data collected had to be adjusted. The reasons for these adjustments include:

- Data not reported or collected
- Changes in format or inconsistent reporting
- Errors in source data



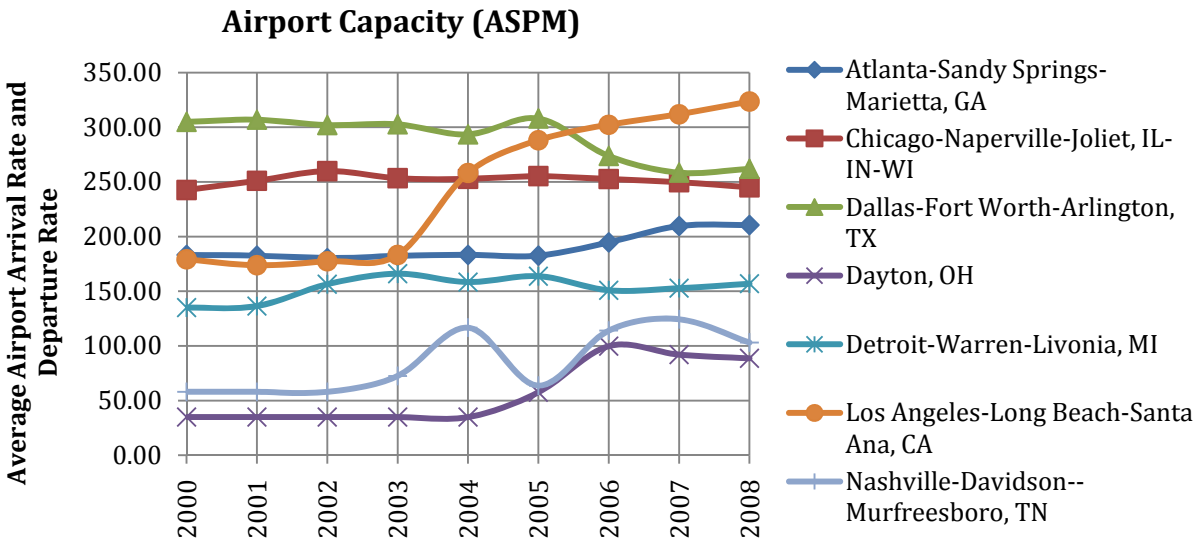


Figure 4. Examples of Graphic Display of Indicators by MSA over Time for Consistency Check

Data Not Reported or Collected

The data for the indicators are collected by different agencies and the year availability of the data varies significantly. For example, BTS started collecting NTAD data in 1996; FAA

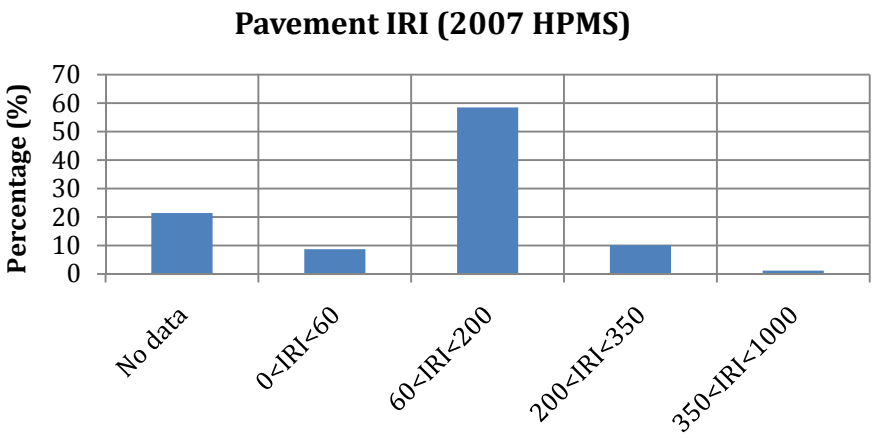
first reported aviation on-time performance data in 1987, while airport capacity data are not available until 2000 in the ASPM database. In general, the data are much more complete after 2000 when compared with the 1990s.

In some cases, even though the data are available, records within the data sets are incomplete. Figure 5 illustrates that more than 20% of the pavement roughness data in 2007 are missing, and roughly 15% of the bridge status data are either missing or coded "not applicable". Another example is that the transit safety data doesn't include any data for commuter rail systems. Commuter rail composes a large portion of the total transit mileage, and the absence of safety data for this mode underestimates the aggregate safety results. Also, occasionally, data in one year for a specific agency are simply missing from NTD. For example, SunLine Transit Agency in Thousand Palms, CA, is inexplicably missing 1998 data for passenger miles travelled (PMT), and Gary Public Transportation Corporation motorbus system in the Chicago-Naperville-Joliet MSA is missing mileage data for the year 2000. In both cases, data are present for every previous and successive year.

Changes in Format or Inconsistent Reporting.

In the NTAD database, there are no functional classes for highway, waterway, and rail in the data sets from 1996 to 2000. In 2002, even though the functional class existed for waterway, roughly 98% of these data sets are missing. The "Number of lanes" of highways was reported in the field named "LANES" in 2001 and 2002, in "THRULAN" in 2006, 2007, and 2008, while there is no such record for 2003, 2004, and 2005. For intermodal facilities, the definitions frequently change. From 1996 to 1998, the data are stored as "Trailer on Flat Car/Container on Flat Car" and "Highway/rail transfer facilities which contain auto loading facilities." From 1999 to 2002, they are labeled "Terminals," while after 2003; they are labeled "Facilities." Figure 6 is the plot of the "Number of terminals per 10, 000 population" indicator, which shows the impact these problems have on the data-- much bigger changes from 1998 to 1999 and smaller from 2002 to 2003.

The HPMS changed the data format twice since 1990. From 1988 to 1992, there was only one expansion factor, which is the "standard expansion factor" in the later HPMS files deployed to expand the standard sample sections to represent national roadways on major functional systems. From 1993, a second expansion factor – "donut expansion factor" – was introduced to estimate Vehicle Miles Travelled (VMT) for the purpose of tracking air quality and conformity. The donut area supplementary sample consists of sections in the rural and small urban minor arterial, rural major collector, and small urban collector functional systems that are located outside of urbanized areas, but within the nonattainment or maintenance area boundary.



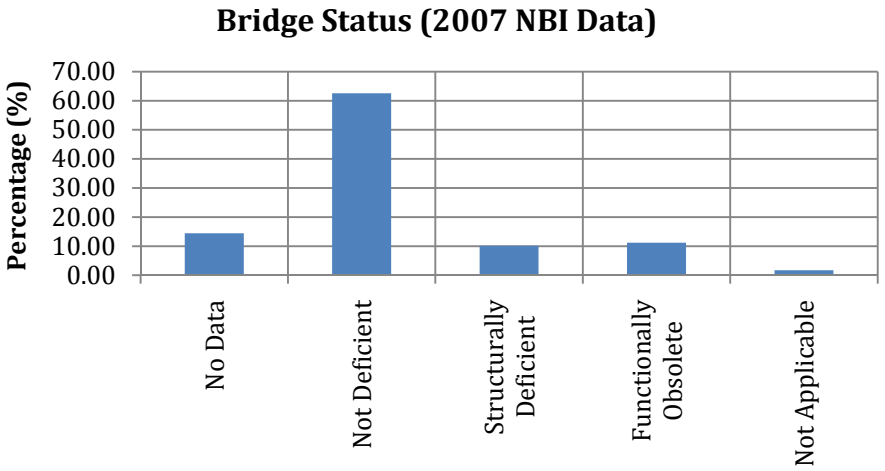


Figure 5. Examples of Data Completeness

The biggest challenge of processing the transit data is due to the file format change and inconsistencies in the reporting of transit agency names. For example, to obtain mileage data from NTD, one must download a set of roughly 30 files. Only two files are used to extract mileage (one file for non-rail modes and one file for rail modes). The formats of these files have been changed three times from 1997 to 2002. In addition, from 1997 to 2002, a separate file is present for the ferryboat mode of transit whereas this mode is included in the non-rail mode files from 2003 to 2008. Also, the agencies associated with

a particular transit system often change names over time (i.e., mergers, discontinuation, ownership changes, etc.). According to NTD data, the Dallas-Fort Worth MSA in Texas possessed two different commuter rail lines and one light rail for the years 2002 through 2008. The transit systems were recorded under two different agencies: Dallas Area Rapid Transit (DART) and Fort Worth Transportation Authority (The T). Before 2002, however, the two commuter rail lines are completely missing. Further investigation revealed that a commuter rail system has been in existence in the Dallas-Fort Worth area since 1996 under the name of Trinity Railway Express (TRE). TRE joined in a partnership with DART and The T in 2001. The limitation to NTD's data in this instance is that it did not report any data for the TRE commuter rail system until 2002, after it had partnered with DART and The T.

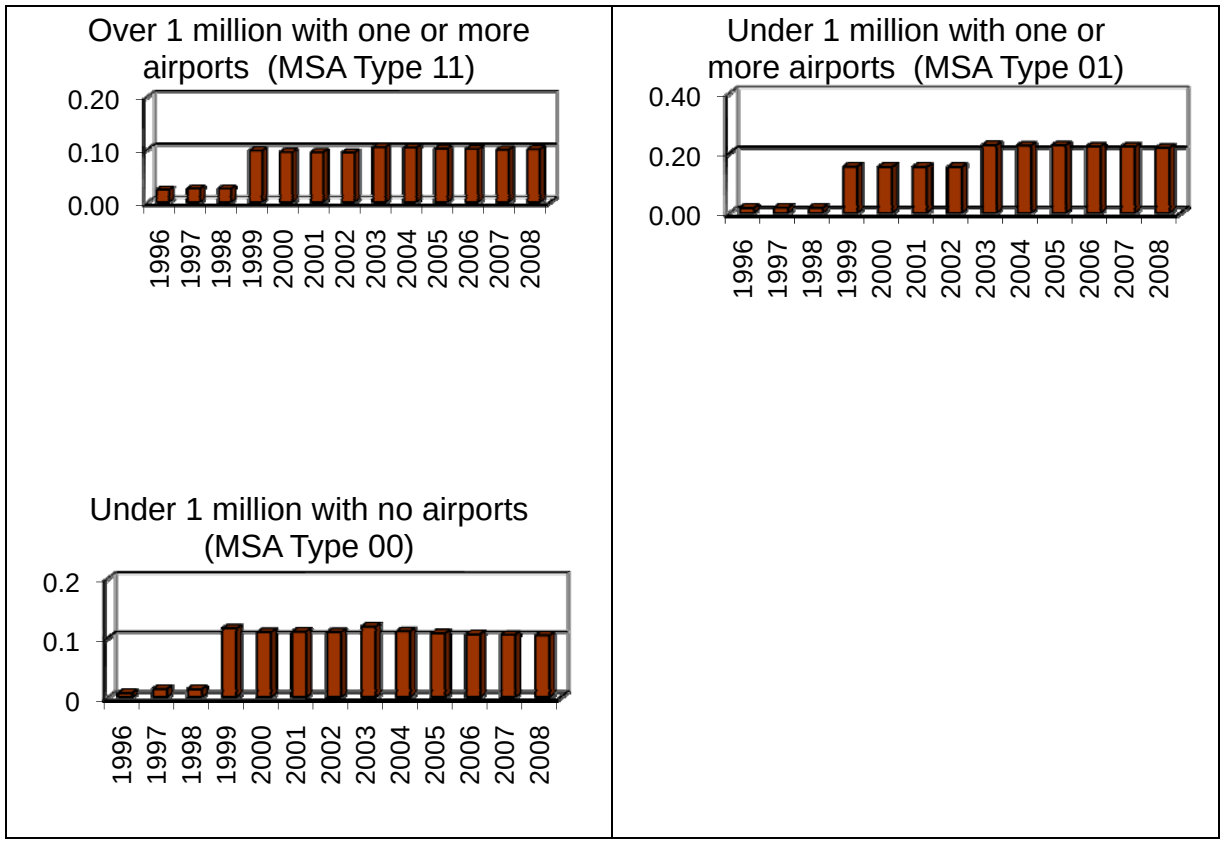


Figure 6. Raw Data for the "number of terminals per 10,000 population" Indicator

Errors in the Source Data.

In addition to identifying missing data, Figure 5 also shows that some of the IRI data are problematic. Approximately 8% of the pavement IRI records are less than 60 in./mile and 2% of the data are greater than 350. It is impossible to have an IRI value of 10 in./mile (extremely smooth) or 950 in./mile (extremely rough). In another example, all the Volume/Service Flow (V/SF) ratios on major highways reported by the state of Louisiana in 1985 range from 241 to 8665, where these numbers should be close to one. Also, again in the HPMS data from 1993 to 1998, the data for donut expansion factors and standard expansion factor were switched and the change was not reported in the file format

documents. Expert judgment adjustments had to be made based on the definitions of these factors. In this case, the standard factors were applied to major functional class and the donut expansion factors were applied to roads with lower functional class.

The end result is that context dependent estimates are required and that data prior to 2000 are less reliable as an indicator of transportation infrastructure performance due to the limited data availability in the 1990s.

Barrier 3: Forecasting and Prediction

Barriers to prediction -- forecasting how the indicators change over time -- exist. Simple extrapolations do not capture interactions, complex interdependencies, substitutions, mode shifts, latent demand, and the relationships among demand, supply, and quality of service with physical degradation of the infrastructure. While transportation demand estimation is a well established field and passenger demand is influenced by socioeconomic variables, very little is known about when users will change travel patterns or shift modes of transportation due to rough roads or infrastructure that is perceived to be unsafe.

Barrier 4: Institutional Constraints

Finally, institutional barriers largely relate to "stove piping" within and across organizations. Passengers and freight do not stop at jurisdictional boundaries. There is no indicator that captures the connectivity of the transportation system that goes beyond these boundaries. Indicators also need to recognize and work around the realities of institutional barriers. Consider the following examples:

- The availability of yard dwell time data on a weekly basis for major North American railroads is a major step forward in making transportation performance data publicly available. However, assembling this data into meaningful aggregate measures requires an understanding of traffic patterns. Those data are not readily available for reasons of confidentiality.
- Several indicators rely on HPMS data. HPMS data quality is highly variable. Improving the quality of HPMS data and making the data more useful was the focus of the 2006-2007 HPMS reassessment (Federal Highway Administration, 2008).
- Port data, other than throughput, are not widely available. Furthermore, the diversity of organizations, in terms of size and control that own and manage ports makes assembling data even more challenging. Some ports own the infrastructure where others simply lease the land to operators. For example, the Port of Pittsburgh is made up of over 200 privately owned terminals.

Vetting and Evaluation

The process was vetted and evaluated in three ways. In the Initiation Phase of the research, a prototype index was constructed to understand the data challenges and limitations of the methodology. Data were collected for 2000 and 2007. The specific values of the index calculated in the Initiation Phase are not useful as it is the relative change in the values that is important; data for at least three years are required to evaluate the changes over time. Instead, in the Initiation Phase the purpose was simply to validate the feasibility of the processes and methodology. In the subsequent phase, a series of workshops was conducted. The workshops involved two groups -- stakeholders and

experts (see Appendix A and Appendix B). These workshops with stakeholders sought input on what aspects of infrastructure are important to the stakeholders (business users, service providers, etc.). The workshops with experts provided input on the specific indicators, measures, data sources, and the overall methodology. The methodology and indicators described above reflect the inputs from both groups. Most importantly, the experts stressed the importance of documenting the current process but seeking opportunities for refinement and continuous improvement.

NATIONAL TRANSPORTATION INDEX RESULTS

Using the methodology described in the Chapter "Building the Transportation Index," the national Transportation Index was computed for the years 1990-2008. This chapter presents the results and explores how to interpret the index, compares the index with other attributes of the transportation system over time and the ASCE Report Card, predicts the value of the index in 2015 based on three scenarios, explores the impact of alternative weighting schemes, and presents next steps.

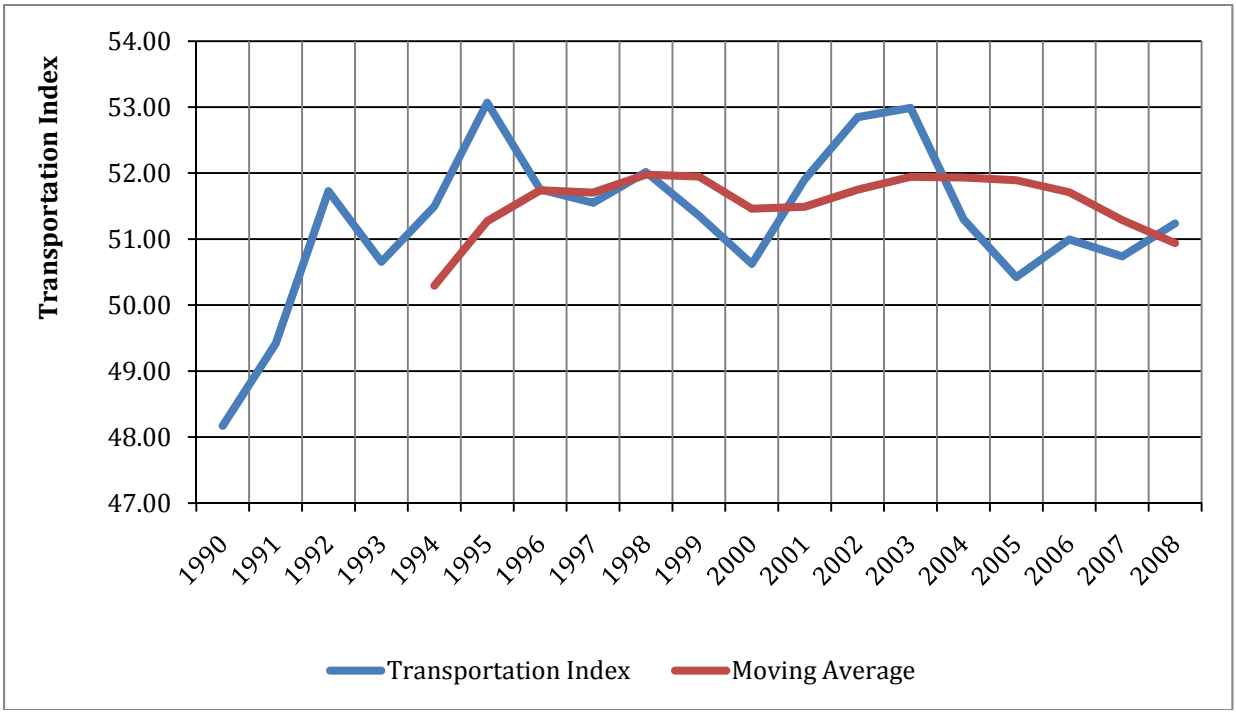


Figure 7. Historical Trend (1990-2008)

The computed Transportation Index is shown in Figure 7 and Table 8. The values range from a low of 48.17 in 1990 to a high of 53.07 in 1995. Since 2004 the index has remained fairly constant ranging from 50.42 to 51.30. The most recent value of the index 2008 is 51.22. The table and graph also includes a five year moving average to show trends over time. Overall, the index showed improvement in the 1990s. Since 2005, however, the Transportation Index has shown a gradual decline. This gradual decline is particularly noticeable in the five-year moving average. The percentage change in the index plotted over time (Figure 8) show a downward trend suggesting that performance is declining.

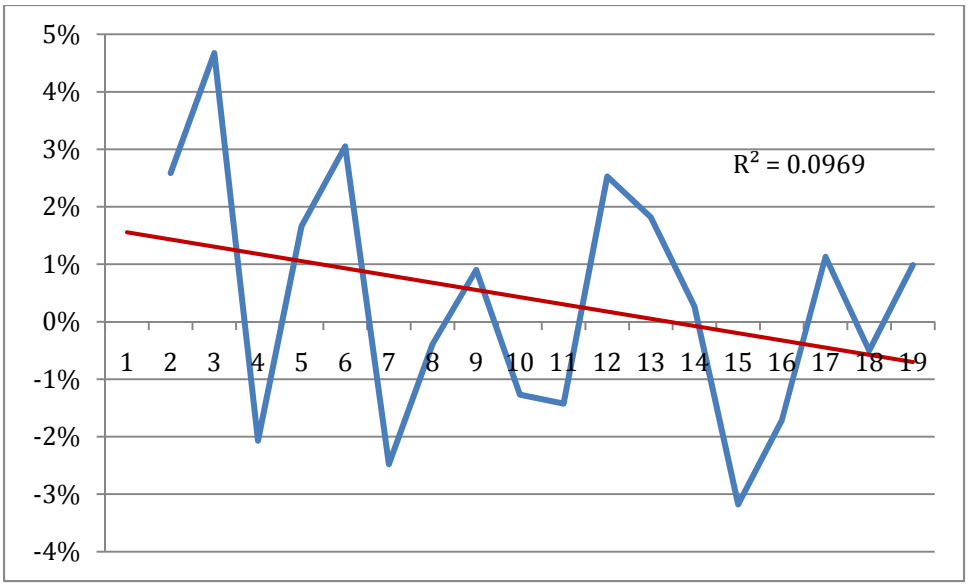


Figure 8. Percentage Change in the Index with Linear Trend

Interpreting the Index

To better understand the index, different ways to interpret changes in the index and the relationship of the changes over time to other relevant variables are explored.

Key points when interpreting the index are:

- Larger is better, smaller is worse
- There is no scale (just like the Consumer Price Index or the Dow Jones Industrial Average (Dow Jones, 2010, Bureau of Labor and Statistics, 2010))

Inherent Variability in the Index

The index in any year is based on data for 21 indicators and 36 MSAs. The sample size was selected in order to estimate any one indicator within +/-5% with a 95% level of confidence. As the relationships among variables are linear, the intent is to estimate the index within 5% with a 95% level of confidence. That is, for 2008 the 95% confidence level for the index is between 48.4 and 53.5. Figure 9 shows the 95% confidence range for the Transportation Index.

The simplest way to interpret this chart is that the 95% confidence level indicates that the index is within two (2) points of the estimated value.

Table 8. Transportation Index (1990-2008)

Year	Transportation Index	Moving Average (5-year)
1990	48.17	
1991	49.42	
1992	51.73	
1993	50.65	
1994	51.50	50.29
1995	53.07	51.27
1996	51.75	51.74
1997	51.55	51.70
1998	52.02	51.98
1999	51.36	51.95
2000	50.62	51.46
2001	51.90	51.49
2002	52.85	51.75
2003	52.99	51.94
2004	51.30	51.93
2005	50.42	51.89
2006	50.99	51.71
2007	50.74	51.29
2008	51.22	50.94

Changes in the Transportation Index over Time.

Explaining the movement of the index from year to year has two parts:

- Is the movement (change) significant?
- If so, why did it occur?

At this point, the answers to these questions are merely hypotheses. Rather than look at year-to year movements (or changes), general trends can be identified recognizing that the index in any year is estimated within +/- 2.5 with 95% confidence. Specifically, the following trends are indentified (both in terms of the index and the moving average):

- 1990 – 1995 (moving average period: 1994 – 1999) – improvement
- 1995 - 2000 (moving average period: 1999 – 2000) – decline
- 2000 - 2003 (moving average period: 2000 - 2004) – improvement
- 2003 – 2008 (moving average period: 2004 - 2008) – decline

The consistency in the trends in the moving average and the raw index suggest that these changes are significant. Turning to explanations for the trends, recall that the infrastructure index is a measure of performance based on disaggregate data for 21 indicators representing our three criteria (supply, quality of service and utilization) and different modes, and 36 distinct areas of the country. No one indicator, no one project, or any specific location will change the index substantially. Furthermore, the transportation infrastructure performance is influenced not just by investment in infrastructure, but the demand for infrastructure, and the regulatory environment. During the period 1990 to 2008, there are many changes that have influenced infrastructure performance, including:

- Increasing emphasis on security.
- Recognition of the importance of creating sustainable infrastructure at the same time as recognizing some of the burdens of regulation.
- An increasingly burdensome project delivery process leading to an interest in streamlining the permitting process as well as environmental impact assessment.
- Significant changes in the Highway Trust Fund, Aviation Trust Fund and Inland Waterway Trusty Fund.
- Challenges to local, state and regional governments' ability to match federal funds including , the willingness of citizens to support infrastructure improvements (e.g. California had not passed a bond issue for almost 20 years)
- Delays in passing authorizing legislation. (e.g. SAFETEA-LU expired September 2009)
- Significant increases in the cost of construction, repair, and maintenance in real dollars.
- Increasing awareness of infrastructure issues.
- State specific initiatives (e.g. Illinois First or the long term impacts of Proposition 13 in California)
- Increasing interest in improved operations (more throughput), multi-modal approaches, regional and corridor issues, impact of bottlenecks, and synergies between modes.

Understanding and correlating these changes to changes in the index is challenging, and warrants further research.

Changes due to a Single Indicator in a Single MSA

Now, the impact on the index of a change in any one variable in any one MSA is explored. The hypothesis is that a change in any one variable in any one MSA has very little impact on the Transportation Index. For example, adding 20 route miles of highways in the Dallas - Fort Worth area MSA (assuming no change in population) raises the national index from 51.22 to 51.23, a change of 0.01. Table 9 shows the data needed for this computation. The relevant indicator is Highway Density (an indicator of Supply) which is measured in route miles per 10,000 of population. This MSA is one of the fast growing regions in the country. Assuming population is growing at 2% per year (the growth rate for this area) the addition of 20 route miles makes no difference to the national Transportation Index.

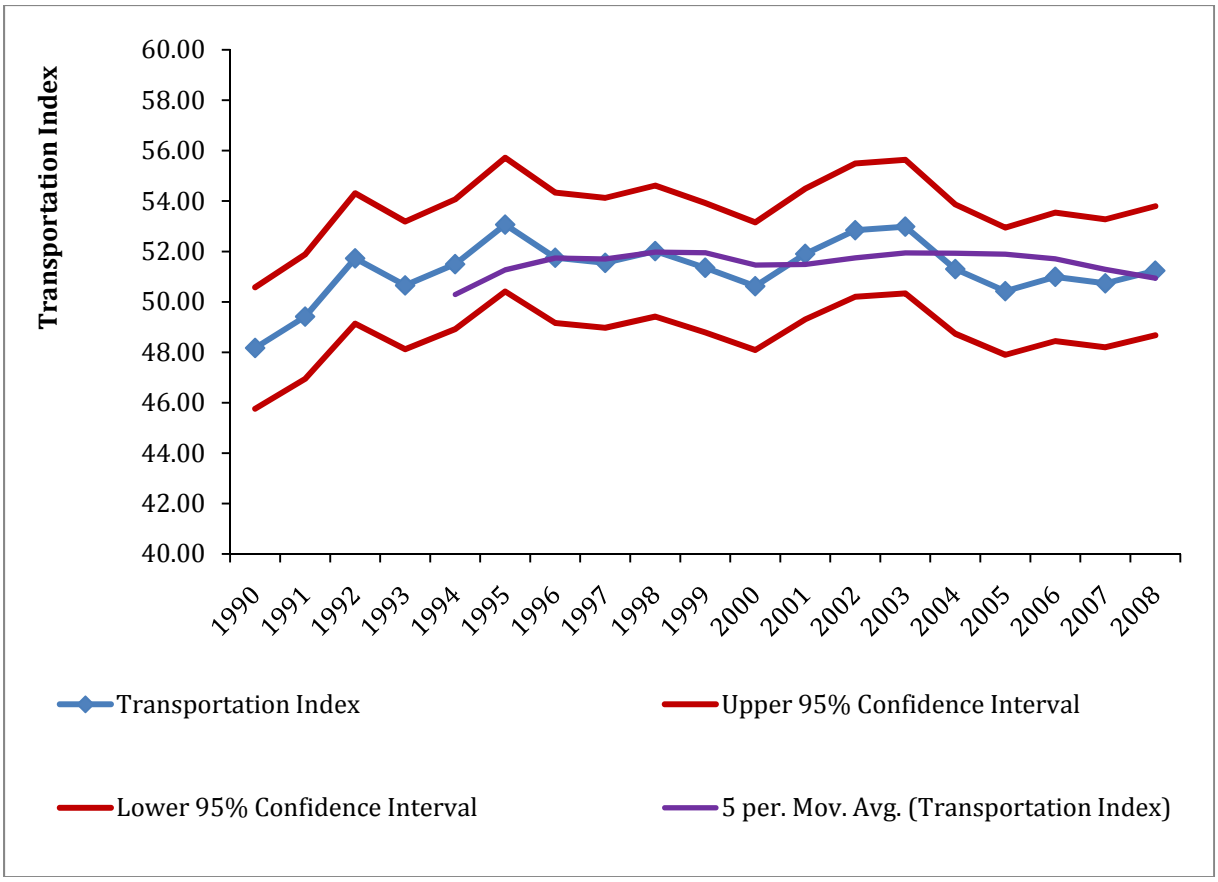


Figure 9. 95% Confidence Interval for the Transportation Index

Table 9. Impact of a Change in Highway Route Miles for the Dallas- Fort Worth MSA on the Transportation Index

Variable	2008	2009	
		No Population Growth	2% Population Growth
Population (10,000s)	61.45	61.45	62.68
Route Miles	262.5	282.5	282.5
Highway Density (IND01)	4.271	4.596	4.506
Normalized Indicator	0.086	0.104	0.099
Index	51.22	51.23	51.22

Percentage Change in Indicators by Mode

To explore the impact of changes in multiple indicators for specific modes on the Transportation Index several "what-if" scenarios are developed. These scenarios are as follows:

- Change all indicators by a given percentage

- Change Highway indicators by a given percentage (Indicators 1, 8, 9, 10, 11, 12, 18)
- Change Aviation indicators by a given percentage (Indicators 3, 4, 13, 14, 19)
- Change Rail (and Intermodal) indicators by a given percentage(Indicators 5, 15,21)
- Change Marine indicators by a given percentage (Indicators 6, 16)
- Change Transit indicators by a given percentage (Indicators 2, 17, 20)

Table 10 shows the Transportation Index computed for each scenario with changes in the relevant indicators of +10%, +5%, +1%, 0% (included for completeness), -1%, -5%, -10% where the positive sign refers to improvements and the negative sign refers to a degradation of the indicators, recognizing that an improvement means that some indicators increase in value and other indicators decrease in value. Figure 10 plots the data as a percentage change from the 2008 indicator. For example, a 10% improvement in all indicators increases the 2008 Transportation Index from 51.24 to 61.75, a 20.5% percent change in the index. A 10% degradation in all indicators reduces the Transportation index by 20.6%.

The results in Table 10 and Figure 10 show that the slope of the line relating Changes in the Transportation Index to Change in the Indicators is 2:1. Therefore, a consistent 1% improvement or degradation in *all* indicators corresponds to a 2% increase or decrease in the Transportation Index.

Table 10 and Figure 10 also show the Transportation Index for five other scenarios representing subsets of indicators that are either improved or degraded.

Consistent with the weighting used to compute the Transportation Index, changes in Highway Indicators have the most impact on the Transportation Index followed by Rail, then Aviation, then Marine, and finally Transit. The data suggests that a consistent 1% change in:

- Highway indicators results in a 1.1% change in the Transportation Index
- Rail indicators results in a 0.4% change in the Transportation Index
- Aviation indicators results in a 0.3% change in the Transportation Index
- Marine indicators results in a 0.1% change in the Transportation Index
- Transit indicators results in little change in the Transportation Index

Table 10. Transportation Index with a Percentage Change in All and Selected Indicators

Percentage Change in Indicators	All	Highway Only	Rail Only	Aviation Only	Marine Only	Transit Only
+10%	61.75	57.31	53.13	52.66	51.84	51.67
+5%	56.49	54.27	52.17	51.94	51.53	51.44
+1%	52.27	51.83	51.41	51.36	51.28	51.26

Base - 0%	51.24	51.24	51.24	51.24	51.24	51.24
-1%	50.16	50.61	51.02	51.07	51.15	51.17
-5%	45.95	48.17	50.26	50.49	50.90	50.99
-10%	40.68	45.12	49.30	49.77	50.59	50.77

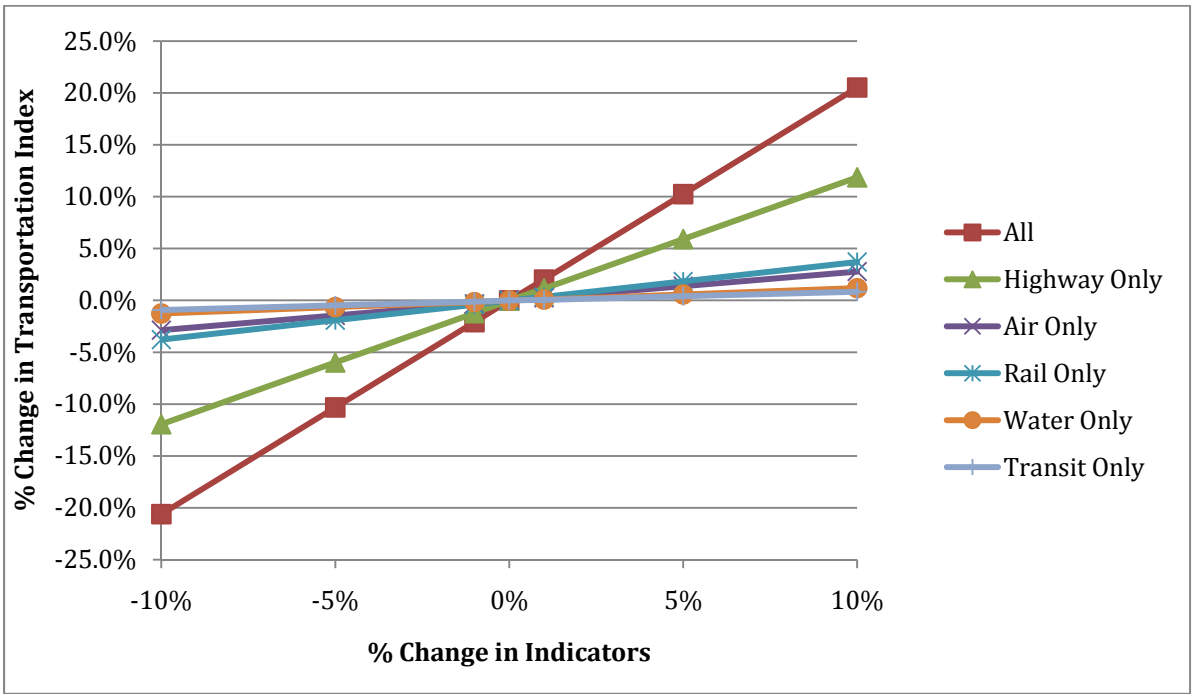


Figure 10. Percentage Change in Index with a Percentage Change in Indicators

Percentage Change in Indicators by Type

To understand the relationship between specific indicators and the transportation index, the impact of changes in a group of indicators referred to as congestion related indicators are explored. The exploration distinguishes between highway congestion related indicators and congestion related indicators for all modes. The indicators selected and the "Best" and "Worst" values are shown in Table 11. The "Best" value is the value for that indicator for the "Best" MSA in 2000 and the "Worst" value is the value for the "Worst" MSA in 2000. Using these values "Best" and "Worst" case scenarios are created in which all MSAs are as good as or as bad as the best and worst MSA in 2000. The resulting Transportation Index values are shown in Table 12.

Table 11. Congestion Related Indicators

IND #	Mode	Indicator	Best (2000)	Worst (2000)	Congestion	
					Hwy	All
IND9	Highway	Travel Time Index	1.07	1.46	X	X
IND13	Aviation	% On-time Arrivals	90.12	67.91		X
IND16	Marine	Lock Delay	1.01	1.6		X
IND18	Highway	% Lane miles at LOS C or better	100	55.2	X	X
IND19	Aviation	% Capacity used 7am- 9pm	14.93	78.69		X
IND20	Transit	PMT per capacity	0	4,290,471		X
IND21	Rail	Ton mile per track mile	8.63	18.89		X

Table 12. Transportation Index Under Various Congestion Scenarios

Scenarios	**Highway Congestion Indicators (% change from 2008)**	**All Congestion Indicators (% change from 2008)**
Best	61.62 (20.3%)	69.89 (36.4%)
2008	51.24	51.24
Worst	41.27 (-19.5%)	35.59 (-30.5%)

The change in the Transportation Index with percentage improvements or degradation in the highway congestion indicators is also explored. The results are shown in Table 13.

Table 13. Transportation Index With Changes in Highway Congestion Indicators

Percent Changes in Highway Congestion Indicators	**Transportation Index**	**% Change in Transportation Index from 2008**
Best	61.62	20.3%
-10.0%	56.17	9.6%
-5.0%	53.71	4.8%
-1.0%	51.71	0.9%
0.0%	51.24	0.0%
1.0%	50.72	-1.0%
5.0%	48.72	-4.9%
10.0%	46.23	-9.8%
Worst	41.27	-19.5%

A 2% decrease (increase) in the Travel Time Index *and* a 2% increase (decrease) in the percentage of lane miles at LOS C or better is found to result in a one point increase (decrease) in the Transportation Index.

Economic Growth

Given the way the index is constructed, the value of the Transportation Index will not change if all indicators stay the same and all MSAs experience the same amount of economic growth. However, the index will change if some MSAs grow more rapidly than others. Specifically, the impact of large MSAs (population greater than 1 million) growing more or less than smaller MSAs (population less than 1 million) is explored. The analysis is summarized in the chart shown in Figure 11. For example if MSAs with population over 1 million experience 5% economic growth and the smaller MSAs experience no growth, the Transportation Index would decline slightly from 51.24 to 51.06. On the other hand, if the MSAs with population under a million experience economic growth the national Transportation Index would improve. While this latter result seems counterintuitive, it reflects the fact that smaller MSAs have better transportation infrastructure. In reality the changes are relatively small and not statistically important.

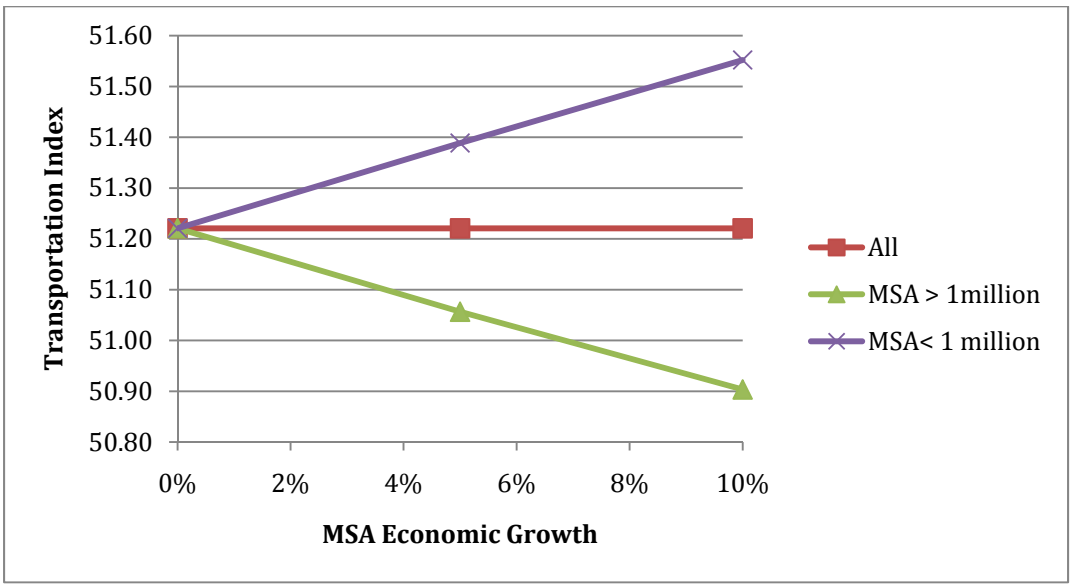


Figure 11. Transportation Index Versus Economic Growth

Sensitivity of the Weights

To better understand the index and how the index changes with the weighting scheme used in this analysis, a variety of weighting schemes are explored and compared the values for the Transportation Index.

In addition to the weights derived from the AHP analysis, five other weighting schemes were explored:

1. Equal weights for all indicators
2. Equal weights by mode
3. Weighted by Passenger Miles
4. Weighted by Ton Miles
5. Equal weights by type of indicator (based on criteria of Supply, Quality of Service, and Utilization)

The resulting Transportation Index values and the Moving Averages are shown in Figure 12 and Figure 13. Both figures show that the results are very similar except for values obtained using the weightings by passenger miles and by ton miles. This is supported by the correlation matrix shown in Table 14, which includes p-values shown in parentheses. The hypothesis that the correlation coefficient could be zero can be rejected at the 95% level for all weighting schemes except:

- Equal by Type and Weighted by Ton Miles
- Weighted by Passenger Miles and Weighted by Ton Miles
- Weighted by Passenger Miles and AHP Weights

When indicators are weighted by the relative number of ton miles, the Transportation Index shows an overall decline since 1996 with a recent increase in 2008. Future work on the index should explore alternative weighting schemes.

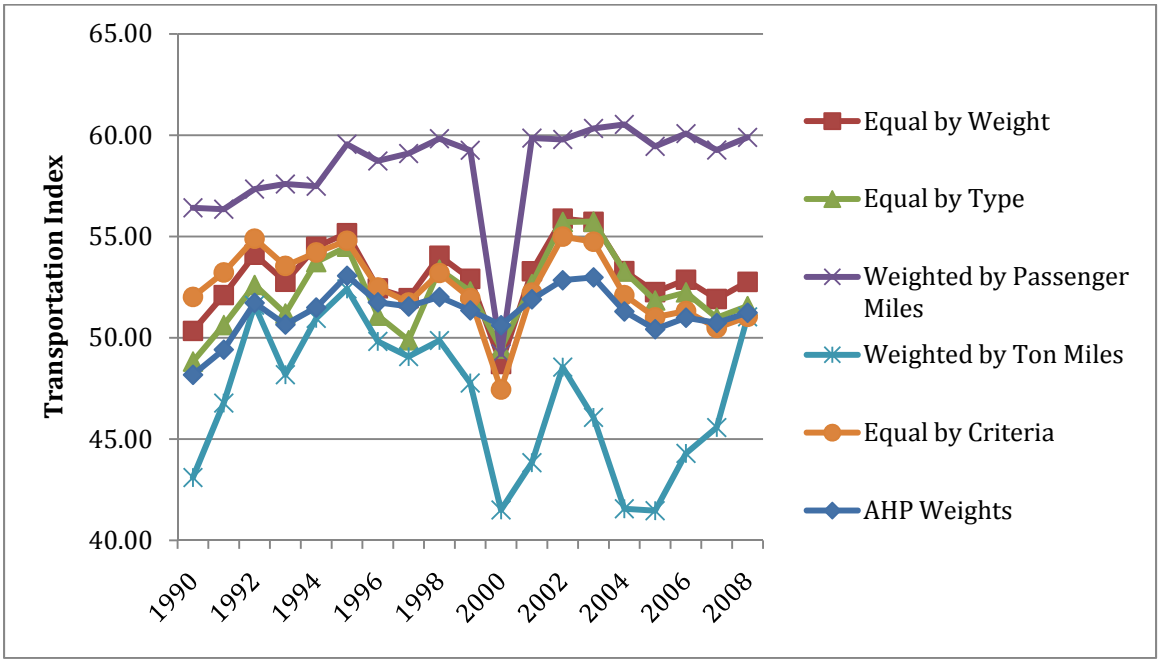


Figure 12. Transportation Index with Different Weighting Schemes

Table 14. Correlation Matrix for the Different Weighting Schemes

Weighting Scheme	Correlation Coefficient (p-value)					
	Equal by Weight	Equal by Type	Weighted by Passenger Miles	Weighted by Ton Miles	Equal by Criteria	AHP Weights
Equal by Weight	1.0					
Equal by Type	0.93 (0.00)	1.0				
Weighted by Passenger Miles	0.68 (0.00)	0.55 (0.02)	1.0			
Weighted by Ton Miles	0.53 (0.02)	0.32 (0.20)	0.25 (0.32)	1.0		
Equal by Criteria	0.86 (0.00)	0.69 (0.00)	0.49 (0.04)	0.61 (0.01)	1.0	
AHP Weights	0.77 (0.00)	0.81 (0.00)	0.44 (0.07)	0.48 (0.04)	0.47 (0.05)	1.0

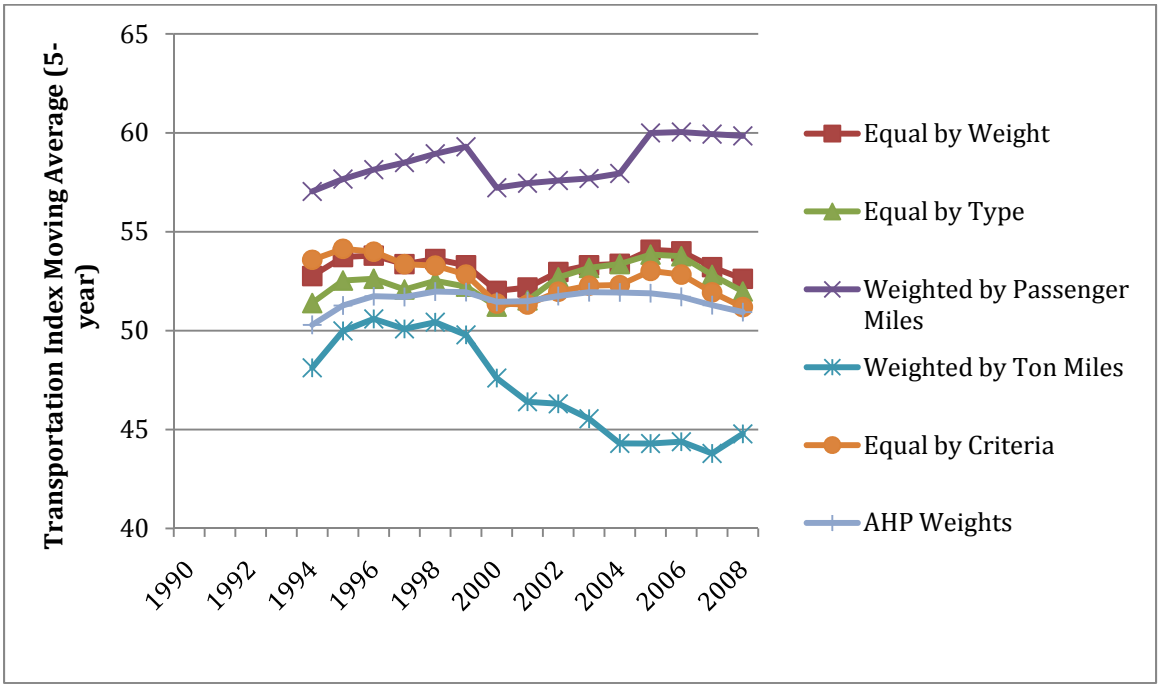


Figure 13. Moving Average of Transportation Index with Different Weighting Schemes

Comparing the Index to Some Time Series Data

The index is also compared to other key indicators that measure related attributes such as usage, costs, population, and expenditures.

Population and Usage

Figure 14 shows the Transportation Index plotted with Population, Passenger Miles Traveled, and Ton Miles of Freight moved in the U.S. These variables capture general changes in the population and changes in the usage of transportation infrastructure. Population, passenger miles, and ton miles are all showing steady increases until about 2006 when both passenger and freight usage of the transportation system drop off slightly. This can be seen more clearly in Figure 15, which reports the same data as a percentage of 1990 values.

From 1990 to 2008, the Transportation Index has increased by about 6%. In contrast, population has grown 22%, passengers 39% and freight 27%. Clearly transportation infrastructure performance is not keeping pace with the growth in population and usage.

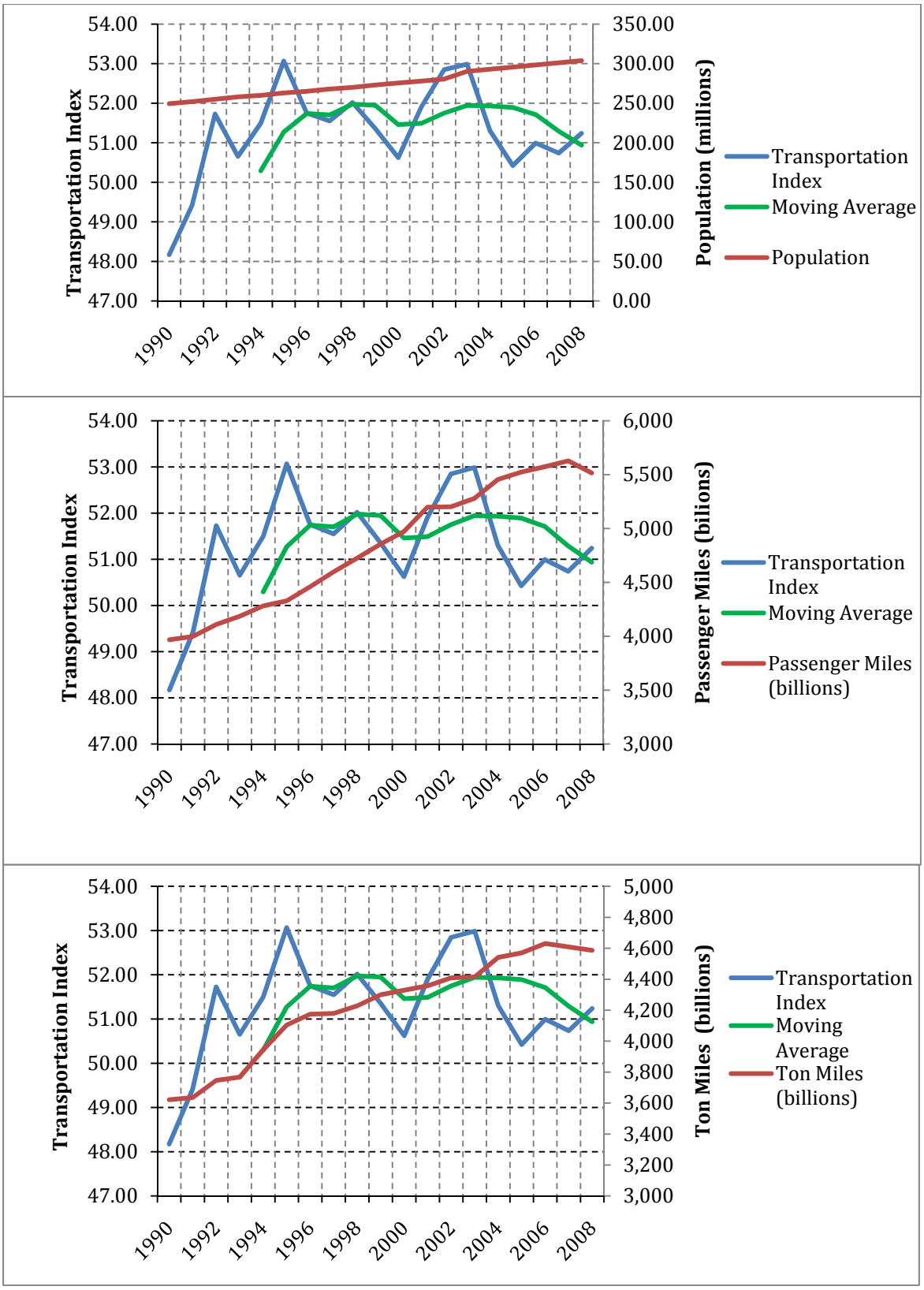


Figure 14. Transportation Index Compared With Population, Passenger Travel, and Freight Moved

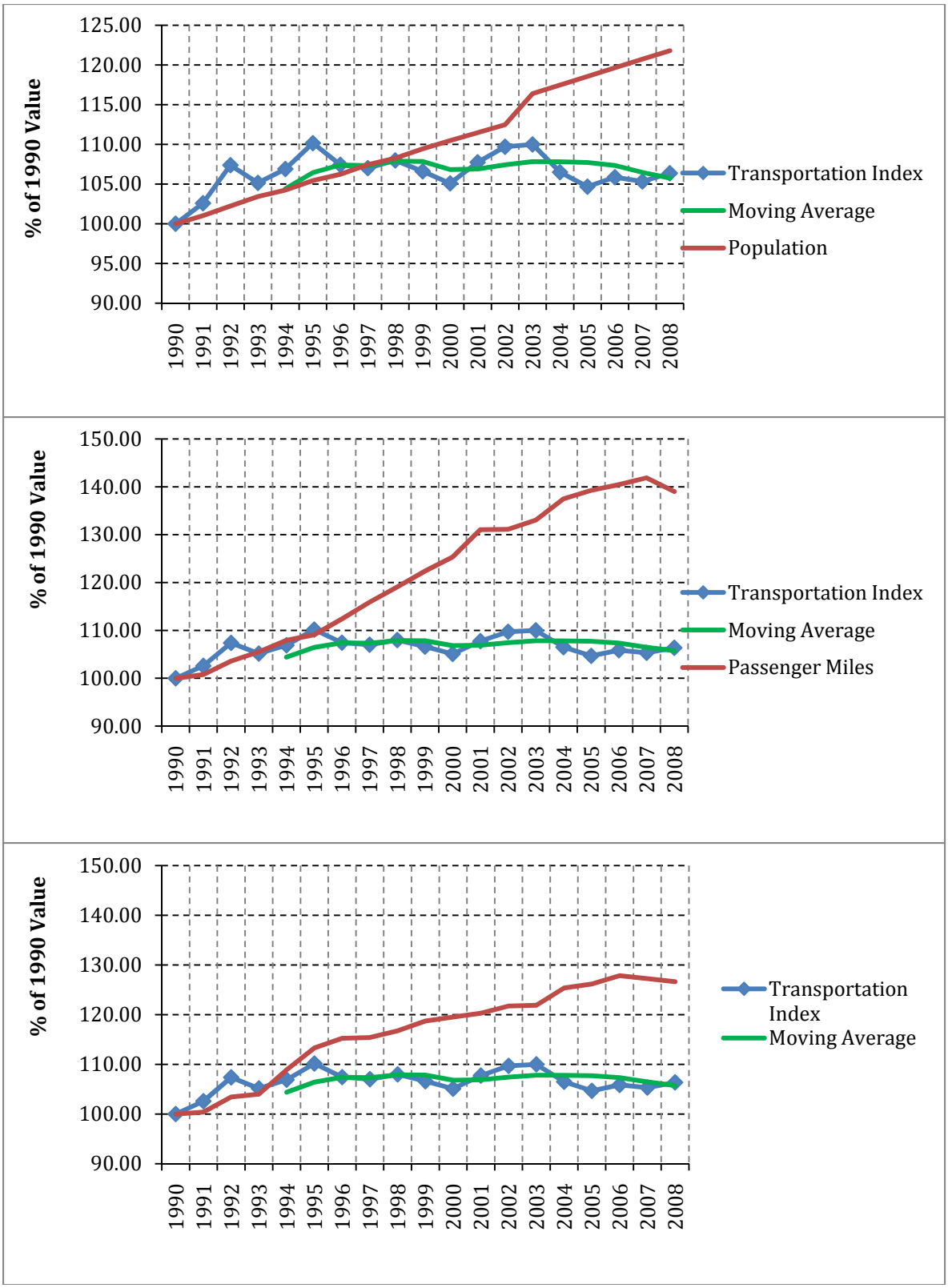


Figure 15. Transportation Index Relative to Population, Passenger Travel, and Freight Moved as a Percentage of 1990 Values

Transportation Services Index

The Transportation Services Index (TSI) is a multimodal, seasonally adjusted economic measure of transportation services used in the for-hire sector. Freight, passenger, and combined indices are available from BTS (Bureau of Transportation Statistics, 2010). Like population, passenger travel, and freight, TSI shows that infrastructure performance is not keeping pace with the demand for services as shown in Figure 16.

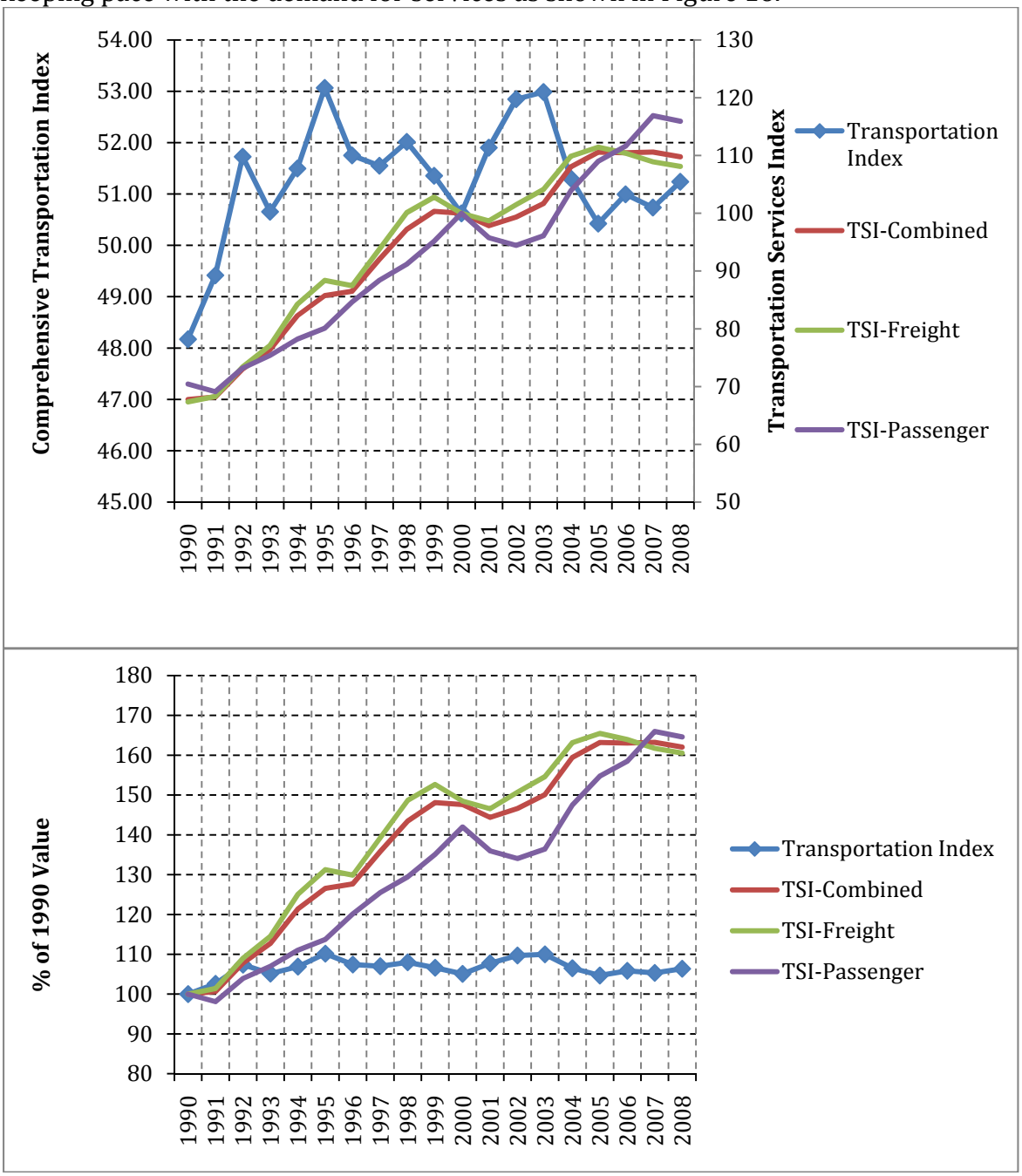


Figure 16. Transportation Index and Transportation Services Index

Federal Expenditures on Transportation

Historical data on federal expenditures on transportation can be obtained from the U.S. Budget (Office of Management and Budget, 2010). To compare expenditures over time expenditures are deflated using a highway construction cost index (Federal Highway Administration, 2010). Historically this index was computed by FHWA. However, since 2007 FHWA has not computed this index. An average of the FHWA index and values estimated by individual states based on data assembled by Washington State Department of Transportation (Washington State Department of Transportation, 2010) is used.

Since 2004, these costs have escalated faster than the Consumer Price Index (Bureau of Labor and Statistics, 2010) as shown in Figure 17. Global fuel price increases and shortages of material have contributed to the fact that the same dollar does not provide as much transportation infrastructure today as it might have in the past.

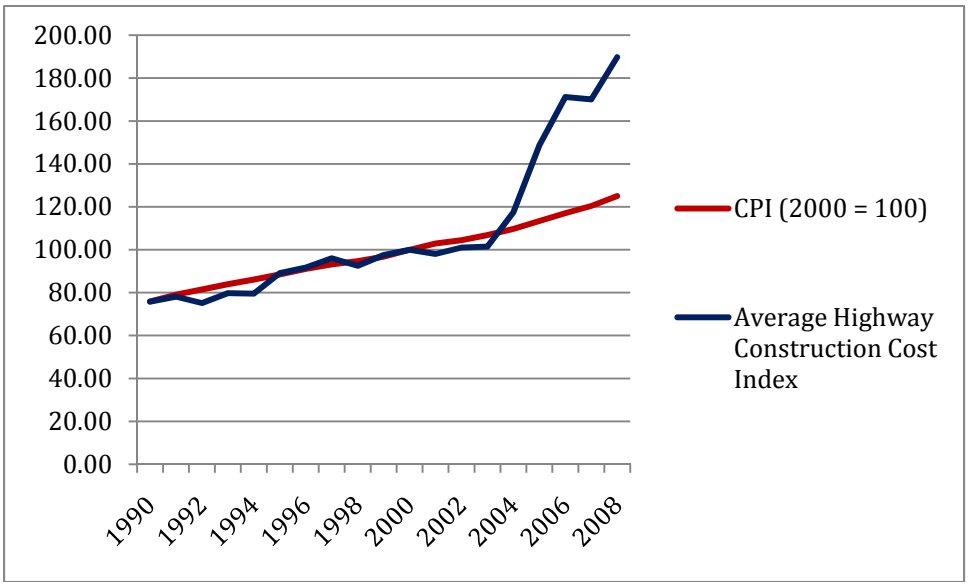


Figure 17. Construction Cost Index and Consumer Price Index

Expenditure data in raw dollars, and constant 2000 dollars computed using both the Construction Cost Index and the Consumer Price Index are shown in Figure 18. The three curves show significant divergence after 2003. For this analysis, the expenditures in constant dollars computed using the average Construction Cost Index are used as that is the truest indicator of the purchasing power of federal dollars invested in transportation infrastructure.

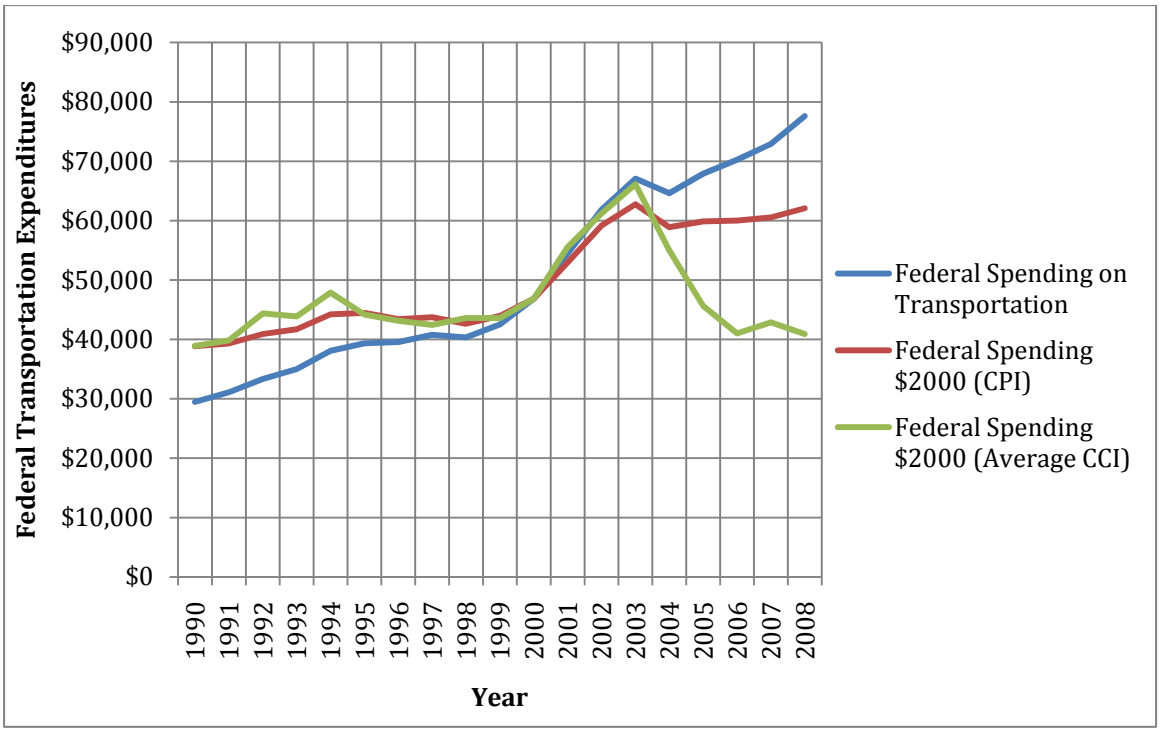
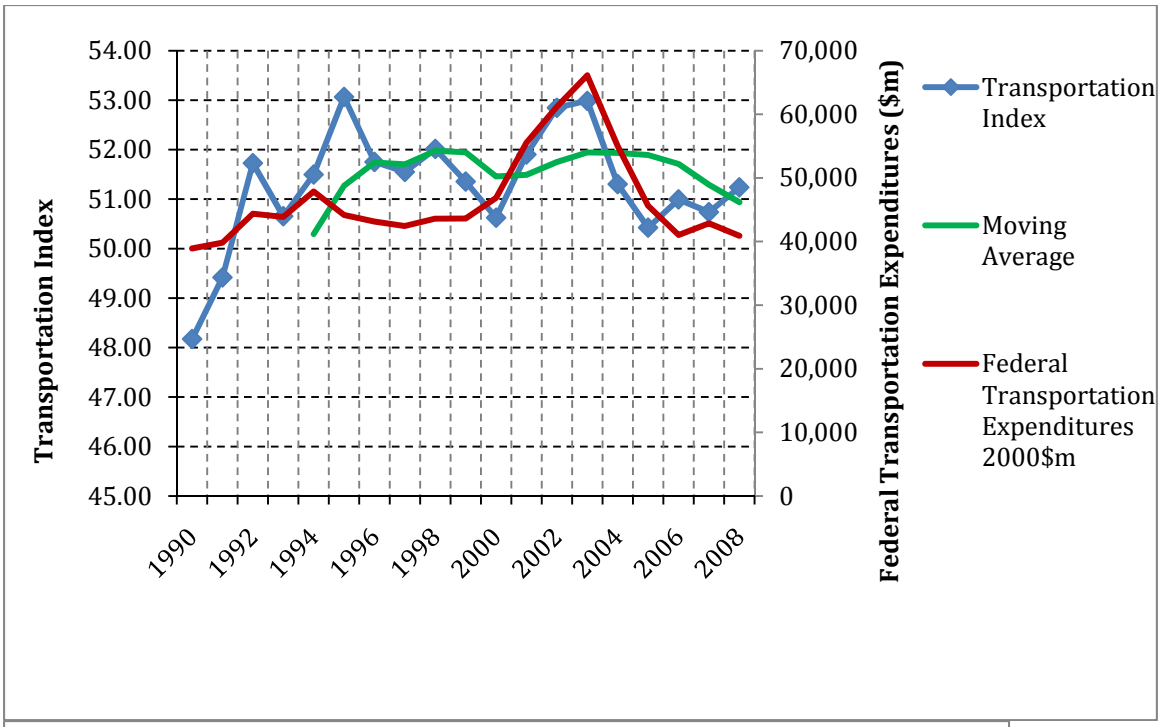


Figure 18. Federal Transportation Expenditures

Figure 19 shows the relationship between federal transportation expenditures in 2000 dollars and the Transportation Index. The first graph shows the Transportation Index and Federal Transportation Expenditures. The correlation coefficient for expenditures and the Transportation Index for the data between 2000 and 2008 is 0.87. Using a t-test and an α = 0.002, the hypothesis that the correlation coefficient could be zero is rejected. The second graph shows the Transportation Index and Federal Transportation Expenditures relative to their 1990 values. Except for the period 2000 to 2005, transportation expenditures in constant dollars have remained fairly constant. Superimposing the relevant transportation legislation, as shown in Figure 20, provides additional insight. The significant growth in expenditures between 2000 and 2003 coincides with TEA-21 and the precipitous decline in 2004 and 2005 coincides with the period during which federal expenditures operated under continuing resolution.



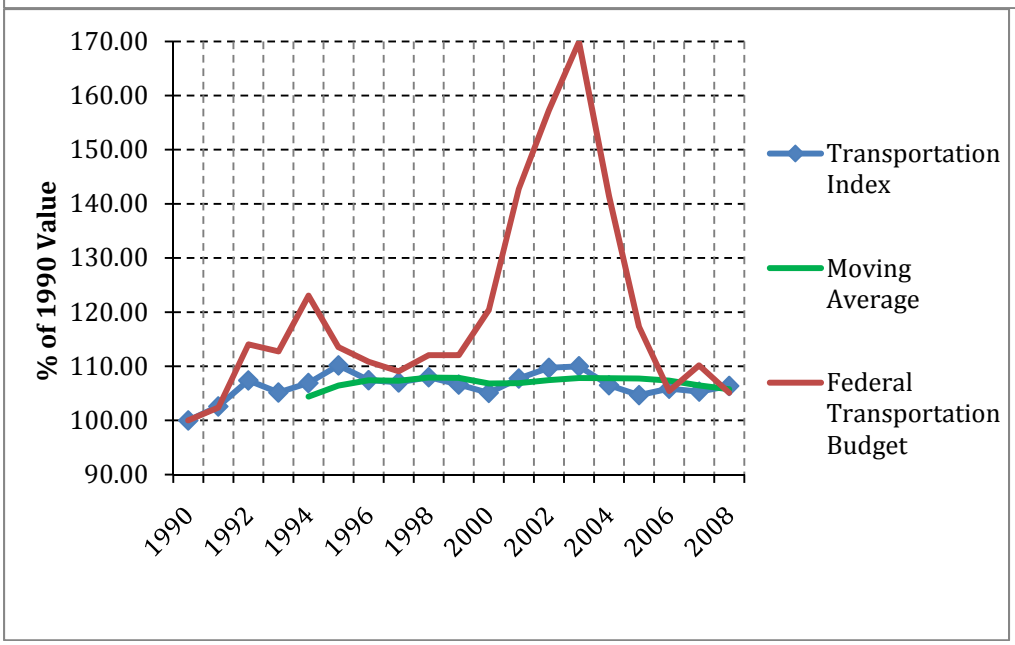


Figure 19. Transportation Index and Federal Transportation Expenditures

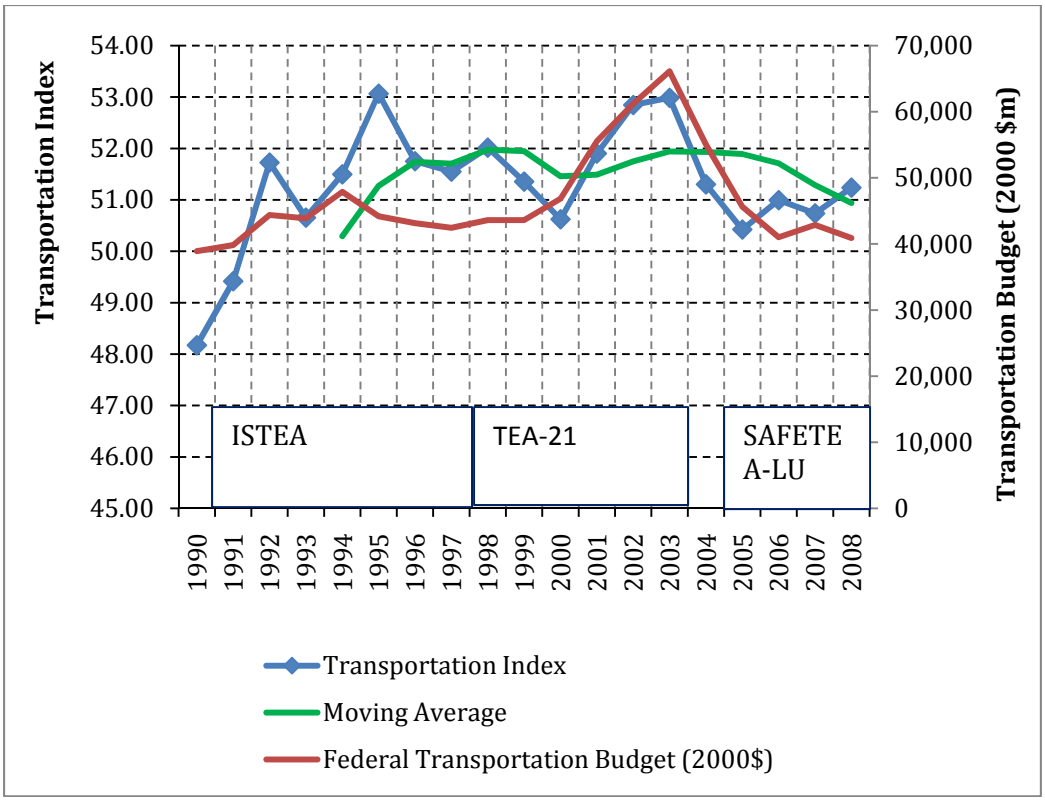


Figure 20. Federal Expenditures and Relevant Legislation

American Society of Civil Engineers' Report Card

Finally, Transportation Index is compared to the American Society of Civil Engineers' (ASCE) Report Card (American Society of Civil Engineers, 2010). Starting with the report card grades as reported for the years 1988, 1998, 2001, 2003, 2005, and 2009, and as shown in Table 15, the grades are converted to a "grade point average" (GPA) using the scoring system commonly used for university grading as shown in Table 16.

Table 15. ASCE's Report Card

	1988	1998	2001	2003	2005	2009
Aviation	B-	C-	D	D	D+	D
Bridges		C-	C	C	C	C
Inland Waterways			D+	D+	D-	D-
Rail					C-	C-
Roads	C+	D-	D+	D+	D	D-
Transit	C-	C	C-	C-	D+	D

Table 16. Grade Equivalency

Letter Grade	GPA
A	4
A-	3.7
B+	3.3
B	3
B-	2.7
C+	2.3
C	2
C-	1.7
D+	1.3
D	1
D-	0.7
F	0

A weighted and an unweighted GPA are then computed. The weighted GPA uses the weights from the AHP process for the each of the indicators and then assigned these weights to the different transportation infrastructure modes as shown in Table 17. The results are shown in Table 18.

Table 17. Determining the Weights for the GPA

Mode	Indicators (see Table 3)	Weight
Aviation	3, 4, 13, 14, 19	0.141
Bridges	12	0.073
Inland Waterways	6, 7, 16	0.068
Rail	5, 8, 15, 21	0.165
Roads	1, 9, 10, 11, 18	0.409
Transit	2, 17, 20	0.146

Table 18. Infrastructure GPA Based on ASCE's Report Card

	1988	1998	2001	2003	2005	2009
Unweighted	2.23	1.53	1.46	1.46	1.33	1.18
Weighted	2.26	1.23	1.38	1.38	1.25	1.05

The GPA for the ASCE is plotted along with the Infrastructure Index in Figure 21. The intermediate values (for the years between when the report card was released) were interpolated. The correlation between the Transportation Index and the GPA from 1998 to 2008 is 0.54 for the unweighted GPA and 0.56 for the weighted GPA. Using a t-test and an $\alpha = 0.10$, the hypothesis that the correlation coefficient could be zero is rejected.

This analysis highlights the value of ASCE's infrastructure report card for communicating the condition and performance of infrastructure. It also highlights the role of the Transportation Index as a quantitative approach to consistently measuring infrastructure performance over time. ASCE cautions against using the report card to make comparisons over time as the methodology is not consistent. Furthermore, the report card was issued only in 1988, 1998, 2001, 2003, 2005, and 2009. The values computed for the intervening years are simply based on interpolation. To illustrate the differences in methodology from year to year, the 1988 report card is based on three broad categories of transportation infrastructure (aviation, roads, and transit) (National Council on Public Works Improvement, 1988), whereas the 2009 report card used six categories (aviation, bridges, inland waterways, rail, roads, and transit). The grades are based on publicly available data and subjective judgment (American Society of Civil Engineers, 2010). The ASCE report card and the Transportation Index should be viewed as complementary tools for communicating the issues related to transportation infrastructure performance.

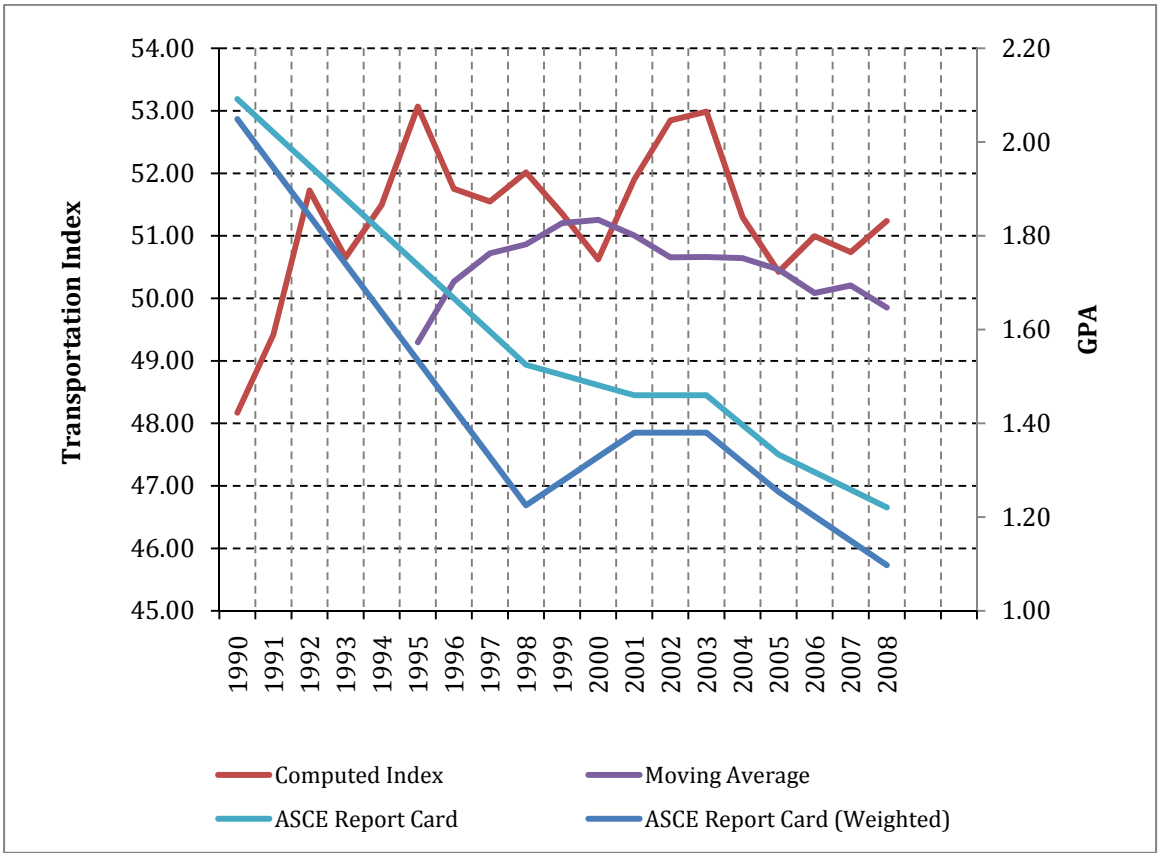


Figure 21. Infrastructure Report Card and Transportation Index (1990-2008)

Extrapolated Future (2015)

To explore how the index might change with respect to the future, three scenarios are explored. In each scenario, the population of the U.S. is assumed to be growing at 1% per year. The analysis also assumes that the structure of the economy does not change in the

sense that the relative contribution of each MSA does not change. The scenarios are defined as follows:

Scenario 1 - (New Investment) - assumes a high level of investment across all modes strategically directed to improve infrastructure performance by about 10% over the period 2008 – 2015. This is equivalent to an improvement of 1.2% per year. The analysis recognizes constraints. For example, the Travel Time Index, which is the ratio of congested travel time to free flow travel time, cannot be less than 1.

Scenario 2 - (No New Investment) - assumes no new investment.

Scenario 3 - (1960s Infrastructure) - assumes that the transportation system devolves to a transportation infrastructure network similar to the network available in 1960 – with few highways and airports.

The specific changes for each indicator for each scenario are shown in Table 19. Changes are reported as percentage changes or as a specific value of the indicator as follows:

- Scenario 1, Airport Access: Indicator =1; interpreted to mean that for all MSAs 100% of the population has access to an airport within 50 miles.
- Scenario 2, Highway Travel Time Reliability: Indicator = 0; interpreted to mean that for all MSAs Travel Time Reliability is as low as the worst MSA for 2000.
- Scenario 3, Highway Reserve Capacity, Air Reserve Capacity, Rail Reserve Capacity: Indicator = 0; interpreted to mean that what infrastructure exists is fully utilized leaving no reserve capacity for growth.

The extrapolated values are shown in Figure 22. The data are interpolated for the years 2009-2014 using a power function to capture growth.

This data can also be extrapolated to 2020 as shown in Figure 23. Caution should be used in interpreting these 2020 values as the analysis assumes that everything is held constant between 2008 and 2020. In fact one would expect that the relative value placed on different modes, criteria and indicators will change. Furthermore technology will change as transportation systems respond to increasing pressures (political, economic and environmental) to reduce emissions, reduce use of non-renewal energy, and improve mobility and accessibility.

Table 19. Changes in Indicators 2008- 2015 for Three Scenarios

#	Description	Scenario 1	Scenario 2	Scenario 3
IND1	Highway Density	No change	-7%	-90%
IND2	Transit Density	+10%	-7%	No change
IND3	Airport Access	Indicator=1	+7%	No change
IND4	Airport Capacity	+10%	No change	-50%
IND5	Rail Density	+10%	-7%	+20%
IND6	Waterway Density	No change	-7%	+20%
IND7	Port Access	-10%	No change	No change
IND8	Intermodal Freight Access	+10%	-7%	-50%
IND9	Highway Travel Time Reliability	-10%	+7%	Indicator=0
IND10	Highway Safety	-10%	No change	No change
IND11	Road Roughness	-10%	+10%	No change
IND12	Highway Bridge Integrity	-10%	+10%	No change
IND13	Air Congestion	+10%	-7%	↑50%
IND14	Air Safety	-10%	No change	No change
IND15	Rail Safety	-10%	No change	No change
IND16	Waterway Congestion	-10%	+7%	No change
IND17	Transit Safety	-10%	No change	No change
IND18	Highway Reserve capacity	+10%	-7%	Indicator=0
IND19	Air Reserve capacity	-10%	+7%	Indicator=0
IND20	Transit Reserve capacity	-10%	+7%	Indicator=0
IND21	Rail Reserve capacity	-10%	+7%	Indicator=0

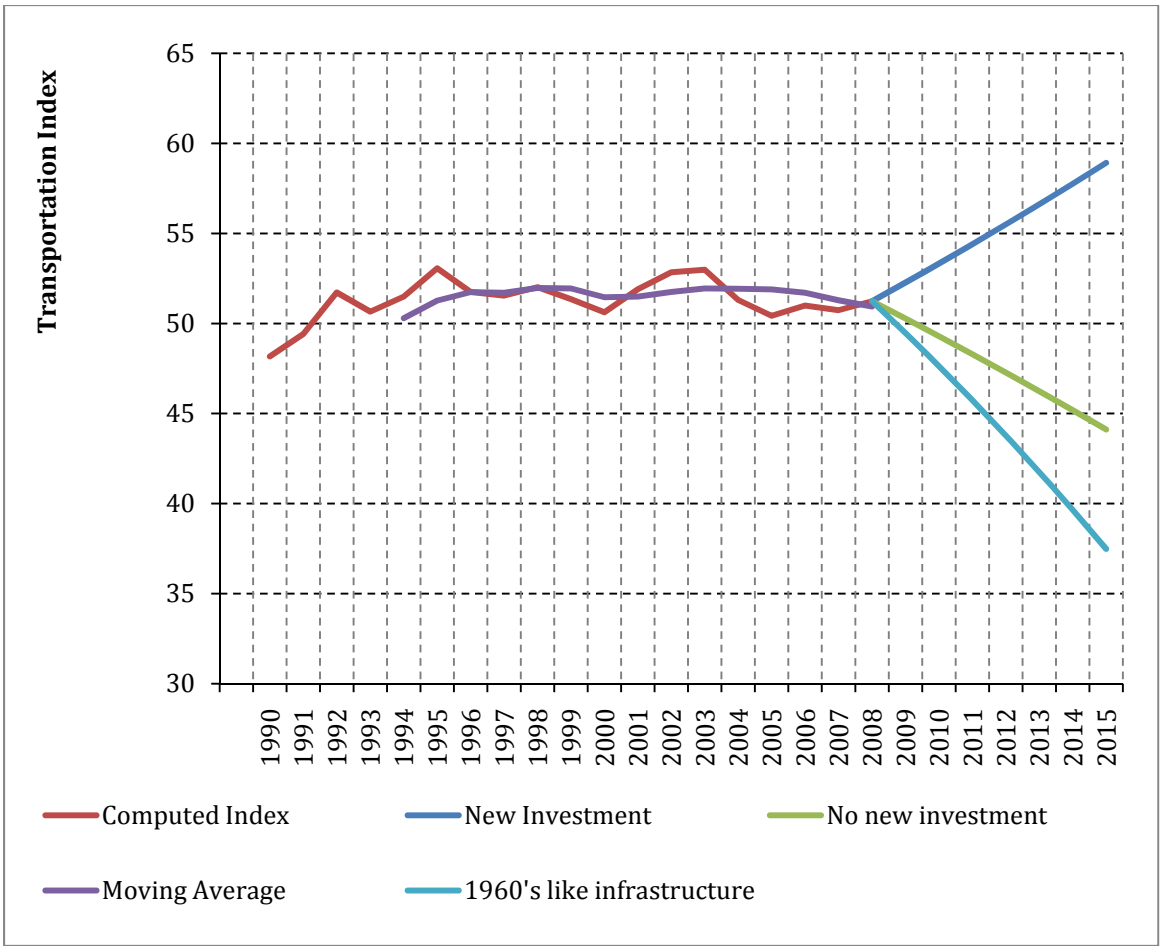


Figure 22. Transportation Index Extrapolated to 2015

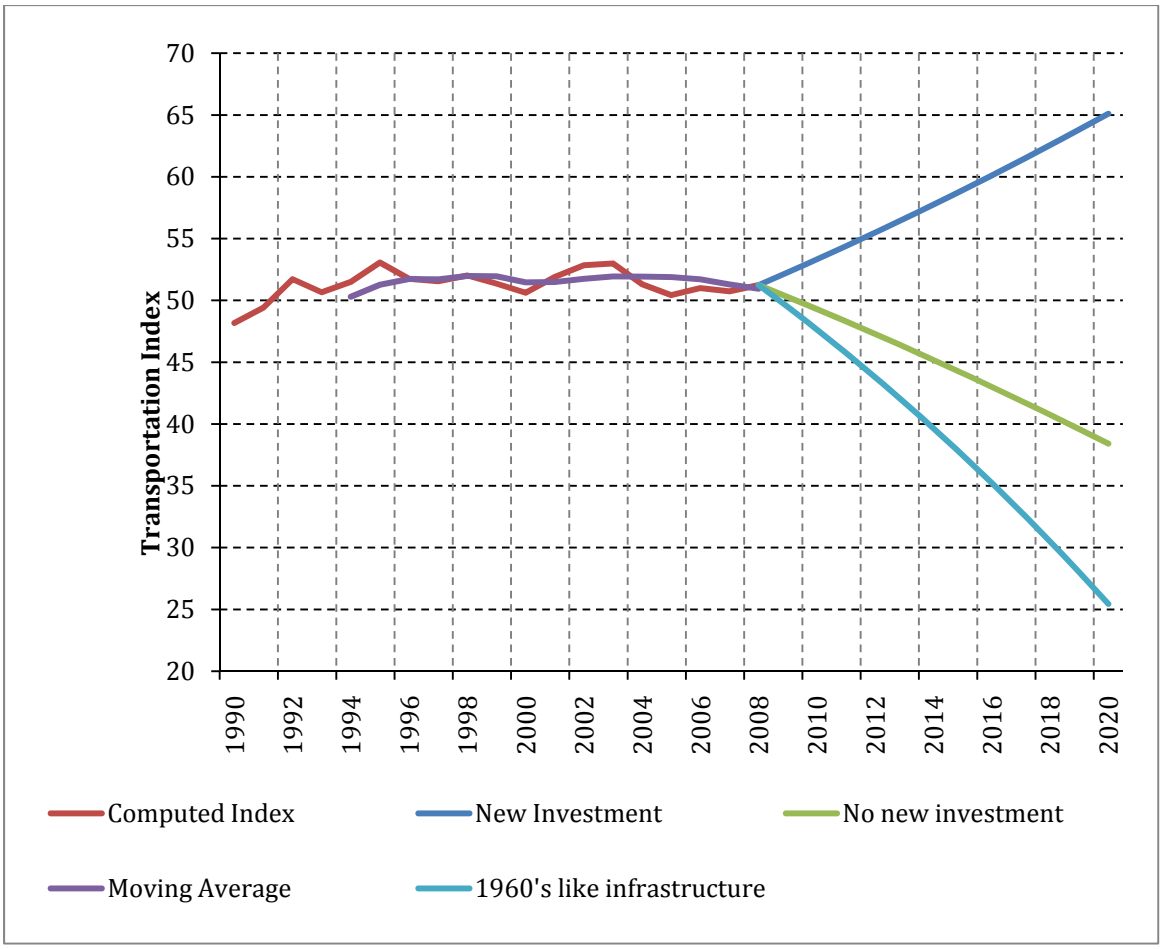


Figure 23. Transportation Index Extrapolated to 2020

Next Steps

The Transportation Index provides us with a rich source of historical information related to the performance of the nation's complex and extensive transportation infrastructure system. This emphasis on performance is reinforced by the focus on performance measures for decision making in the 2007 report of the National Surface Transportation Policy and Revenue Study Commission (2007), the National Transportation Policy Project (Bipartisan Policy Center, 2009), and the U.S. House of Representatives Transportation and Infrastructure Committee's "Blueprint for Investment and Reform" (2009).

While all infrastructure and all performance measures are not necessarily captured by the index, the index is intended to provide a general picture of the performance of infrastructure across the nation. The Transportation Index suggests that transportation infrastructure performance is "barely holding steady". Despite massive investments, the Transportation Index has not improved significantly over the last decade. Furthermore, despite significant population growth and increases in passenger miles traveled and ton miles of freight moved, it is surprising that the Transportation Index is not worse. This perhaps is a testament to American ingenuity.

Time and time again stakeholders talked about how they work around the issues created by the existing transportation system by scheduling deliveries in off-peak hours, implementing innovative employee work policies, substituting information technology for transportation services, and exploring new markets. There are also countless stories of infrastructure owners using the engineering equivalent of Band-Aids to hold the infrastructure together to deliver service, and innovative operational strategies to enhance throughput.

The Transportation Index tells us that it is time to be proactive. Even attempting to continue with "business as usual" will result in the performance of the U.S. transportation infrastructure declining. Making investments across all modes and all criteria – supply, quality of service, and utilization – is essential is the U.S. is going to have a transportation infrastructure system that supports the 21st century economy.

STATE-BY-STATE TRANSPORTATION INDEX RESULTS

To get a sense of how transportation infrastructure is performing on a state-by-state basis, a Transportation Index is developed for each state and the District of Columbia. The indices are developed using the same methodology as the national Transportation Index using data for each state (without sampling) and a subset of the indicators for which statewide data could be obtained. The indices are computed for 1995, 2000, and 2007, and estimated for 2015.

Indicators

The original list of indicators used for the national Transportation Index is shown in Table 20. The table also shows which indicators are not available for individual states, data sources, and the years for which data are available. As the state-by-state index is developed only for 1995, 2000, and 2007, missing data had to be estimated. If 1995 data are missing, 2000 and 2007 indicator data is used to extrapolate to 1995. Some indicators do not have 2000 data either. The extrapolation process is based on the data in 2007 and the first year that data were available.

The indicators used are:

- Supply
    - Highway Density - Route Miles per 10,000 Population
    - Transit Density - Miles of Transit per 10,000 Population
    - Airport Access – Enplanements per population
    - Rail Density - Route Miles per 10,000 Population
    - Waterway Density - Miles of Waterways per 10,000 population
    - Port Access - Distance from the Center of the State to the Closest International Container Port
    - Intermodal Connectivity - # Ramps per 10, 000 Population
- Quality of Service
    - Highway Safety - Fatalities per 100 Million VMTs
    - Road Roughness - % of Lane Miles with IRI Greater Than 170 in./mi.
    - Bridge Integrity - % of Bridges Structurally Deficient or Functionally Obsolete
    - Air Congestion - % of On-Time Performance of Departures
    - Air Safety – Number of Runway Incursions per Million Operations
    - Rail Safety – Number of Incidents per Million Train Miles
    - Transit Safety - Number of Incidents per 100 Million PMT
- Utilization
    - Uncongested Roads - % of Lane Miles at LOS C or Better
    - Transit Utilization - PMT per Capacity (Standing + Seating)

- Rail Utilization - Million Ton Miles of Freight per Track Miles

A summary of each indicator is provided in Appendix D.

The weights used to calculate the national index from the indicators were also used for the state-by-state indices with one adjustment for Hawaii and Alaska that do not have access to any of the major ports. While one could argue that the weights should vary depending on how the business community in each state views the relative importance of the various indicators of performance for transportation, the data collection effort involved was beyond the scope of this project.

Results

The Transportation Index was computed for each state and the District of Columbia for 1995, 2000, and 2007. The results are shown in Table 21 and Figure 24. The results are listed by state in alphabetical order. In 2007, the Transportation Index ranges from a high of 81.25 in 2007 for North Dakota to a low of 31.25 in 2000 for the District of Columbia. While the District of Columbia is somewhat of an anomaly, New Jersey is the next lowest with a value of 46.71 in 2007.

Also of note is the fact that the State-by-State Transportation Index values are generally higher (better) than the national Transportation Index. This is due to the fact that the State-by-State Transportation Index does not include an indicator for travel time reliability. This indicator was heavily weighted and tended to score low in sampled MSAs that contributed significantly to GDP.

Figure 24 gives the general impression that the index has improved over time. Closer inspection indicates that while few states have experienced a downward trend, changes over time are more complex and can be summarized as follows:

- Transportation Index is Relatively Stable (index change <2)(13 states)
  - Alabama, Arizona, Indiana, Kentucky, Louisiana, Nevada, New Hampshire, New Jersey, New Mexico, North Carolina, Oklahoma, Tennessee, Texas
- Transportation Index Consistently Improves (15 states)
  - Alaska, Colorado, Delaware, Florida, Illinois, Iowa, Maryland, Minnesota, Mississippi, Nebraska, North Dakota, Rhode Island, Utah, Vermont, Virginia
- Transportation Index Consistently Degrades (2 states)
  - Connecticut, West Virginia
- Transportation Index Improves (1995-2000) and Then Degrades (2000-2007) (3 states)
  - Georgia, Hawaii, Ohio
- Transportation Index Degrades (1995-2000) and Then Improves (2000-2007) (18 states)
  - Arkansas, California, District of Columbia, Idaho, Kansas, Maine, Massachusetts, Michigan, Missouri, Montana, New York, Oregon, Pennsylvania, South Carolina, South Dakota, Washington, Wisconsin, Wyoming

Figure 25, Figure 26, and Figure 27 are plots of the Transportation Index for each state for 1995, 2000, and 2007 respectively. In these plots the states are ordered from the state with the best Transportation Index (North Dakota) to the state with the worst Transportation Index (District of Columbia).

To help communicate the results, the states are organized into regions using the Bureau of Economic Analysis regions (U.S. Chamber of Commerce, 2010) and the State-by-State Transportation Indices are plotted for each year. These plots are shown in Figure 28 (New England), Figure 29 (Mideast), Figure 30 (Midwest), Figure 31 (Plains), Figure 32 (Southeast), Figure 33 (Southwest), Figure 34 (Rocky Mountain), and Figure 35 (Far West). Notable is the cluster of "better" states in the Plains, and the cluster of "worse" states in New England and the Mideast.

Finally, two groups of states are identified – the top 10 states and then the next 15 states – based on the Transportation Index and mapped these as shown in Figure 36. The clustering of states in the Plains is again notable.

Table 20. Indicators Use for the State-by-State Transportation Index

Criteria	Mode/ User	#	Indicator	Possible Source	State?	Available Year
Supply	Highway – passenger and freight	1	Route Miles per 10,000 Population	National Transportation Atlas Database (NTAD), Bureau of Census	X	00, 07
	Transit – Passenger	2	Miles of Transit per 10,000 Population	National Transit Database, Bureau of Census	X	00, 07
	Aviation – Passenger	3	# Enplanements per population	Terminal Area Forecast, Bureau of Census	X	95, 00, 07
	Aviation – Passenger	4	Average (AAR + ADR) per Hour	Removed		
	Rail - Freight	5	Route Miles per 10,000 Population	National Transportation Atlas Database (NTAD), Bureau of Census	X	00, 07
	Marine – Waterway	6	Miles of Waterways per 10,000 population	National Transportation Atlas Database (NTAD), Bureau of Census	X	00, 07
	Marine - Port	7	Distance from the Center of State to the Closest International Container Port	National Transportation Atlas Database (NTAD)	X	00, 07
	Intermodal	8	# Ramps per 10, 000 Population	National Transportation Atlas Database (NTAD), Bureau of Census	X	00, 07

Criteria	Mode/ User		#	Indicator	Possible Source	State ?	Available Year
Quality of Service	Highway	Congestion	9	Travel Time Index	Removed		
		Safety [4]	10	Fatalities per 100 Million VMTs	Fatal Accident Reporting System (FARS), and Highway Performance Monitoring System (HPMS)	X	95, 00, 07
		Impedance	11	% of Lane Miles with IRI Greater Than 170 in./mi.	Highway Performance Monitoring System (HPMS)	X	95, 00, 07
		Impedance	12	% of Bridges Structurally Deficient or Functionally Obsolete	National Bridge Inventory (NBI)	X	95, 00, 07
	Transit – safety [4]		17	# Incidents per 100 Million PMT	National Transit Database	X	02, 07
	Aviation	Congestion	13	% of On-Time Performance of Departures	Bureau of Transportation Statistics (BTS), and Terminal Area Forecast (TAF) (# of enplanements)	X	95, 00, 07
		Safety [4]	14	Runway Incursions per Million Operations	Runway Safety Office Runway Incursion (# incursions) and Terminal Area Forecast (TAF) (# of operations)	X	02, 07
	Rail	Safety	15	# Incidents per Route Miles	Bureau of Transportation Statistics (BTS)	X	00, 07
	Marine - Waterway Congestion		16	Average Lock Delay per Tow (Hrs.)	Removed		
Utilization	Highway		18	% of Lane Miles at LOS C or Better	Highway Performance Monitoring System (HPMS)	X	95, 00, 07
	Transit		20	PMT per Capacity (Standing + Seating)	National Transit Database	X	00, 07
	Aviation		19	% Capacity Used between 7am and 9pm	Removed		
	Rail		21	Million tons of commodity shipped per route mile	Bureau of Transportation Statistics (BTS)	X	00, 07

NOTE: There is no data available to indicate utilization for marine infrastructure; or quality of service for transit.

Table 21. State-by-State Transportation Index

State	1995	2000	2007
Alabama	61.33	61.09	60.48
Alaska	54.59	56.86	62.7
Arizona	58.26	59.13	61.05
Arkansas	56.13	53.16	55.52
California	52.59	48.54	51.76
Colorado	56.69	56.91	61.52
Connecticut	57.64	54.11	53.81
Delaware	54.7	57.11	57.43
District of Columbia	32.69	31.25	35.08
Florida	45.91	52.89	55.26
Georgia	58.17	60.5	59.72
Hawaii	47.97	51.07	49.98
Idaho	58.93	57.6	63.03
Illinois	53.13	54.23	58.33
Indiana	58.83	60.52	61.32
Iowa	63.67	64.29	67.65
Kansas	61.37	61.02	66.78
Kentucky	59.26	58.47	59.51
Louisiana	53.83	55.29	56.37
Maine	62.77	62.2	66.15
Maryland	55.12	55.9	58.57
Massachusetts	51.65	47.7	52.19
Michigan	52.96	50.63	60.67
Minnesota	58.45	59.86	65.02
Mississippi	52.82	53.83	61.68
Missouri	59.09	54.59	59.6
Montana	66.95	66.68	70.89
Nebraska	65.03	65.51	71.66
Nevada	54.07	52.2	51.64
New Hampshire	58.74	57.72	59.48
New Jersey	47.06	47.92	46.71
New Mexico	53.94	53.91	52.59
New York	52.1	50.78	55.19
North Carolina	51.89	53.86	53.39
North Dakota	75.43	76	85.12
Ohio	57.02	61.69	59.64
Oklahoma	61.87	61.37	62.34
Oregon	59.94	59.34	64.72
Pennsylvania	54.12	51.7	56.16
Rhode Island	46.7	47.81	57.29
South Carolina	59.09	58.37	60.38
South Dakota	68.02	66.83	74.47
Tennessee	60.21	59.29	60.44
Texas	58.9	57.57	59.46
Utah	58.18	59.52	63.37
Vermont	61.83	62.07	66.26
Virginia	59.4	59.5	63.77
Washington	60.85	59.52	62.06
West Virginia	58.95	59.85	57.76
Wisconsin	58.82	56.62	57.26
Wyoming	63.33	60.13	65.56

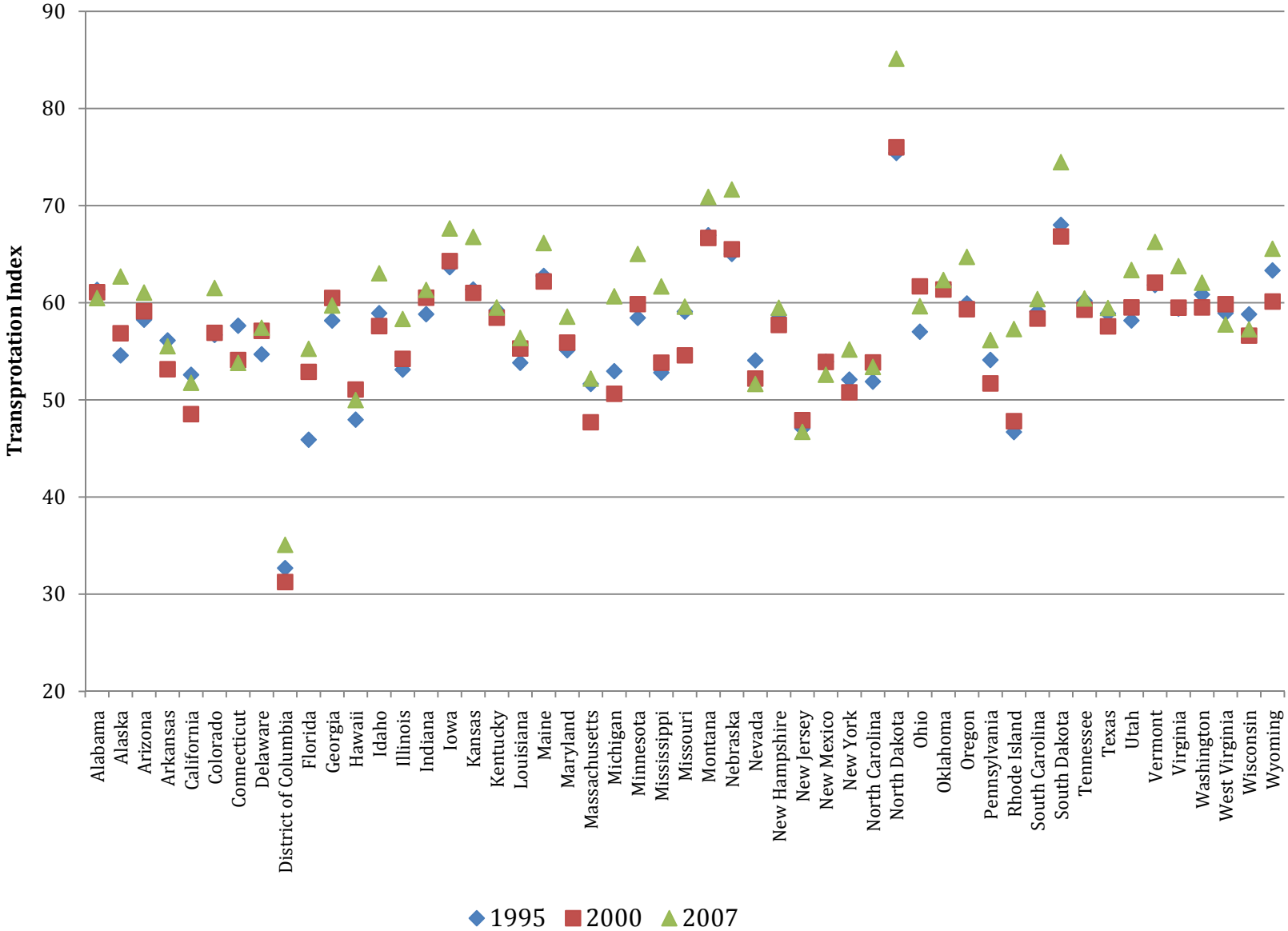


Figure 24. State-by-State Transportation Index (All Years, All States)

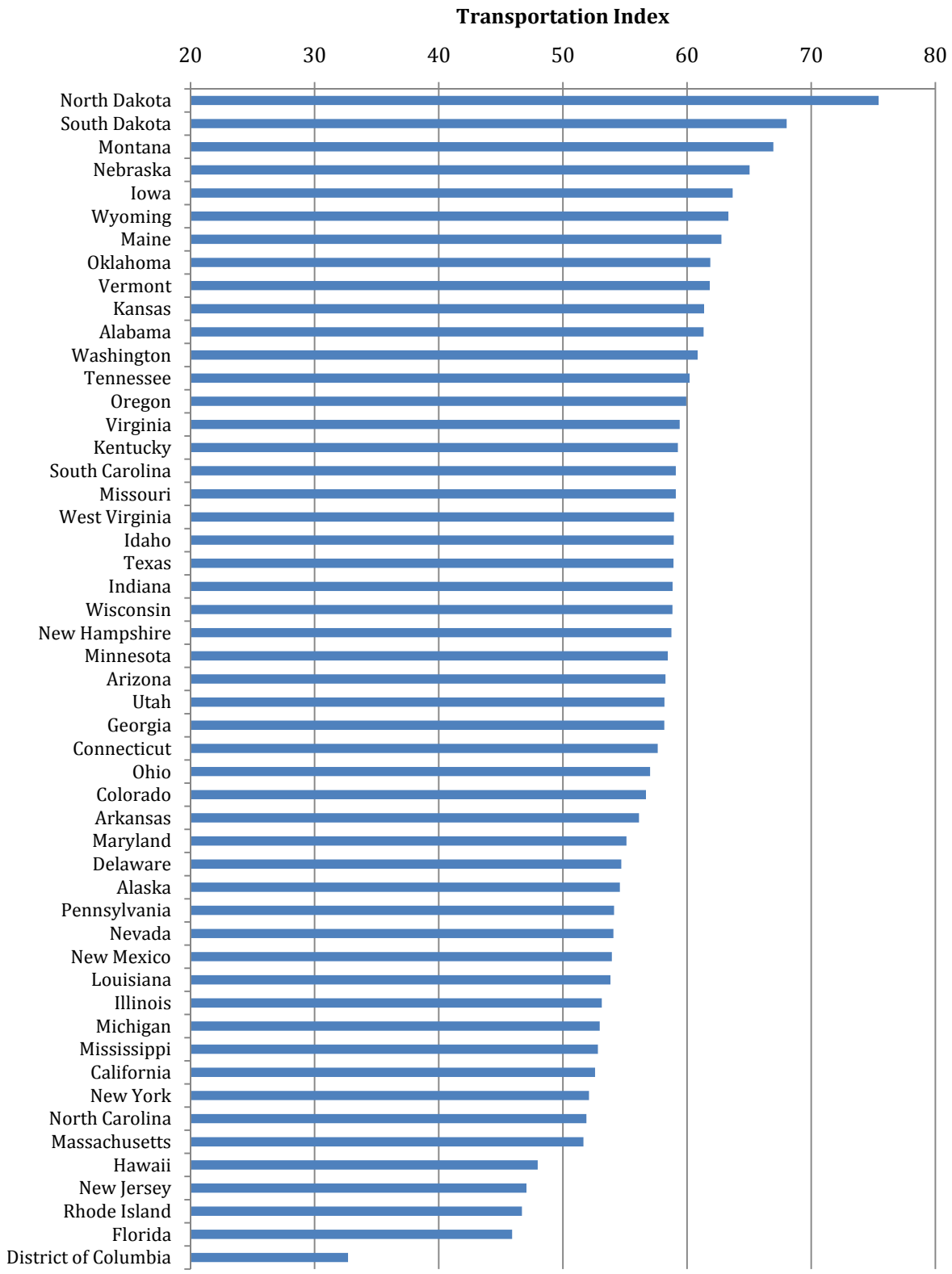


Figure 25. State-by-State Transportation Index 1995

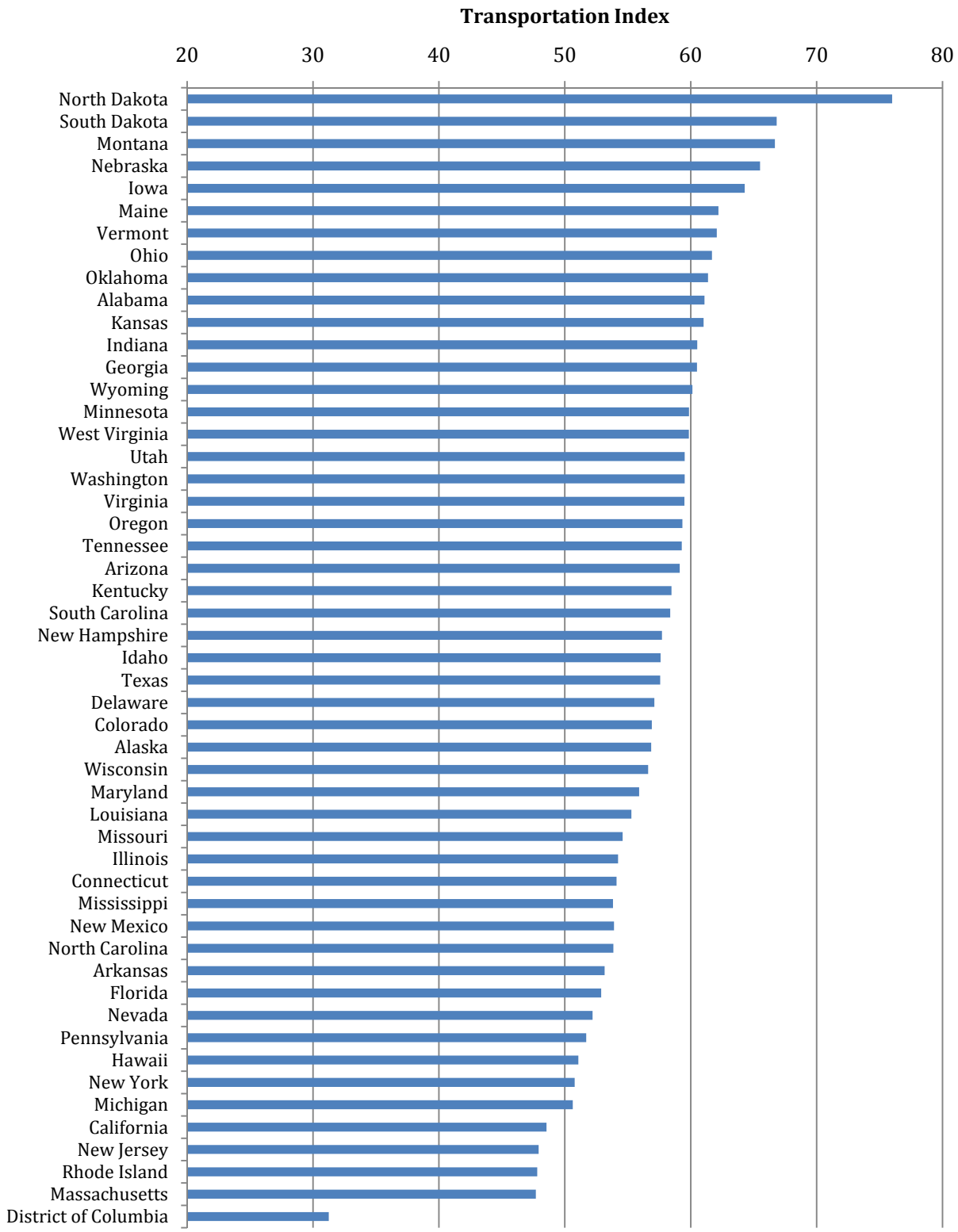


Figure 26. State-by-State Transportation Index 2000

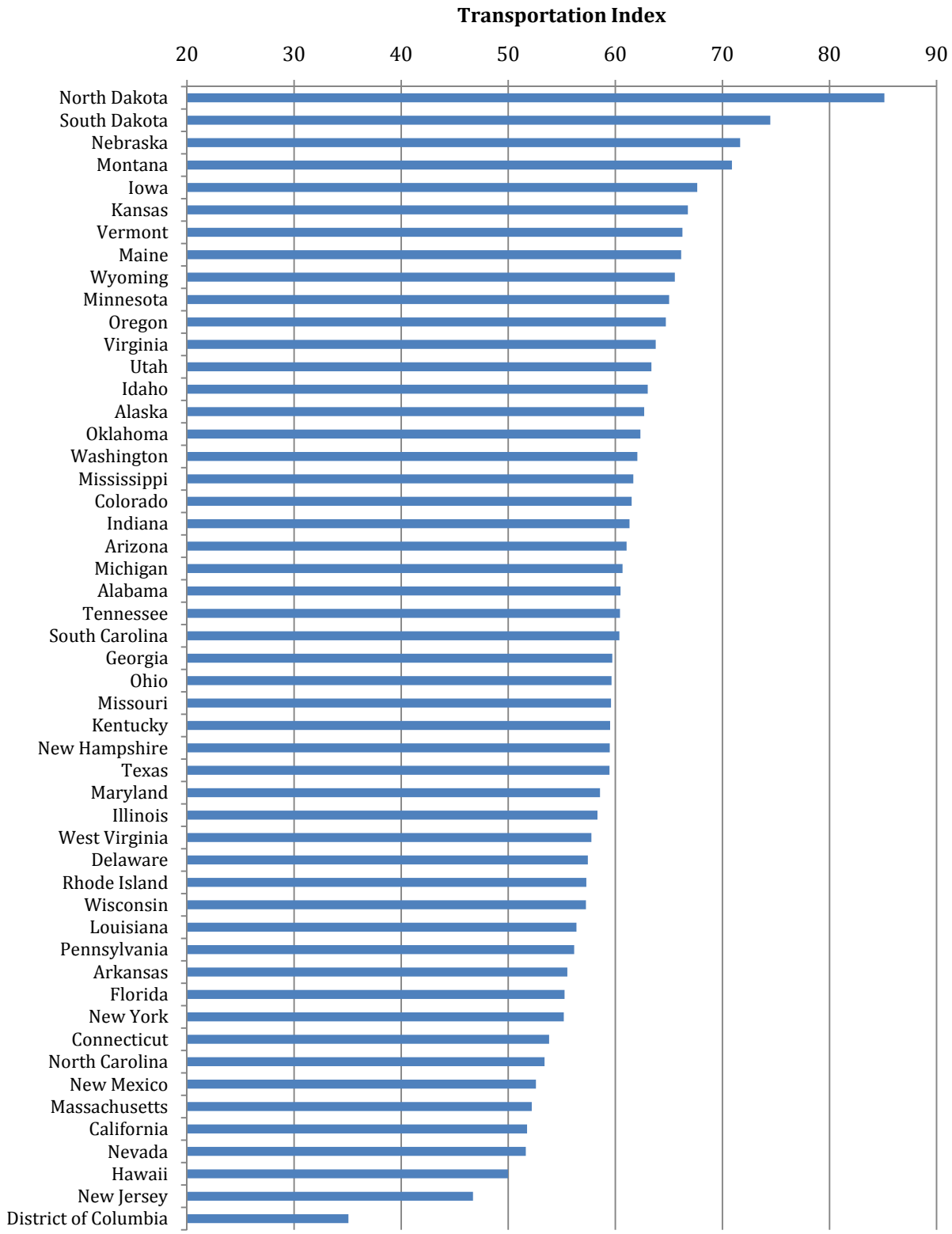


Figure 27. State-by-State Transportation Index 2007

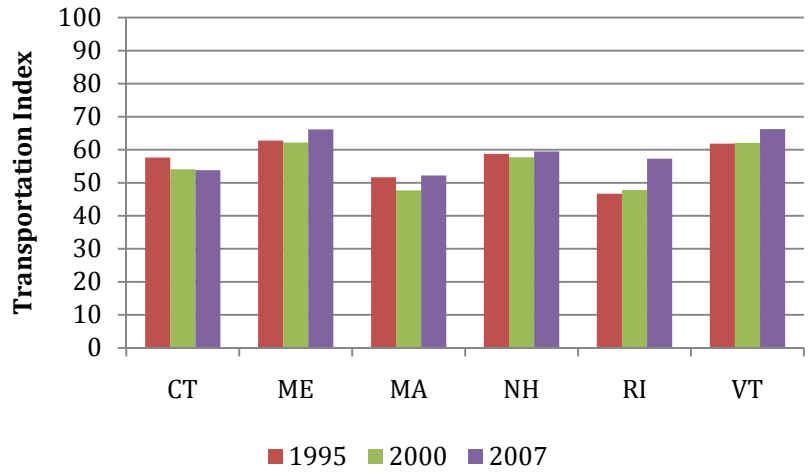


Figure 28. State-by-State Transportation Index New England Region

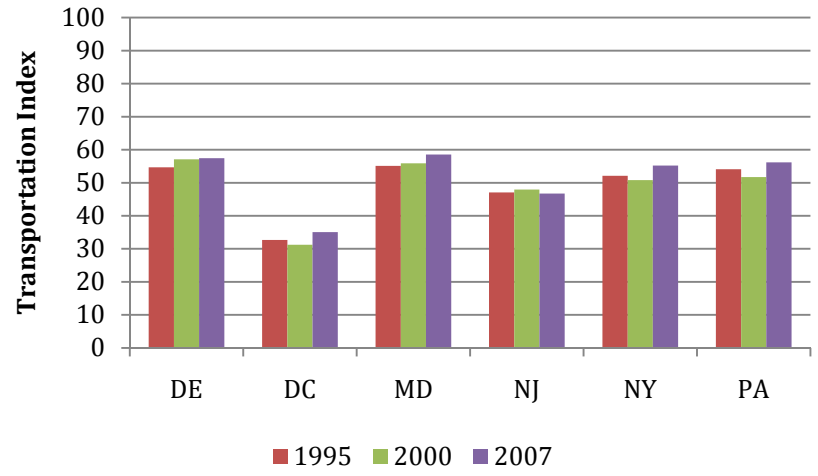


Figure 29. State-by-State Transportation Index Mideast Region

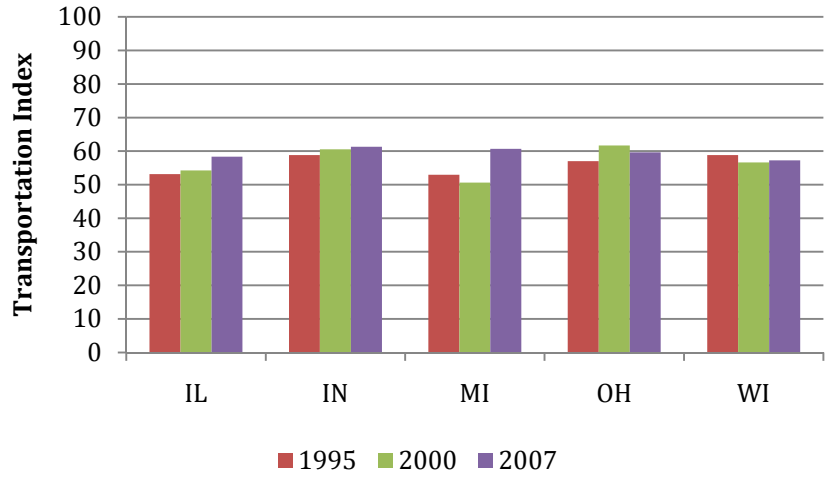


Figure 30. State-by-State Transportation Index Midwest Region

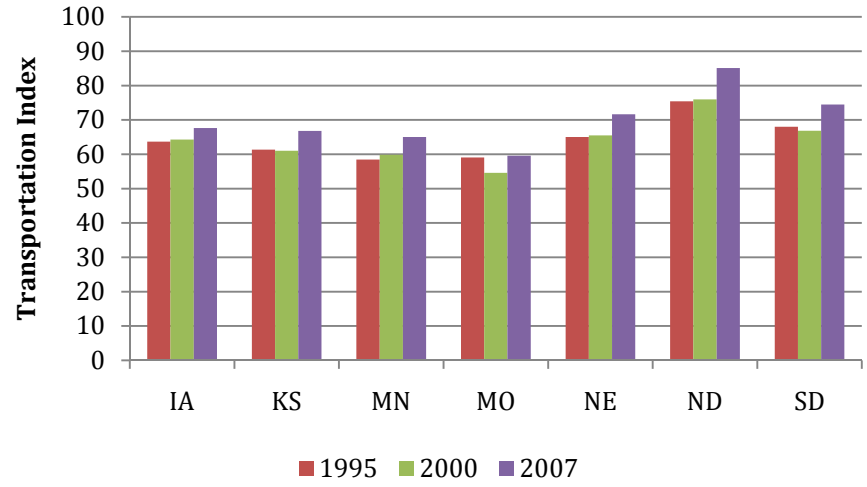


Figure 31. State-by-State Transportation Index Plains Region

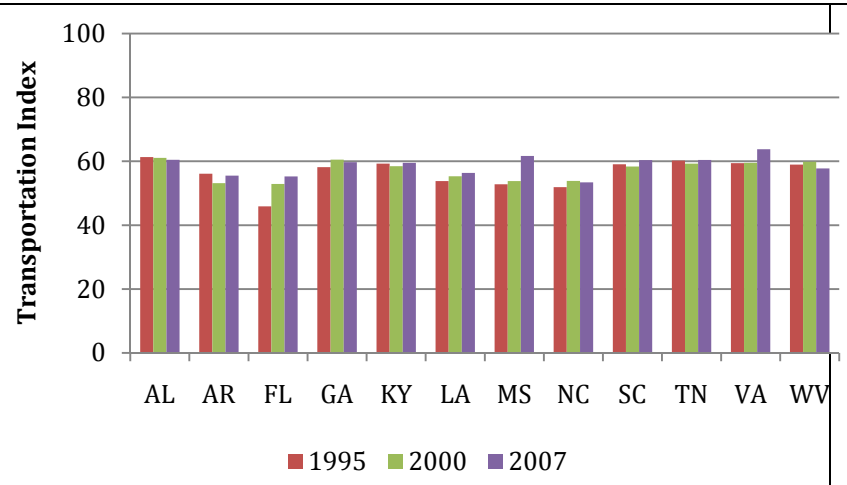


Figure 32. State-by-State Index Southeast Region

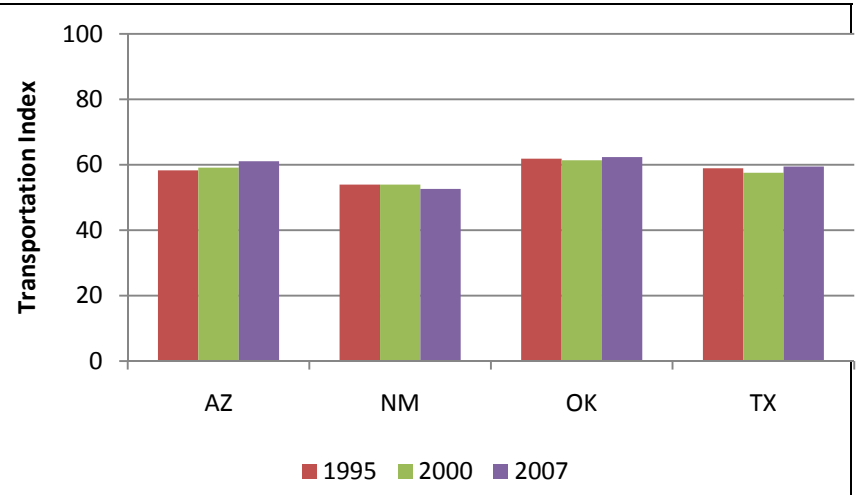


Figure 33. State-by-State Transportation Index Southwest Region

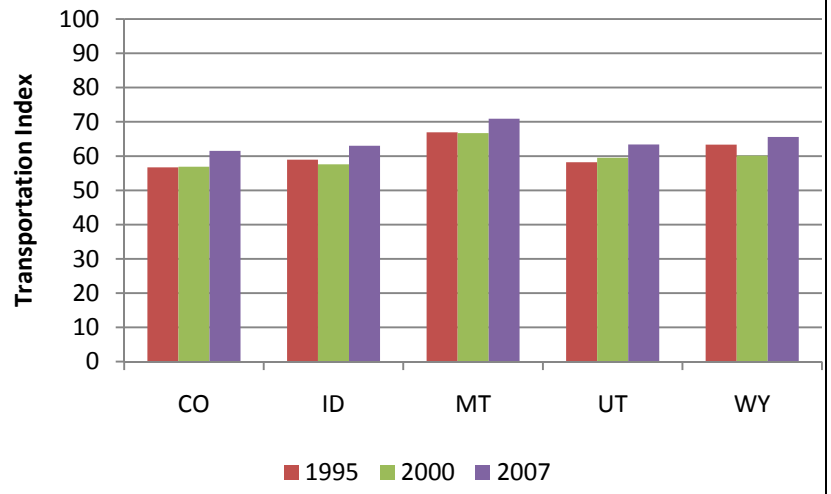


Figure 34. State-by-State Transportation Index Rocky Mountain Region

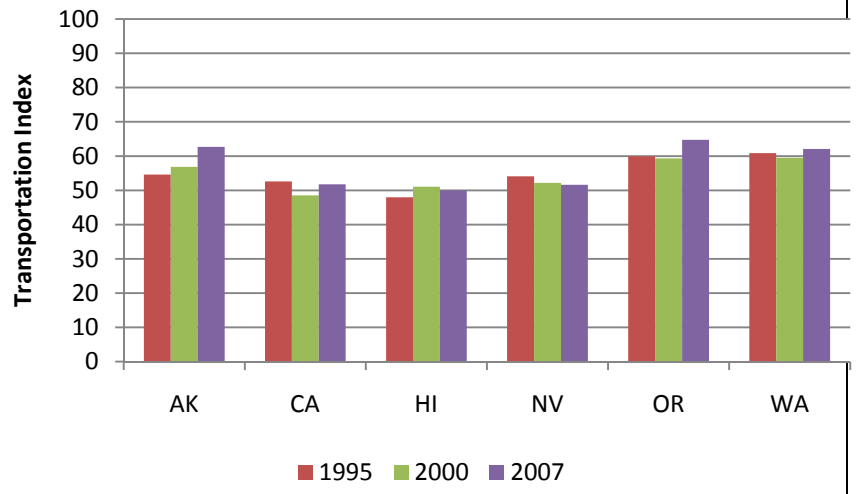


Figure 35. State-by-State Transportation Index Far West Region

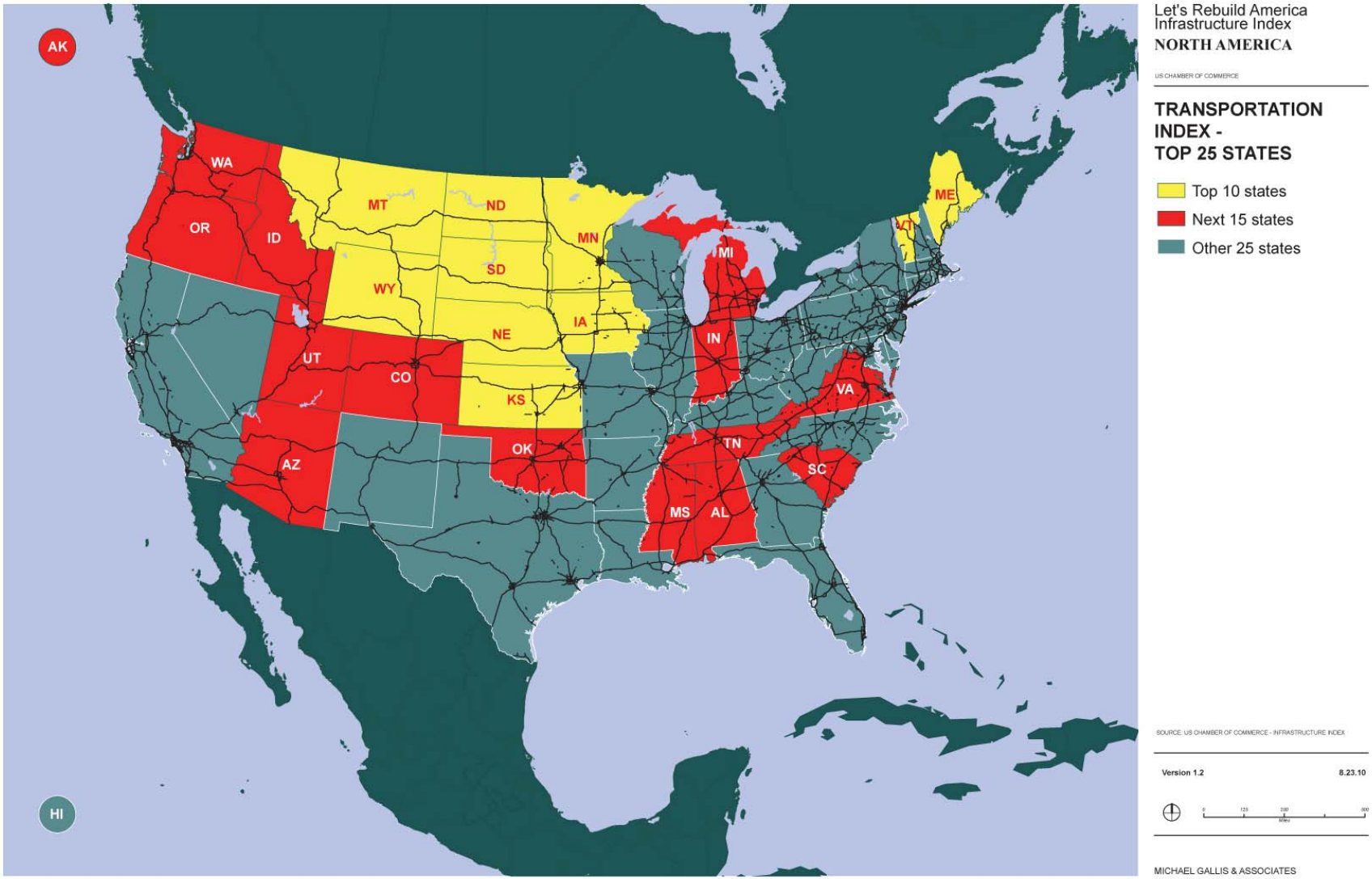


Figure 36. Top Twenty Five States Based on the Transportation Index

Interpreting the Index

The state-by-state index can be interpreted in much the same way as the national index:

- Large is better; smaller is worse.
- The index has no scale.
- No individual project is going to change the index significantly.
- Changes in several different indicators can have the same impact on the index.
- The relative contribution of each mode to the indicator is based on the relative weighting.

Comparing the Transportation Index to Other Cross Sectional Data

The 2007 Transportation Index are compared to data on population growth (2000-2007) and population density (2007). The results, shown in Figure 37 and Figure 38, suggest that higher growth rates and higher population densities are generally associated with lower Transportation Index values. While this warrants more rigorous analysis, closer examination of the states with a Transportation Index less than 60 reveals that all these states experience significant pressure in terms of population growth, high levels of development, limited access, or aging infrastructure.

Comparing the Transportation Index to Other Studies

The Transportation Indices are also compared to two other studies that have attempted to capture the performance of transportation index on a state-by-state basis. The first is the CNBC Special Report *America's Top States for Doing Business 2010* (CNBC, 2010). Each state was ranked in terms of transportation infrastructure based on the follow criteria (CNBC, 2010):

Access to transportation in all its modes is key to getting your products to market and your people on the move. We measured the vitality of each state's transportation system by the value of goods shipped by aviation, land and water. We looked at the availability of air travel in each state, and the quality of the roads.

The correlation coefficient for the rank of the Transportation Index and the CNBC ranking is very small and statistically insignificant (the hypothesis that the coefficient could be zero cannot be rejected). Methodologically, the two rankings are different. For example, the value of goods shipped (used in the CNBC ranking) is not an appropriate performance measure. One prominent example of the disparity between volume and value of goods in transit is to compare high value/low weight computer inputs with commodities like steel and coal.

The second study, *Enterprising States,* was also supported by the U.S. Chamber of Commerce National Foundation (Praxis Strategy Group and Kotkin, 2010). *Enterprising States* looked at three indicators: Investment in Airports and Ports, Condition of Roads, and Condition of Bridges. This study simply reported the top 10 states, followed by the next 15 states. Figure 39 assembles similar data for the Transportation Index (similar to Figure 36) and the CNBC index, and compares these data with the assessment made by *Enterprising States.* Not surprisingly, the results are indicative of the fact that all three approaches are completely different.

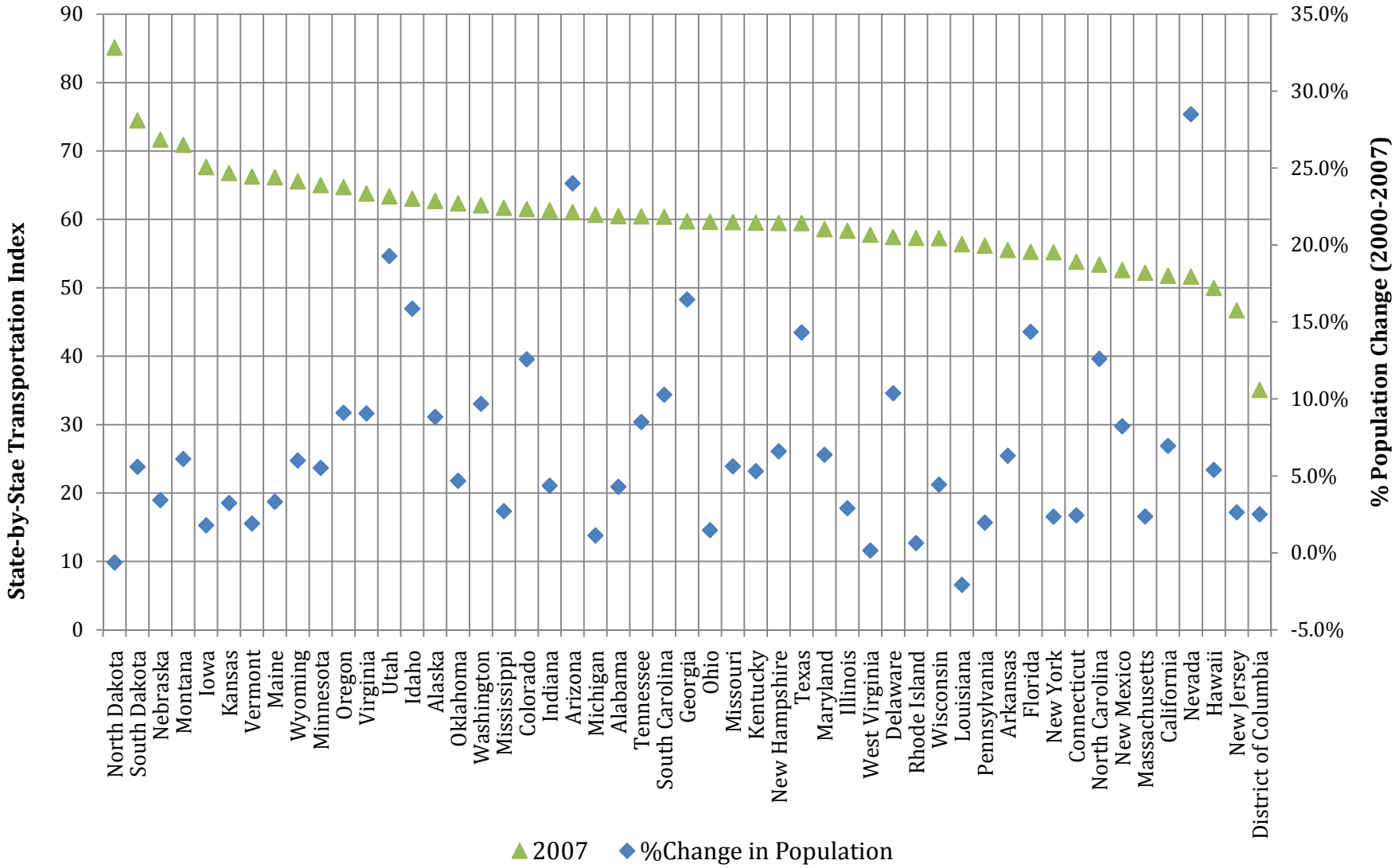


Figure 37. State-by-State Transportation Index and Population Growth (2000-2007)

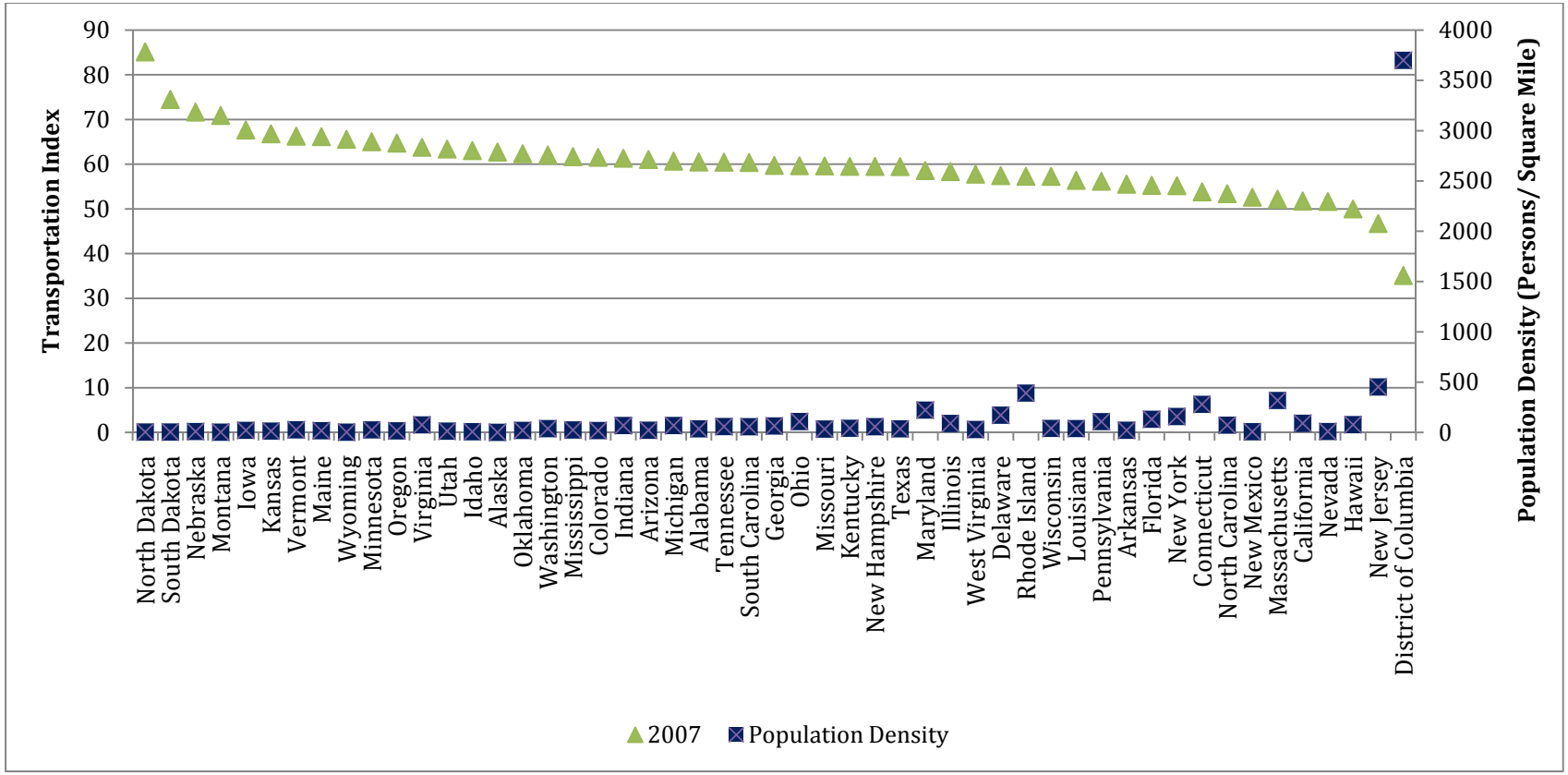


Figure 38. State-by-State Transportation Index and Population Density

Region	State	Transportation Index	CNBC Index	*Enterprising States*		
				Air & Port Investment	Bridges Condition	Road Condition
MW	IL					
	IN					
	IA					
	KS					
	MI					
	MN					
	MO					
	NE					
	ND					
	OH					
	SD					
	WI					
NE	CT					
	ME					
	MA					
	NH					
	NJ					
	NY					
	PA					
	RI					
	VT					
ST	AL					
	AR					
	DE					
	FL					
	GA					
	KY					
	LA					
	MD					
	MS					
	NC					
	OK					
	SC					
	TN					
	TX					
	VA					
	MV					
WT	AK					
	AZ					
	CA					
	CO					
	HI					
	ID					
	MT					
	NV					
	NM					
	OR					
	UT					
	WA					
	WY					
		Legend:		Top 10 States		Next 15 states

Figure 39. Comparison of Transportation Index, CNBC Transportation Index and Enterprising States Indicators

Comparing the State-by-State Indices to the National Transportation Index

To better understand the connection between the state-by-state Transportation Indices and the national Transportation Index, the aggregated state-by-state is compared with the national Transportation Index and a modified Transportation Index. The aggregated state-by-state index is computed by weighting each state by the state GDP for that year. The modified Transportation Index does not include the indicators that are not included in the state-by-state Transportation Index. The results are shown in Table 22 and Figure 40.

Table 22. Estimated National Transportation Indices

Estimate	**1995**	**2000**	**2007**
Aggregated State-by-State	55.04	54.60	57.36
Transportation Index	53.07	50.62	50.74
Modified Transportation Index	52.38	50.00	51.97

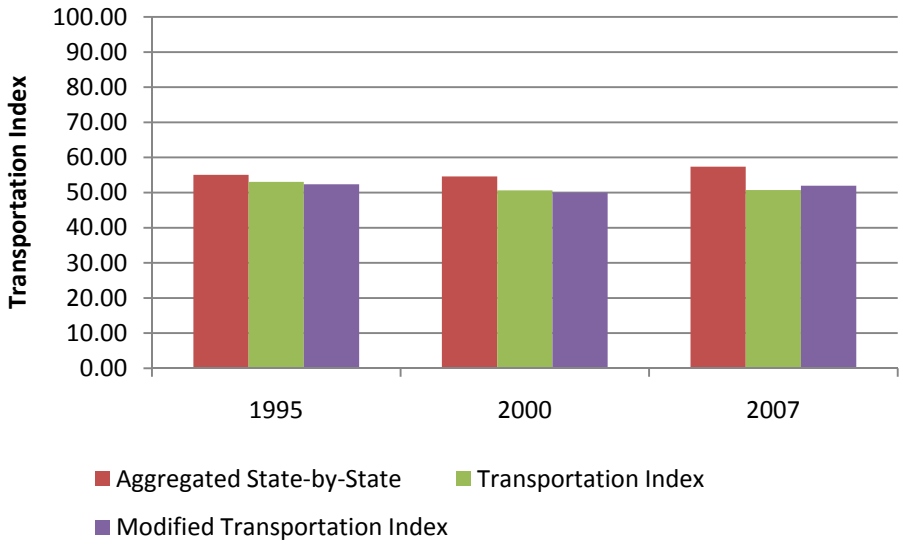


Figure 40. Estimated National Transportation Indices

As stated, the state-by-state Transportation Indices, and hence the aggregated state-by-state Transportation Indices tend to be higher than the national Transportation Index because they do not include four indicators that tend to perform poorly over time – air arrival rates and departure rates, highway congestion, waterway congestion, and air utilization. Furthermore, the aggregate state-by-state indices include both urban and rural infrastructure and for the indicators used, rural infrastructure will perform much better.

Detailed Analysis for Selected States

To better understand the state-by-state Transportation Index five states are selected for more detailed analysis. These states – Alabama, Illinois, Nevada, North Carolina and North Dakota – are ranked 23, 33, 48, 44 and 1 in 2007 based on the Transportation Index. The Transportation Index is shown in Figure 41,

These states were selected to be representative of the range of rankings, different regions and different populations, economic activity, growth rates and development patterns. The analysis explores pressures imposed on the infrastructure by population.

The following figures show Population (Figure 42), Population Growth (Figure 43) and Population Density (Figure 44) for these select states. In all cases, North Dakota, the state with the highest Transportation Index has the lowest population, the lowest population growth rates and the lowest population density.

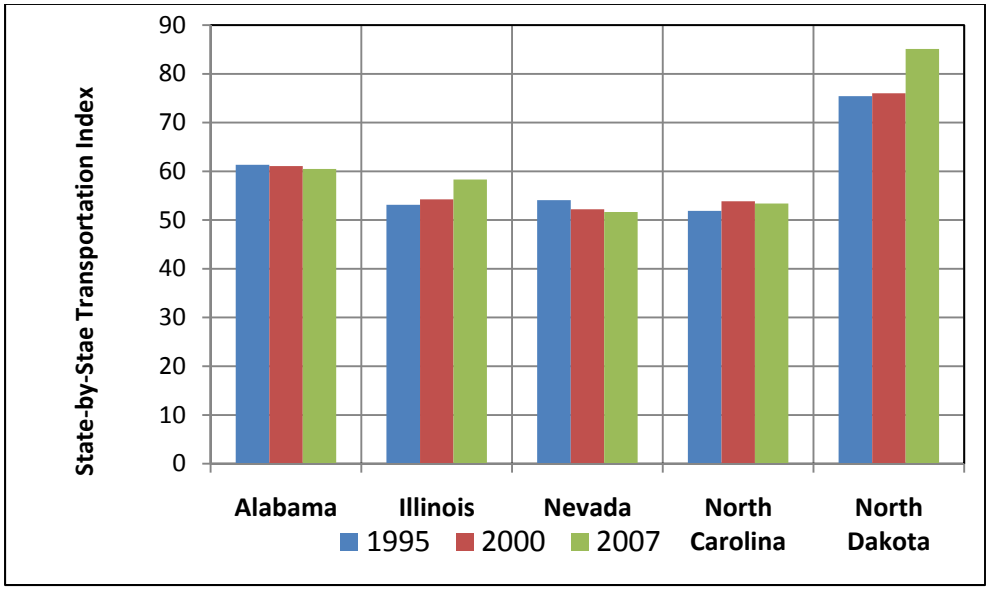


Figure 41. Select State Transportation Indices - Alabama, Illinois, Nevada, North Carolina, and North Dakota

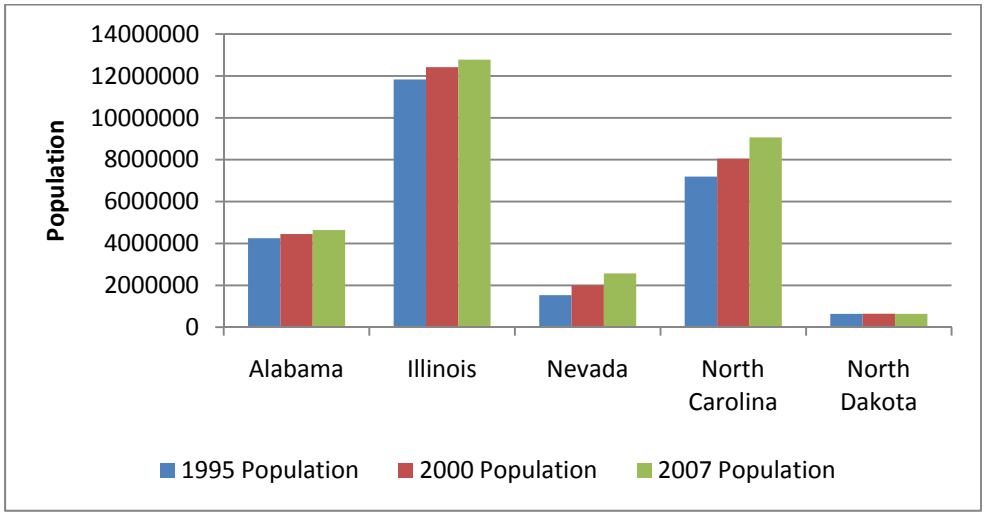


Figure 42. Population - Select States

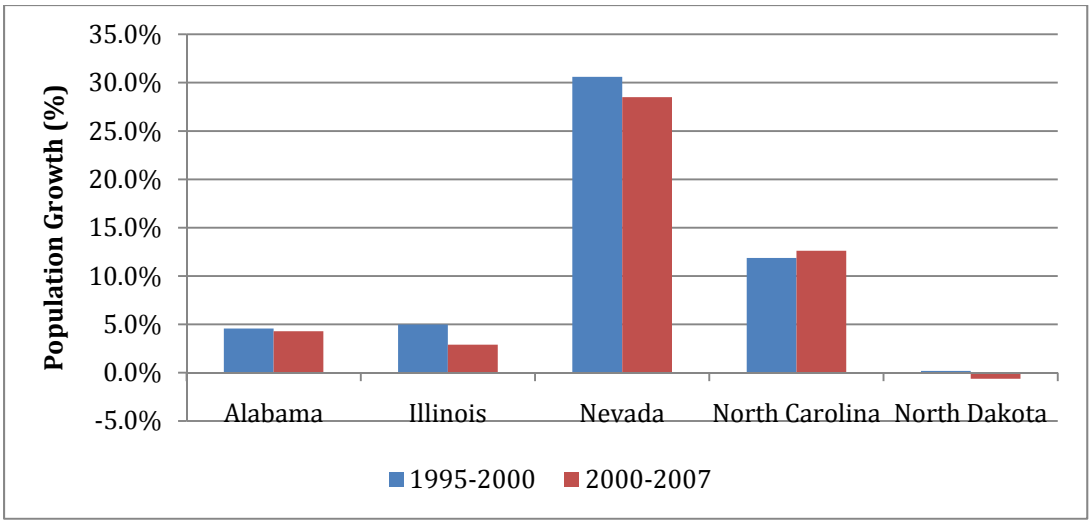


Figure 43. Population Growth - Select State

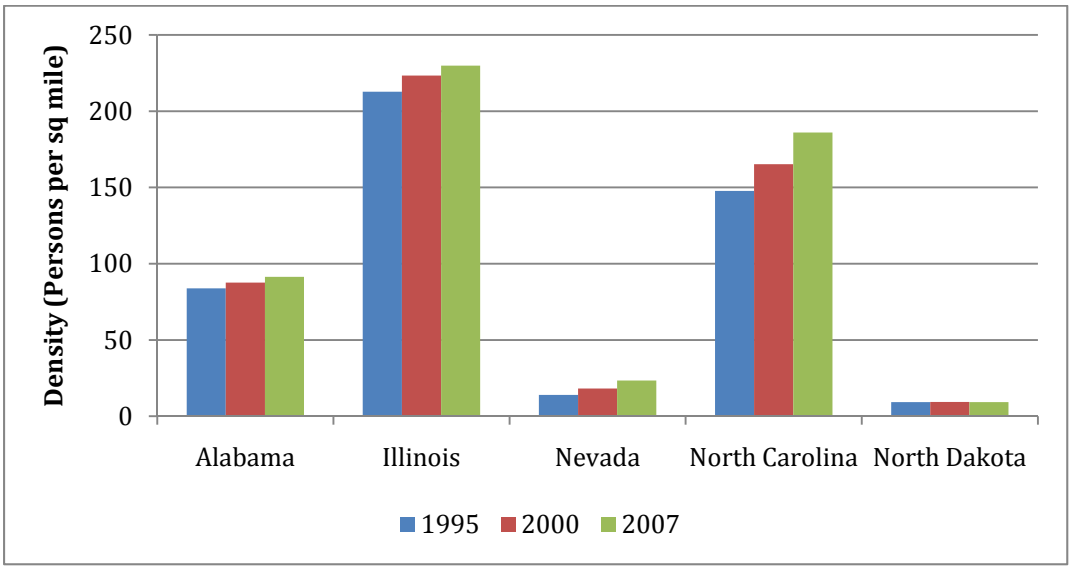


Figure 44. Population Density - Select State

While this analysis does not begin to offer a causal explanation, the three states that perform the poorest (Illinois, Nevada, and North Carolina) each experience pressure on the infrastructure from growth or density.

Interestingly, the Illinois legislature passed Illinois First in 1999. Illinois First was a five year program to rebuild the state's infrastructure. Other than North Dakota, Illinois was the only state to show an improvement in the Transportation Index over the period 1995 to 2007.

Extrapolated Future (2015)

Similar to the analysis for the national Transportation Index how the index might change with respect to the future using scenarios is explored. For the state-by-state analysis only two scenarios are used assuming that the state population is growing at 1% per year. The scenarios are defined as follows:

Scenario 1 - (New Investment) - assumes a high level of investment across all modes strategically directed to improve infrastructure performance by about 10% over the period 2008 – 2015. This is equivalent to an improvement of 1.2% per year. The analysis recognizes constraints. For example, Air Congestion, the percentage of on-time arrivals, cannot exceed 100%.

Scenario 2 - (No New Investment) - assumes no new investment.

The specific changes for each indicator are summarized in Table 23.

Table 23. Scenarios for the Extrapolated Future for the State-by-State Analysis

#	Description	Scenario 1	Scenario 2
IND1	Highway Density	No change	-7%
IND2	Transit Density	+10%	-7%
IND3	Airport Access	Indicator=1	+7%
IND5	Rail Density	+10%	-7%
IND6	Waterway Density	No change	-7%
IND7	Port Access	-10%	No change
IND8	Intermodal Freight Access	+10%	-7%
IND10	Highway Safety	-10%	No change
IND11	Road Roughness	-10%	+10%
IND12	Highway Bridge Integrity	-10%	+10%
IND13	Air Congestion	+10%	-7%
IND14	Air Safety	-10%	No change
IND15	Rail Safety	-10%	No change
IND17	Transit Safety	-10%	No change
IND18	Highway Reserve capacity	+10%	-7%
IND20	Transit Reserve capacity	-10%	+7%
IND21	Rail Reserve capacity	-10%	+7%

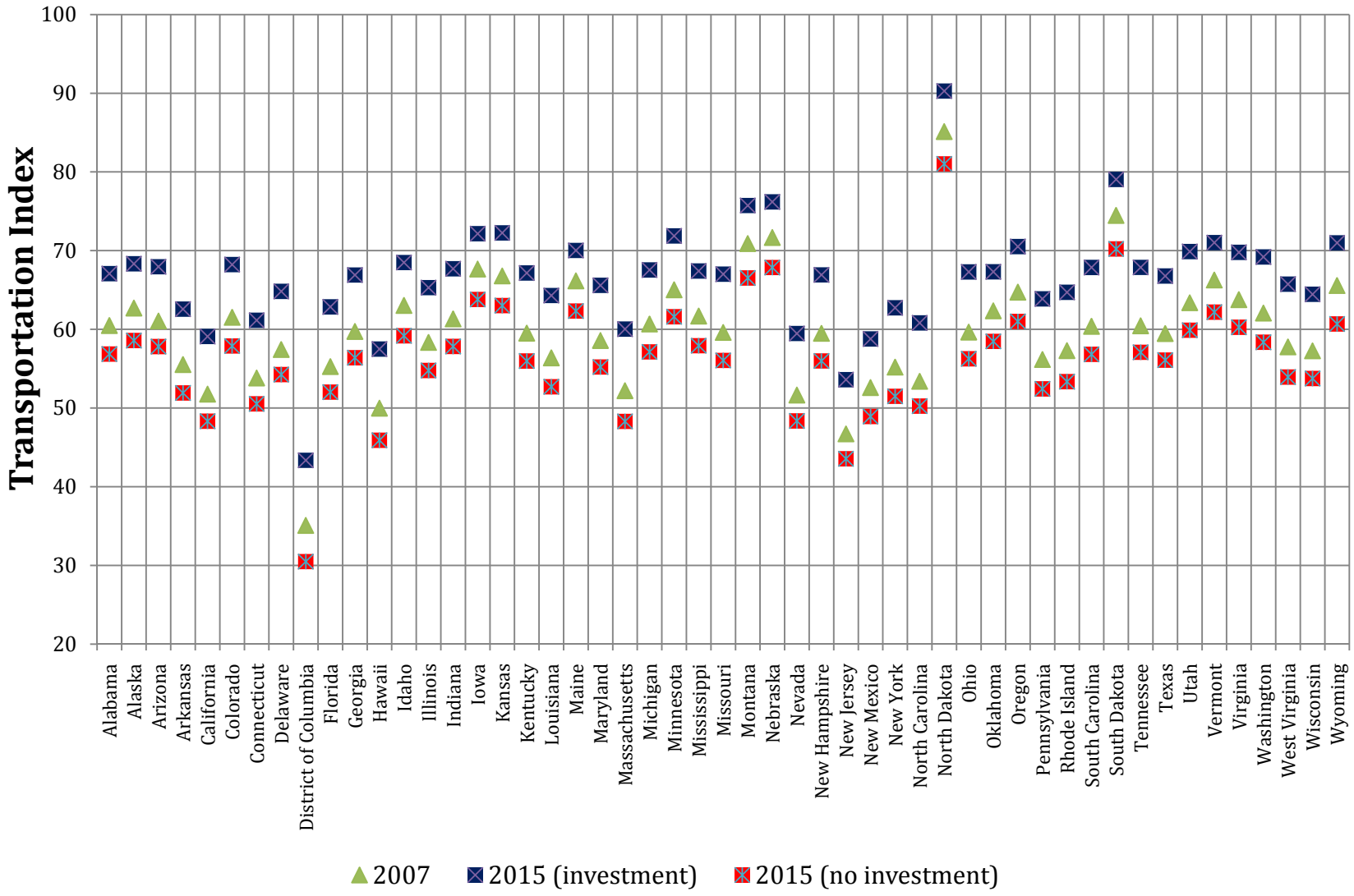


Figure 45. Transportation Index 2015

Next Steps

The results presented underscore the need for comprehensive investment in all modes of transportation including physical infrastructure, operational improvements, and maintaining and improving existing infrastructure. North Dakota may be ranked highest, but the nation cannot afford to disinvest in infrastructure in North Dakota. At the same time, the U.S. cannot afford to ignore the pressures on the transportation system in states like New Jersey. The challenge is to now convert these ideas to rational investments.

ECONOMIC ANALYSIS

Introduction and Background

Transportation plays a key role in economic development even in advanced economies. The progression of economies from agrarian to industrial – to use a simplified example – requires that each nation specializes in the goods and services that it can produce most efficiently. As a nation's economy moves away from a focus on agriculture it does not stop using agricultural products. Instead, it needs to be able to trade the industrial goods it produces for the other products it needs. International trade makes this possible. And transportation infrastructure makes international trade possible. When production is done by the nation with a labor force that excels in the skill set best suited to that product, specialization of labor occurs.

What worked to move economies from agrarian to industrial applies to the more complicated choices and location decisions that businesses and nations make in today's increasingly globalized marketplace. This economic study differs from existing research on the topic of infrastructure and the economy because it examines the overall contribution from well-performing infrastructure rather than the impact on growth that results from spending (and the creation of jobs during construction) due to the initial investment. The problem of causation – does investment in infrastructure cause the growth or does growth cause the investment in infrastructure – is well identified in the literature on this topic.

When attempting to analyze the role of infrastructure in the economy, prior research identified the additional problem of matching units of measure (MSA versus state versus country, etc.) for both infrastructure and economic activity. Study after study points to the need for a tool for measuring the importance of infrastructure to a national economy. Drawing on this rich body of work, the analysis provides a straightforward time-series model following estimation methods that have been widely tested in the economic growth literature.

The U.S. Chamber of Commerce's Transportation Infrastructure Index measures performance using over 10,000 statistics, on all modes (rail, road, transit, aviation, and marine) of the vital systems that bring labor and materials to the places where American businesses create goods and services. That system is also used to deliver goods and services to customers and users throughout the U.S. and around the world. We view using the Transportation Infrastructure Index as a unique opportunity to measure the economic importance of the performance of transportation infrastructure.

The economy runs on infrastructure. Transportation infrastructure performance in the United States is declining –resulting in a drag on the economy. The econometric results using the Index demonstrate that as the performance of transportation infrastructure falls, so does the economy.

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 – foreign firms do the same when they consider locating here (Mataloni, 2008). Transportation maintains the productivity benefits of specialization (Taylor, 2007). Producers must be able to bring inputs from strategic partners in their own low cost locations and to send goods/services to distant customers to have the full economic advantage of trade. Good transportation infrastructure can enable the economic specialization that leads to lower costs – making U.S. businesses more efficient, making the U.S. a desirable location for foreign businesses, and making U.S. produced goods and services more competitive in the global economy.

If a highway can give one U.S. county a competitive advantage over another (Chandra and Thompson, 2000), why couldn't high-performing transportation infrastructure give the United States a competitive advantage over another country? Some studies of the economic impact of a highway in one county (of a state versus nearby counties) find that the effect of a new highway is in the spatial re-distribution of economic activity and not in the overall contribution to the size of the state economy. Here, we are studying the transportation infrastructure of the entire nation. The methodology for generating the Index values (described elsewhere) relies on sampling geographic areas which make performance data available, then expanding the results in such a way (based on geography, population, and contribution to national economy) so that they are representative of the total United States. We seek to explore the idea that the U.S. is one option competing with about 200 other countries for the location of businesses – including American businesses.[1]

The primary purpose of the economic analysis is to demonstrate the usefulness of the Index for exploring the contribution of infrastructure to keeping American businesses competitive in an increasingly global economy. Other countries are constantly competing with us, constantly building and rebuilding their infrastructure, constantly developing their economies. While the United States has maintained its position at the top of the overall World Competitiveness Yearbook ranking, the sub-ranking for Basic Infrastructure has not (Table 24). While the ranking varies considerably with a poor ranking of 15 in 2000 and the top ranking for several years, the rank has degraded since 2005.

The World Economic Forum also performs an annual infrastructure ranking in the Global Competitiveness Report. In their Executive Opinion Survey, when asked the question, "How would you assess general infrastructure in your country?" the U.S. scored 5.9 out of 7, above the median score of 4.1, but ranking only 14th in 2009(see

[1] Location decisions made by households and businesses – which contribute to regional economic growth – are too complex to model in our context. For a review of the literature and a model demonstrating these issues, see Wu and Gopinath (2008). They conclude that transportation infrastructure contributes to economic development in remote areas after controlling for natural amenities. They also report spatial variations in income, employment and housing prices in this context.

Appendix F).[2] Details on the 2009 scores for the quality of Roads, Railroads, Ports and Air Transport are available in the Appendix for the U.S. and the Top 20 ranked countries, along with global rankings for GDP and GDP per capita.

Table 24. World Competitiveness Annual Ranking for U.S. Basic Infrastructure

Year	U.S. Basic Infrastructure Rank
1997	1
1998	1
1999	2
2000	15
2001	1
2002	2
2003	2
2004	1
2005	1
2006	2
2007	2
2008	2
2009	4
2010	11

Source: IMD (2010) World Competitiveness Yearbook 1995-2010

The economic importance of transportation infrastructure is summarized in Table 25. Deteriorating infrastructure in the United States may actually be contributing to increased costs and decreased efficiency for U.S. businesses (Cambridge Systematics, 2008). Many of our "less-developed" and "emerging market" competitors are already preparing their infrastructure now to move away from producing low-wage goods to producing the types of products that require the specialization of labor that transportation infrastructure makes possible (Praxis Strategy Group and Kotkin, 2010).

[2] Unlike the Index, the Global Competitiveness Report includes some survey data in addition to several actual measures of infrastructure. The responses, which form the basis of the report, are from in-country users of transportation infrastructure.

Table 25. Economic Importance of Transportation Infrastructure

MODE	ECONOMIC IMPORTANCE
Highways	Moving inputs to production and outputs to customers. Also used to transport labor to the place of production.
Transit	Bringing labor to the place of production.
Aviation	Moving high tech (low weight/high value) inputs, outputs and products. Enabling the service sector.
Rail	Moving commodities from point of production to end-users.
Marine(Ports)	Connecting producers to global consumers of goods and commodities; bringing valuable inputs to producers.
Intermodal	Providing local producers with access to global consumers by moving products.

A litany of the problems created for the U.S. economy by our transportation infrastructure has been produced by a wide range of sources -- from city mayors to international research institutions.

Highways:

- Taylor (2007): The Texas Transportation Institute estimates that [road] *congestion* is costing drivers $2 billion a year in lost productivity, or $955 per driver (the lack of sufficient infrastructure).
- Colorado Legislative Council (2008): Eighty-three percent of all Colorado commodities are *transported by truck*.

Ports:

- Blonigen and Wilson (2008): U.S. ports became less efficient – as reflected in a 4% increase in costs – between 1993 and 2003. In the meantime, foreign ports (that ship to the U.S.) became more efficient – gaining 5% in the same period. This gap is significant.

Multi-modal:

- Richardson (2009): "Today for us [in South Dakota] to get to the Pacific Northwest with corn, the typical path takes that corn first east [by truck] and then up north [by rail] and finally west again [by *ship*]."

This is just a sampling of the problems – obvious even to the casual observer – with U.S. transportation infrastructure. Rail – moving commodities to production centers and goods to the ports – is the least studied for its economic impact in the last 20 years. This is probably due to two factors. First, most railroads were built by 1880 so that more recent studies would not have interesting changes in the supply. Perhaps just as significant is the regulation and deregulation of the industry. What economic research has been done on railroads has focused more on efficient pricing

and the impact of ownership structures than on the specific impact of railroads on the economy.

The benefits of well-performing infrastructure have also been enumerated:

Highways:

- Taylor (2007): the investment in Michigan's *interstate system* [highways] is estimated to have saved every Michigander $2,728 per year in safety, time, fuel, and lower finished goods costs, or about $27.6 billion per year.
- Cervero (2006): According to the Federal Highway Administration, in the manufacturing and services sectors the investment in *roads* helps lower transportation costs/mile. The impact in manufacturing may be obvious – traffic congestion poses a threat to Just In Time production and delivery systems that rely on quick and predictable infrastructure. In the service industry, where face-to-face meetings are still preferred to online meetings (Harvard Business Review 2009), a travel delay can mean a missed opportunity.

Aviation:

- Cervero (2006): High-tech professionals *travel by air* at least 60% more frequently than other professionals.
- Green (2007): After the Cincinnati airport expanded to accommodate daily non-stop service to five European cities, "the number of high-technology jobs in the Cincinnati region had jumped from about 65,000 in 1989 to almost 80,000 in 1996."
- (Green 2007): "The number of foreign-owned companies in the [Cincinnati] region more than tripled since 1987—from 70 to about 250" in 2007.

Transit:

- Taylor (2007): Firms increasingly consider "reasonable *commute* times – a common quality of life issue – in order to attract and retain high quality employees."

Literature

In this section, we focus on studies specific to transportation infrastructure. The reader is referred to the *Infrastructure Performance Index: Initiation Phase Report* (U.S. Chamber, 2010) for more detailed review of prior research on infrastructure and growth. There are at least four areas of literature covering issues relevant to infrastructure and economic development: public finance, economic development, urban studies ("on the impact of transportation on agglomeration economies"), and mode-specific literature (see Green 2007, in the context of airports).

Most of the studies are centered on only one or two parts of the system, like commute times and highways or rail versus highway freight movements. The primary finding on road infrastructure and the economy is that the effect is to re-

distribute economic production and not to increase it (Cervero, 2006). Even if this is true, we are concerned that the U.S. will be chosen less often as a location for business and industry without a robust transportation infrastructure. In other words, fewer foreign firms will locate here and more U.S. firms may look elsewhere. Companies can be lured to other locations by newer infrastructure or proximity to airports just as easily as they can be lured with tax incentives, lower property prices, etc. Focusing only on the cost of building and using transportation infrastructure reflects an inward, myopic vision that ignores the important question of performance.

Studies of the economic impact of airports tend to focus on jobs created at the airport, or the price of plane tickets purchased by outbound passengers (Green 2007). While this is sufficient for a cost/benefit analysis to support requests for financing (ICAO 2006), it does not provide a good indication of the overall impact of having well-performing transportation in an economy.

Measuring infrastructure in terms of spending has resulted in "bi-directional results," where infrastructure affects growth and growth affects infrastructure. In other words, that a growing economy can afford more infrastructure could just as likely be a cause of positive statistical results as the possibility that more infrastructure helps the economy grow. Calderón and Servén (2008a) report that *less than half* of the empirical studies using expenditure-based infrastructure measures find that 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.

Our Approach

The difficulty in the economic analysis was separating the impact of the performance of one sector of infrastructure – transportation – from all the other influences on the whole economy. We narrowed our focus by examining two specific ideas:

1. *U.S. business efficiency a) improves the domestic standard of living and b) makes U.S.-produced products and services globally competitive.*
2. *Foreign direct investment – especially the inflows that result in new establishments and create jobs – is dependent on transportation infrastructure.*

In this section we focus on the specification of the model used for this report. The reader is referred to the *Infrastructure Performance Index: Initiation Phase Report* (U.S. Chamber 2010) for a more detailed review of the literature background on the methodology used for modeling the impact of infrastructure on the economy. 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. Those studies were focused on developing infrastructure as a way out of poverty. Instead, we assume the existence of basic infrastructure and go on to measure whether its performance serves the needs of the business community.

We rely on Sala-i-Martin (1996, 1997a, 1997b, 2002) for the specification of a pure time-series model to estimate a long-run relation between infrastructure and the economy. 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 with only 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).

Therefore, our model takes the general form:

GDP per capita = f (Index, GDP (level), Government policy, Population health)

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. "Omitted variable" problems are avoided by using the new Transportation 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. The Index already accounts for population in the sample selection. (Population is a common instrumental variable used to address the issue of identification. See Calderón and Servén (2008a)). The Index is determined independent of the economic analysis.

Table 26. Data Variables (Acronyms, Definitions and Sources)

GDPpc: Log GDP per Capita (in 2000 dollars). Bureau of Economic Analysis, United States Department of Commerce.
Index: Transportation Index (lagged 3 years).
GDP: Real GDP (level, 2000 dollars). Bureau of Economic Analysis, United States Department of Commerce.
Debt: Federal debt as a percent of GDP. Bureau of Economic Analysis, United States Department of Commerce.
LifeE: Life Expectancy (at birth). Centers for Disease Control.
Spend: Log Federal Outlays on Transportation (lagged 3 years, in 2000 dollars). Spending from White House Budget Report, Table 3, Outlays (historical). Construction Cost Index from Federal Highway Administration.

Data: Descriptive Statistics

The Index is very comprehensive (as shown in Table 26). Our ground rules required that the data 1) should reflect performance (and not cost), 2) should be publically available, and 3) be available from 1990 forward. To meet these requirements, we did not fill in missing items with survey data (a method used, e.g., for the World Competitiveness Yearbook).

Table 27. What is Measured in the Index

	Freight	Passenger		Supply	Quality	Utilization
Aviation	X	X		X	X	X
Highway	X	X		X	X	X
Intermodal	X			X		
Marine	X			X	X	
Rail	X			X	X	X
Transit		X		X	X	X

In focus group workshops with local Chamber of Commerce members and other businesses in San Jose, Chicago, Atlanta, and Houston, we repeatedly heard business managers talk about ways in which they "work-around" poorly performing transportation infrastructure. We hypothesize that transportation infrastructure performance would need to deteriorate for some years before the impact would be seen on the economy. The correlation of the index with GDP increases and gets statistically stronger with longer lags. However, for our purposes, we use the Index lagged by only 3 years to conserve observations.

Table 28. Correlation coefficients for GDP per capita with various lags on Index

		Lag				
	Index	1 year	2 years	3 years	4 years	5 years
GDPpc	0.2344	0.3213	0.4382	0.5273	0.6632	0.733
prob>|t|	0.3341	0.1935	0.0785	0.0358	0.007	0.0029

Table 29. Descriptive statistics for all variables in use

Variable	Mean	Std. Dev.	Min	Max
GDPpc	10.40	0.1083	10.24	10.5522
Index	51.28	1.2165	48.17	53.07
GDP	12.97	0.1776	12.67	13.22
Debt	65.12	8.8215	55.74	94.27
LifeE	76.67	1.0343	75.21	78.44
Spend	24.56	0.1462	24.38	24.91

Table 30. Correlation coefficients for all variables in use

	GDPpc	Index	GDP	Debt	LifeE
Index	0.5273	1			
prob>|t|	*0.0358*				
GDP	0.9783	0.3286	1		
prob>|t|	0	0.1979			
Debt	0.5773	-0.267	0.6408	1	
prob>|t|	*0.0031*	*0.2841*	*0.0006*		
LifeE	0.9861	0.4689	0.9845	-0.0002	1
prob>|t|	*0*	*0.0669*	*0*	*0.9993*	
Spend	0.3181	-0.0476	0.2288	-0.3363	0.2474
prob>|t|	*0.1844*	*0.8611*	*0.346*	*0.1592*	*0.3071*

Life expectancy has a statistically significant correlation with the Index; this could result from a connection between improved infrastructure and well-being. There are measures of safety in the Index, but it is not heavily weighted. Federal spending on transportation infrastructure is not significantly correlated with either GDP or GDP per capita. We include it here for completeness as we will use spending in a supplemental regression. The correlation coefficient reported here between the Index and Spending is different from that in the Chapter describing the Transportation Index. There are two reasons for this difference. We use the Index lagged by 3 years and we report the correlation for the period 1993 to 2009 (where the earlier correlation was for 2000 to 2008 using the contemporaneous Index).

Analysis

We expect that our results will stand up to this economic analysis because the Index represents the entire transportation system, including those elements that are necessary for access to global markets (trade). Our regressions are estimated with robust standard errors using STATA (7) software. We specify the Huber/White/sandwich estimator, which produces consistent standard errors even if the data are not identically distributed.

Table 31. Regression Results

GDP per Capita	1	2	3
Transportation Index	0.0378	0.0065	0.0037
Real GDP		0.6130	0.6120
Federal debt			-0.0025
R-squared	0.2780	0.9872	0.9953

All coefficients significant at 99 percent level; all regressions significant at 99 percent level (F-statistic) using 16 observations.

We also ran regressions with the Index current and lagged up to 5 years. Results are robust to various specifications. The addition of life expectancy to the regression adds very little explanatory power to our results so is not reported here.

Spending

As past studies have attempted to connect changes in infrastructure spending to the economy, we want to test the hypothesis that our Transportation Index and Transportation Infrastructure Spending are not highly correlated. Below we present graphs of Federal Spending on transportation in 2000 dollars, current and lagged 5 years, compared to the Index. The weak relationship in this context says that technically we have achieved our goal of measuring performance and not spending.

Figure 46. Infrastructure Performance and Real Federal Spending

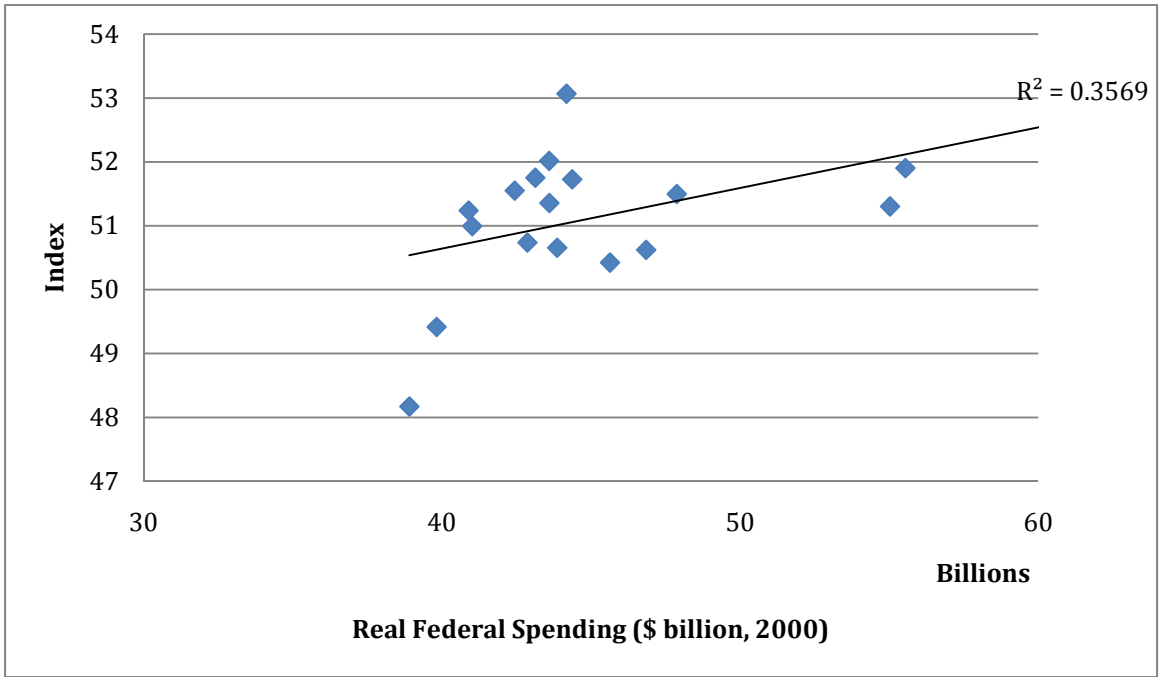
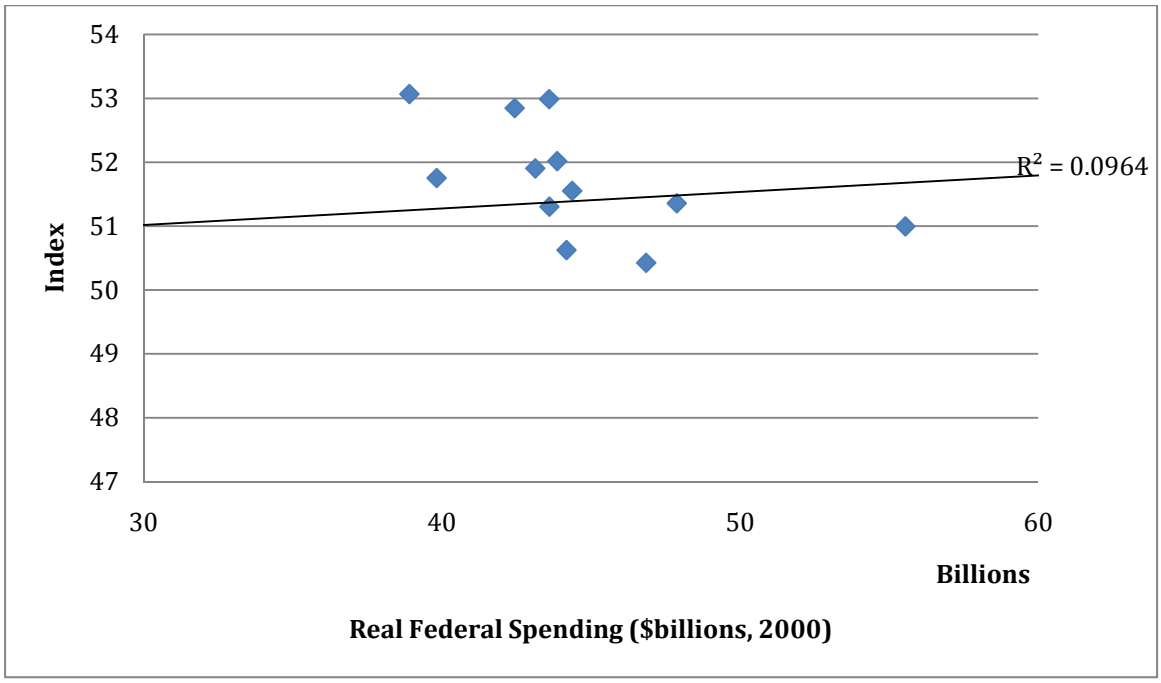


Figure 47. Infrastructure Performance 5 years after spending



Federal spending (actual) on Construction and Rehabilitation of Ground (highways, rail and mass transportation), Aviation, Marine, and Other Transportation; Table 3, Federal budget. Deflated using Construction Costs Index 1990-2003 (GDP deflator 1985-1990). Transportation Infrastructure Index 1990-2008.

Our implementation is similar to that used in Sanchez-Robles (1998), who generated an infrastructure index in the context of developing economies and economic growth.[3] Since Sanchez-Robles demonstrated that measurements of the physical infrastructure are more useful than measurements of spending, we repeat our model substituting spending for the index. Statistically insignificant coefficients are marked with an asterisk. The results are not robust to various specifications. To reiterate, we do not believe it is possible to separate the impact of spending on the economy from the impact of the infrastructure in this specification. The Index gives a more robust, stable result.

Table 32. Supplemental Regression Results using Spending

GDP per Capita	**1**	**2**	**3**	**4**
Federal Spending	***0.4278***	-0.0056*	0.0155*	0.0383
Real GDP		***0.6442***	***0.6132***	0.3140
Federal debt			***-0.0030***	***-0.0027***
Life Expectancy				0.0430
R-squared	0.4946	0.9808	0.9938	0.9966

[3] Sanchez-Robles' specification used a GDP deflator on infrastructure spending. Our results use the Construction Cost Index. In our planned analysis for later this year, we intend to repeat the model with the GDP deflator on infrastructure spending to make it more directly comparable.

Foreign Direct Investment:

We examined annual in-bound foreign direct investment (FDI) using the Index. This measure of FDI does not include foreign investments used to acquire U.S. businesses already in operation or purely financial investments. We hypothesize that infrastructure performance will "lead" FDI investment because of the time necessary to make plans to open new establishments. Further, even if infrastructure performance begins to deteriorate, foreign companies will not be able to remove their investment immediately, although they are likely to stop planning new investments.

Table 33. Correlation coefficients for FDI with various lags on Index

		Lag				
	Index	**1 year**	**2 years**	***3 years***	**4 years**	**5 years**
FDI	0.1114	0.2738	0.4506	*0.6659*	0.5552	0.3212
prob>|t|	0.6499	0.2716	0.0695	*0.0049*	0.0317	0.2628

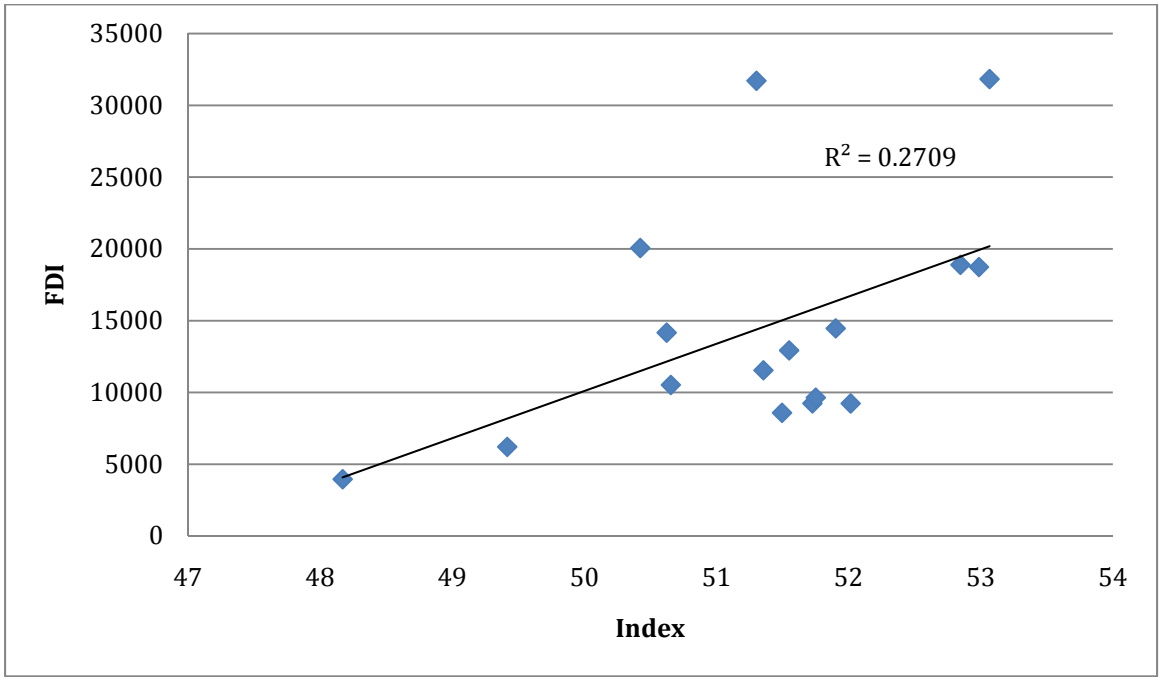


Figure 48. FDI and the Index (3 year lag)

We find a positive relationship between foreign direct investment that opens new establishments in the U.S. – creating new jobs – and the performance of transportation infrastructure as measured by the Index. We believe that this type of investment is more dependent on transportation infrastructure than other types of

infrastructure because of the need to move goods and people between the "home" country and the U.S. According to studies done by the Bureau of Economic Analysis (Department of Commerce), manufacturing (43.4%) and wholesale trade (17.4%) industries account for most of FDI value-added in the U.S. (non-bank). We use data on newly established businesses – excluding financial investments and the acquisition of existing businesses -- with the Index because they reflect changes in infrastructure that might reasonably induce this specific kind of FDI. Most of what these firms import and about half of what they export is shipped from and to the parent company in the "home" country. FDI establishing new enterprises created over 300,000 jobs in the United States in 2008 (Anderson 2008).

Results

As much as transportation infrastructure can be shown to support the economy, we must recognize that this also means that poor-performing transportation infrastructure presents a drag on the economy. A five-year moving average shows a downward trend (see Chapter on Index for details).

Our result could be understood as additive to the 1% stimulation to the economy that is estimated to result from spending on infrastructure construction (Tal 2009). In other words, the real long-term impact on the economy could be one-third higher than what most other studies are estimating since we measure the impact on the economy from the improved performance of transportation infrastructure and not just from the added economic activity required to improve that performance.

Conclusions

The positive impact of infrastructure on the economy was recently shown to be robust across different methodological approaches (Torrisi 2009), provided that infrastructure is not measured by spending or investment (Sanchez-Robles 1999). We started our analysis with a theory about the contribution of transportation infrastructure to economic prosperity. When we looked at the existing data, we realized that no one was measuring infrastructure – they were equating the price of infrastructure with its value.

Prior research that failed to show a relationship between infrastructure and economic prosperity started with the data, using only what was available. Our approach justifies and proves right the proposition that business has been saying by word and by action for decades: infrastructure matters.

CIBC World Markets released a report in February 2009, estimating that new global spending on infrastructure could total $25 trillion to $35 trillion over the next 20 years. North America is expected to spend $180 billion each year, Europe $205 billion, and Asia $400 billion (Tal 2009). The CIBC report includes estimates of all infrastructure spending, of which about 40% will be spent on transportation infrastructure. In Table 33, we summarize only the 2009 stimulus packages that were approved in each country for transportation infrastructure projects. Advances in infrastructure among the United State's competitor nations was the topic of discussion at the World Economic Forum session in 2010. For example, after 30

years of development in China, "railway infrastructure is now the second largest in the world…." China's plans for transportation infrastructure will increase the supply of roads to 53,000 miles by 2020, topping the United States' system by more than 12%.

Table 34. Stimulus Spending specific to Transportation Infrastructure

Country	Stimulus Spending on Infrastructure (2009)
China	$ 393,000,000,000
Italy	$ 114,000,000,000
U.S.	$ 40,000,000,000
India	$ 33,500,000,000
Mexico	$ 31,600,000,000
Romania	$ 30,000,000,000
Germany	$ 28,946,580,000
Taiwan	$ 16,600,000,000

Source: Foreign Affairs and International Trade Canada

As the performance of transportation infrastructure deteriorates, it will produce a drag on prosperity. Well-performing infrastructure is required to support the U.S. economy. A cost/benefit story alone will not suffice to justify the money required to fix this problem. If we consider "real" transportation spending (using the construction cost index described earlier) as a percent of GDP (in 2000 dollars), then it becomes obvious why the performance of transportation infrastructure is in decline. In these terms, spending for 1990 was 0.83% of GDP; by 2008 that ratio had dropped to 0.25%. Transportation infrastructure should add value to the process of getting products to customers and not simply be a way to reduce costs. Our results indicate that a commitment to raising the performance of transportation infrastructure would provide positive long-term value for the economy.

Suggestions for Further Research

We will re-visit this analysis during the coming months, as the Infrastructure Index project progresses. By the end of the project, we will be able to conduct this analysis using measures of the performance of all U.S. infrastructure: Broadband, Energy, Water, and Transportation. We do not take into consideration, by design, negative externalities – for example, that an increase in the availability of transit may lead to undesirable urban sprawl. We see these as MSA or at least regional issues that require model specifications unique to the geographic and economic areas. We also did not consider any externalities that could arise from funding the improvement of transportation infrastructure performance with government spending – and the resulting negative impact of deficits and public debt.

U.S. businesses are less likely to take production off-shore if they can efficiently transport inputs to their locations and move goods and services to their customers. It would be useful to find a way to include this element in the models, although we did not attempt it here. Transportation, of course, is not the only factor that makes a country competitive. Labor costs, trade policy, proximity to markets, etc. all play a role in the decision of firm location. The results here could be expanded except for the fact that other countries – to the best of our knowledge – have not developed measurements of infrastructure performance that could be used in economic modeling (except see Sanchez-Robles (1998) for an approach using limited data).

The state-by-state Index is not used in the economic analysis because the "government" component in the specification is for federal government policy. At the state level, there will be more variation; for example, different corporate tax rates, and location-specific tax incentives. Local agencies, advocacy groups, and stakeholders are encouraged to experiment with this new measure of transportation infrastructure performance. The State-by-State Index might be employed to see if businesses within the U.S. prefer one state over the other based on transportation infrastructure. State-by-state data might also be used with spatial geography to advance knowledge of if/how economic activity relates to the spatial distribution of infrastructure.

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APPENDIX A: BUSINESS COMMUNITY MEETING NOTES

Chicago, IL – April 8, 2010

Key Issues for infrastructure

- Planning and predictability
  - Cost efficiency
  - Need to price the usage of infrastructure correctly so it is used efficiently and maintained appropriately, including pricing water
- Measure the difference in productivity of a built out, fully functioning system vs. a low-functioning system, to support appropriate investment
- Reliability
- Regulatory and reporting burdens
  - Streamline planning processes
  - Speed up permitting processes for siting and building new infrastructure (power plants, roads)
  - Promote regional/economic region planning and markets
  - Interagency collaboration
- Need for broad national infrastructure policy to promote synergies, meet our infrastructure needs for maintenance and upgrades
  - Energy-broadband-transportation synergies (i.e., fuel costs and routing efficiencies need broadband accessibility)
  - Traffic control systems (i.e., control signals and flow so that traffic, rail, bus, etc. work efficiently in the same space)
  - Intermodal transportation that works
- Linkages between all types of infrastructure, for example:
  - need energy to treat water supply, need water to cool power plants
  - transportation planning choices of pavement type influences storm water management and flood prevention efforts
- Find a way to compare "biggest bang for the buck" across the four types of infrastructure for the biggest national benefit

Examples/Stories

- Natural Gas: In fall 2009, the limited capacity of natural gas pipes in one rural town meant that farmers couldn't dry their crops while leaving enough power for residents to heat their homes.
- Broadband: Farmers now using broadband for precision farming in which they know how many seeds to plant per foot using GPS, increasing efficiency in rural areas.
- Rivers: Asian Carp threat (invasive species) may cause rivers in the mid-west to be closed to shipping, which would have a huge impact on companies.
- Transportation: A Canadian company moving goods from Canada to the southern part of the U.S. realized it was taking as long to get their goods through the Chicago

area as to move them across Canada. They bought an old railroad line, renovated it, and now ship their goods on that line and, presumably, pass the increased costs of the infrastructure improvement on to clients.

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Locks/Dams/Bridges	• Especially important for agriculture transportation • Get products to market • Bridges important for rail • Flood prevention, protection of property	• Aging • Current size of locks does not accommodate size of some ships (width/depth/length) • Delays in locks cost time in ship energy use, delays transfer of goods • Generally works at critical times • Bridges too narrow, can't handle higher speeds or heavier weights • Invasive species a threat – may cause river closures	• BTU/bushel to get product to market • Time waiting for or in lock • Weight limits on bridges • Amount of traffic • Bridge height • Bridge conditions • Rivers open to shipping • Lock length • Channel depth • Others[4]
Rail	• Moves people & goods • Gets products to market • Gets raw materials to producers	• Diminishing confidence in on-time performance, especially in choke point areas (bridges, Chicago, etc.) • Needs to have good connectivity with ports, highways, airports	• Confidence in on-time performance • Cost efficiency • Number of at-grade crossings
Airports	• Moves people & goods • Gets products to market • Gets raw materials to producers • Tourism	• Needs to have good connectivity highways • Generally slower with security issues • Perishable goods enter the U.S. via Florida because customs are there, causes delays	• Number of flights • Access to airport • Number of entry points with necessary customs checkpoints

[4] Data includes: Waterways Inc. data, and AWO data

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Highways	• Moves people & goods • Gets products to market • Gets raw materials to producers • Tourism	• Weight limits are currently problematic for some and may become more problematic in future • Congested choke points cause significant delay, e.g., Chicago • Diminishing quality (potholes, debris) • Need good connectivity with intermodal • Poor planning & coordination across jurisdictions	• Weight limits • Congestion/time to move through an area • Speed limits • Road conditions (pot holes) • Road materials (how long they last, how sustainable) • Time it takes from identifying increased capacity need to completion of upgrade • Safety
Water Systems (treatment facilities, pipes & sewers)	• Manufacturing • Crop irrigation • Heating/cooling • Cooling power plants • Supportive infrastructure for all businesses • Fire suppression for building occupancy • Ingestion • Storm water management	• Impacts types of crops or businesses that are viable in certain areas • Determines/limits growth of business and or employment forces • Currently have water, but future availability in some areas is uncertain • Regulation of water uncertain in future • Pipes not adequately maintained today	• Codes • Quality of water pipes • Length of pipes • Quantity of water • Leaks • Regulations • Incremental costs of letting the system deteriorate (lost productivity) • Frequency and costs of failures of public water supply systems • Frequency of storm water/flooding problems • Costs of workarounds in places without clean, adequate supply of water
Energy (Natural Gas)	• Agriculture use • Heating, power, etc. • Fuels machines	• Impacts growth in rural areas • Old • Not enough pipeline/limited scale in rural areas is a choke point	• Pipe size in rural areas • Brownouts • RTO data (how much do they sell on other markets) • Capital costs for transition to natural gas

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Energy (Diesel/Petrol)	• Agriculture use • Heating, power, etc. • Fuels machines • Transportation (petroleum, biofuel)	• Essential for Just In Time delivery • Business structures in place for managing/reducing energy costs • Need infrastructure for biofuels	• Price stability • Supply during peak hours • Brownouts • # of back up energy supplies (i.e., generators) • Real cost of importing a barrel of oil from the Middle East
Energy (Electricity)	• Agriculture use • Heating, power, etc. • Fuels offices • Powers electric cars	• Essential for Just In Time delivery • Business structures in place for managing/reducing electricity costs • Transmission system is insufficient • Supply insufficient during peak times (supply hasn't changed much recently, business electricity use has) • Infrastructure lacking for electric cars • Real time information on usage and cost is insufficient • How green are new electricity sources overall, life cycle assessments?	• Price stability • Supply during peak hours • Brownouts • # of back up energy supplies (i.e., generators) • Cost/kw • Cost of catastrophic failure • Connectivity between electricity sources

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Public Transportation	• Move workers • Tourism	• Out of sync with planning process (density planning at local and regional level is not always in line with public transportation funding, planning processes) • Quality is sporadic in some areas • Funding unpredictable • Dictates where businesses grow in urban areas	• Speed relative to other modes • Parking availability • Funding structures • Age of ridership • Ridership • Energy per passenger mile
Broadband	• Used to make transportation decisions, movement of goods (GPS) • Used to make navigation decisions • Used to make farming decisions (precision farming) • All businesses use to communicate and get information • Used to reduce paper consumption • Used to educate workforce	• Data safety is a growing concern • Essential to all businesses • Ever faster communication directly tied to business efficiency • Rural area coverage is not enough, speedy, or reliable • Concern about maintenance of Russian and U.S. satellites on which GPS is based • Regulations stifling investment. Could be more robust or built out with more investment • Other nations have competitive advantage because government subsidizes R&D to improve broadband	• Number of users • Expectations of speed/data carrying capacity • Speed/data carrying capacity • Data safety • Distance of lines/cables • Spam (security) • Federal R&D support • Opportunities lost if inadequate service in certain regions • Reliability (how often down because of storms)
Intermodal systems	• Key to businesses moving goods • Key for moving people	• Do not always work well together to facilitate direct connections (seamless connections)	• Investment in R&D on how best to move goods and people from A to B

Atlanta, GA – April 22, 2010

Key Issues for infrastructure

- Planning and predictability
- Cost efficiency
    - Measure the difference in productivity of a built out, fully functioning system vs. a low-functioning system, to support appropriate investment
- Reliability
- Regulatory /Multi-jurisdictional changes
    - Streamline planning processes
    - Promote regional/economic region planning and markets
    - Planning needs to occur across jurisdictional boundaries for water and transportation
    - Water rights are unresolved and key in sound investment in water infrastructure
- Need for broad national infrastructure policy to promote synergies, meet our infrastructure needs for maintenance and upgrades
    - Energy-broadband-transportation synergies (i.e., fuel costs and routing efficiencies need broadband accessibility)
- Linkages between all types of infrastructure, for example:
    - Need energy to run broadband
- Economic recession has led to a decrease in infrastructure maintenance and new construction
- All transportation systems are interlinked; to move goods or people, you need to use several systems (car to train, cargo ship to truck, etc.)
- If we want to maintain international competitiveness, we need to compare how the United States is doing with other countries on each of the four indicators. We can learn from countries that are very advanced and improve our systems.
- Ports are especially important in Atlanta region.
- Broadband was highlighted as an especially key infrastructure.

Examples/Stories

- Transportation: One quarry business has lost entire quarries because of a decrease in transportation infrastructure and loss of federal funding to maintain roads.
- Transportation: As congestion slows highways, the available labor pool for a particular business shrinks geographically because people will only spend X amount of time commuting per day.
- Transportation: When waterways are unavailable for moving goods and people, highways use and road congestion increase.

- Broadband: If broadband is not trustworthy, businesses may have mobile or cable back up. Some businesses look for multiple sources and availability. If all else fails, businesses have to work by land line phones. One financial company has backup satellite phones in case broadband fails because broadband is essential to business function.
- Water systems: One company uses public water for its industrial processes, cleans it, and then sells it back to the municipality.
- Broadband: Several companies use teleconferencing technologies to save on air flight costs and employee travel time.
- Water systems: Business decided not to locate in a certain area because there had been major flooding in the past and flood infrastructure had not been improved to mitigate possible damages in the future.
- Public transportation: Public transportation is essential for service sector businesses at the airport (hotels, restaurants). These businesses would not be able to find enough workers if they could not get to work via public transportation because it is too expensive, time consuming for most low wage workers to drive.

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Waterways: Locks, Dams, Bridges, Ports, Rivers	• Moving people, including commuters • Moving freight: cars, military equipment, goods • Tourism • Economic engine • Emergency evacuation • Ports employ people	• Capacity decreasing, e.g., Mississippi River • Policy barriers today to doing adequate dredging (Army Corps permitting) • When waterways are not available, highway congestion increases • Influenced by weather: hurricanes, flooding, freezing • Growing port use by businesses. Use will grow as ports grow • Important part of the supply chain • Last mile connectivity to ports is poor (congested, not enough ways to get in and out of ports) • Larger ships are coming into U.S. ports and current infrastructure cannot accommodate them • Growing short-sea shipping • Security is becoming more problematic (harder to implement, more time to wait)	• Holistic planning and forecasting regionally to invest for anticipated growth • Safety: inspection systems, port security • Depth/width of shipping channels • Broadband available for tracking all containers • Movement through waterway (time through locks, water level, no ice) • Maturity of tracking technology • Connections with on-dock transportation (rail, highway) – accessibility, speed of those modes • Size of ships that can pass through U.S. ports • Congestion in last mile • Time it takes to get through security • # people ports employ
Long-distance Rail	• Moving agricultural products to market • Moving: coal, lumber, vehicles, construction materials, rail cars • Moving people • Moving input and output (sand, gravel, concrete)	• Capacity decreasing • Old infrastructure, so hard to upgrade • Competition for rail between uses (moving freight vs. people) • Rights of way challenging, hard to widen • Limited track availability • Takes too much time to use due to delays, priority trains on the track that take precedence, repairs • Not reliable way to move goods • Only use it when we need to move a lot of stuff because freight moves when it is full, not on a schedule	• Condition, maintenance • Safety: casualty, deaths • Rail down time & service interruptions • Number of at-grade crossings for cars • On time performance (delivery, pick up) • Average train speed: speed limits of the trains, speed limits of the rails • Safety – # of accidents/incidents • # of service disruptions

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Airports	• Moving people: for work, learning, travel • Moving goods (e.g., • Just In Time delivery) • Economic development for communities • Connecting to other modes of transportation, such as rail or highways	• Higher costs for air travel reduce tourist and conference dollars in urban hubs • Congestion – delays in takeoff and landing • Employee travel is rising • As costs rise, we are using airports less • Connectivity to major airports is a problem	• # Airports • Quality and number of staff in air traffic control • % airports using next generation air traffic control technologies • Modes available to get people to the airport • Time to get to the airport • Duration of the average security check • Trade-offs between flight/driving time and when people choose to drive instead • Frequency of departures and arrivals • Punctuality, % on time • # of flights (to show scale of airport) • Average cost per flight • Equipment reliability (escalators, in-airport shuttles, airplanes)
Roads/Highways	• Moving people: workforce • Moving goods, military equipment • Emergency evacuation • Leisure travel • Road construction provides jobs	• Capacity decreasing • Congestion • Some bridges not high enough so disrupt road traffic when raised to let boats through • Quality of road – safety, pothole maintenance needs work • Many bottlenecks • Leadership/management authority over highways is diffuse so hard to make big changes. • Interstate highways are congested, so trucks use secondary highways because travel time is more predictable	• Planning for the future • Travel time to a highway entrance • Is data updated often enough? • Age of bridges • Bridge condition rating • Number of potholes • Congestion volume • Daily back up of traffic (duration, distance) • Average commute time • # dedicated truck lanes • Cost efficiency: time, maintenance • Weight limits • Life cycle cost of highways • # law suits • Use of roads by trucks (primary and secondary roads)

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Water Systems: treatment facilities, pipes & sewers, levees & floodwalls	• Recreation • Energy (hydro) • Consumption • In restaurants • Manufacturing • Bathing/cleanliness • Agriculture • To protect major metropolitan and suburban areas businesses, homes, and infrastructure • To determine where to site businesses, homes, and growth in general • To protect drinking water • To cool equipment	• Deteriorating pipes (out of sight, old) • Significant loss of water in pipes because of leakages • Polluted water increasing because of trash, chemicals, wastewater, rendering it non-potable or usable (insufficient post-use water treatment) • Treating, storing and managing storm water is a challenge with new development • Cross-jurisdictional issue • When it fails, it has significant disruptive impacts on productivity, people's ability to get to work, property value, supply chains • Secondary long-term impacts of inadequate flood control, such as reductions in investment in a certain area, less growth in a certain area, etc. • Changing regulations on flood control and data (new flood maps will be released soon) • Most businesses use public wells	• Economic loss caused by deteriorating systems, flooding • % used, % reused on site • The capacity/resources of water treatment utilities • # gallons lost through leaking pipes • Conservation measures in place (policies, physical systems) • Reductions in water use • Cross jurisdictional efforts to jointly manage limited water resources • Cost of flood insurance • Water demand vs. capacity to provide it • Base flood evaluation • Floods prevented • Impervious cover • # businesses using public wells vs. private wells.
Energy: Sources (nuclear, hydro, natural gas)		• Linked to transportation: reduced demand for fuel means less funding available for offshore research & extraction	

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Energy: Electricity	• Residential • Business, to make products, to stay open, to complete transactions • Hospitals • Military • Transportation infrastructure (stoplights, traffic control) • For broadband • Lighting • Security systems • Comfort (temperature) • Job creation in new energy sectors	• Transmission systems over capacity today (brownouts) • Increasing need for power • Siting challenge of power plants and transmission lines • Vulnerable – small problems cause ripple effects because of grid system • Old technology • We take our electrical system for granted • Clean energy systems are influencing our electricity/power use • Pressure for clean energy may drive up costs • Currently meets our needs • Diversity of supply is not good • Companies make business decisions based on electricity reliability • Green energy is a growing business sector	• Proximity to a power source (means efficiency) • Compare our sources to those other countries are using • Safety trends, e.g., coal mining • Cost of electricity – are we competitive internationally? • Willingness to conserve • Number of permits for new construction • % of sources that are international • % of sources that are efficient/clean • Quantity of energy imported • Consumption/ demand • Production domestically • # outages • # of backup systems • Availability of other sources of energy

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Public Transportation (Transit)	• Moving people in high density areas • Economic development (businesses locate nearby) • Access to workforce • How tourists get around • Conduit among other transportation systems (i.e., getting to airport) • Decrease road congestions and increase average highway speed • Move workers in service industry (lower wages) to large employment centers	• Insufficient funds to expand and make effective (need capital costs and costs of operation) • Lack of transit, which has caused more highway congestion • Inadequate political support (at multiple levels of government, cross-boundary) • Inadequate community support (NIMBY) • Often ineffective because too few lines, infrequent stops, not enough geographic area covered • Connectivity between systems is problematic (too slow, not enough modes to make it efficient) • Public transit takes more time than private transportation • Safety issues on public transit • More workers are telecommuting	• Ridership numbers (shows if people can get where they want to get) • Reach/geographic area • Density • Regional cooperation, cross-boundary overarching transportation plan covering multiple modes and jurisdictions • # of single occupancy vehicles • Congested highways vs. where there is transit • % growth of infill development (trend into or out of the city?) • Regional joint dedicated funds for a multi-modal transportation agency • Land available for public transportation (or not available)

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Broadband	• Emergency services: police, fire • Business people can work from anywhere • Enables small and large businesses to function • Communication: Internet, phone • Ordering products • Enables multiple sites to be in contact • Fleet location & routing • Determining best place/price to get goods (such as fuel, raw materials)	• Linked to time saving and personal and business productivity • Some areas are outside of broadband service • Rural infrastructure is not adequate to meet current demand • Financial institutions cannot operate without it • Teleconferencing – to reduce business costs • Increasing demand for faster, more reliable, more powerful broadband • There is higher speed and better technologies abroad	• Availability (yes, no), access across socio-economic areas, levels, education, for the public • Speed • Up/down time, reliability • Cost • Investment • Capacity – size, ability to save and send data • What other countries are doing on this so we can see if we are keeping up • Density of towers • Users per tower • MPG saved due to broadband access • Average throughput • # towers • Time it takes to site towers and wires
Intermodal systems (including bike lanes)	• GPS in vehicles which allow drivers to be "smart travelers" • Financial institutions use it to transfer data		

Houston, TX – May 13, 2010

Key Issues for infrastructure

- Common issues for all infrastructure include: systems reliability, effectiveness, utilization, efficiency, operations and maintenance consistency, design and construction standards, regulatory oversight, public funding for the public good.
- Congestion was highlighted as an especially problematic issue.
- The increasing risks and likelihoods of floods and droughts highlight the need for sufficient infrastructure to address both of these conditions.
- Water access will be a growing concern for many companies, including manufacturing, petrochemical producers, and tourism. Water reuse infrastructure is currently lacking but will be a growing necessity in many parts of the country.
- Cyber terrorism and cyber security are growing concerns for businesses. Meeting participants did not know what current cyber protection infrastructure looks like or how well it performs. They noted that an act of cyber terrorism could paralyze the business community across the U.S.
- Energy was identified as an essential type of infrastructure as it is needed to treat water, provide power to all technology, move goods, etc.). The cost of energy is closely linked to GDP and quality of life.
- There is a need for investment in infrastructure disaster mitigation and prevention. Businesses have high expectations for all types of infrastructure and rely heavily on infrastructure working properly. The systems cannot afford to fail. There is a need for ways to monitor infrastructure systems more easily (i.e., being proactive and not waiting for systems to fail).
- Regulatory/Multi-jurisdictional changes
    - Need to rethink our 100 year storm metric which is outdated.
    - Concern about broadband regulation. If those who build the infrastructure cannot profit from it, they will not be incentivized to build more.

Examples/Stories

- Transportation: Effective transportation and broadband are essential for Just In Time delivery. Just In Time businesses are a growing sector in U.S. and these businesses will continue to grow if they can minimize their need for warehouse space. Companies like Home Depot, Walmart, etc., are locating to the area because there is reliable broadband and transportation (rail, highways, ports) so they do not need to build as many warehouses.
- Broadband: Colleges with multiple locations across hundreds of miles have benefited hugely from broadband enabling the creation of webinars and online courses. Lone Star College covers 1400 square miles, offers online courses and virtual libraries and staff have significantly reduced their cost and travel time.

- Broadband: increases one company's efficiency and distribution of work among staff across Texas, which also increases their expertise and satisfaction.
- Broadband: An estimated 70% of commercial transactions are made with credit cards, which are reliant on broadband since most credit card machines operate using broadband or wireless technologies. During Hurricane Ike, broadband service was disrupted and stores could accept only cash purchases. Since most people use credit cards to make their purchases, sales were adversely impacted by this disruption in services.
- Broadband: During Hurricane Ike, the power was down for some businesses for weeks because the systems needed to be rebuilt. One business drove its network facilities to Houston where there was power and let employees work from away. This was possible only because workers could be connected via broadband, which meant the business suffered only minimal loss and that they could help provide services to clients during that difficult time.
- Water Systems: Flooding: In New Orleans, after people were evacuated, many never moved back into the city. This includes emergency service workers whose homes were flooded, so now they live far from the emergencies they are providing service for.
- Water Systems: Flood protection: Insurance companies get sued by individuals who believe they should have been covered for flood by their home insurance policies though flooding is not covered under such policies; court defense takes money and time, which could be prevented if high water events produced less damage.
- Hurricanes Ike and Katrina taught a company that provides roadside assistance that they need to have diverse, safe places to store fuel for tow trucks if they are going to help stranded motorists in emergencies.
- Severe storms like Katrina provide lessons about what happens when all systems fail and there is no power, no potable water, congested highways, etc.
- Electricity and Power Sources: Since so many small businesses suffered loss of electricity for an extended period of time during Hurricane Ike, most small businesses in the Houston area have since purchased backup generators to mitigate future power disruptions.
- Electricity: A broadband/telecommunications provider relies on electricity to power their central offices (servers), which are essential components of the broadband and telecommunication systems. Without power to these facilities, the company cannot provide broadband access. They have back up diesel and natural gas generators that will allow the telephone systems to work for 24 hours without electricity.
- Water Systems: A petrochemical company relies on access to water for their industrial processes. At times, drought has forced them to purchase water, at great cost, from other water suppliers.

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Water Systems: treatment facilities, sewers, & reuse	• Office support • To treat by-products from production, such as oil production	• Old infrastructure • Reuse infrastructure is lacking and there is a growing need for it as droughts become more common.	• Water quality of supply and treated effluent • Coordination across boundaries around water treatment • Rates of waterborne illness • Percentage of a system that is old technology (e.g., clay pipes) • Design capacity vs. actual # of users • Water table level changes • % of area served by reused treated water
Water Systems: pipes, towers, and sourcing	• Manufacturing (heating, cooling, as a component of production) • Office support • Water crops • Aesthetics (landscaping, fountains) • Public safety • Recreation & tourism • Making energy	• Generally old technology • Water scarcity is a growing problem for businesses • Water scarcity forces companies to purchase water at higher costs	• Cost • Supply • Quality (potability) • Capacity utilization (i.e., How much never gets used) • Availability / quantity • Leakage rate from pipes (both those carrying clean and wastewater) • Age of infrastructure vs. the technology's formal useful age • Age of pipes • Amount of usable surface water • Volume of present and planned water storage • Empoundments available for emergency services • Water shortages (shows effective backup systems) • Water use per person, per industrial output, per dollar
Water Systems: levees & floodwalls	• Transport goods • Protect public & supportive infrastructure from flooding • Public safety	• During droughts and/or storms businesses	• Number of floods prevented • Business lost to floods • Water conserved • Economic losses due to storms • Systems identified by U.S. Army Corps as in need of investment

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Energy: Sources & production (nuclear, hydro, natural gas, diesel, coal, renewables)	• Industrial processes • Natural gas or coal as a feedstock for petrochemical companies • Support residences • Run water treatment & flood control infrastructure • Run transportation infrastructure and vehicles	• Sources of natural gas and crude are generally reliable. • Wind energy is a booming industry in West Texas, but is reliant on lots of open space • Other parts of the country may have problems linking new energy sources to the grid. • There is diminishing demand for new oil refineries. • Permitting for new energy facilities is difficult and time consuming.	• Carbon footprint (efficiency) • Number of disruptions due to storms • Reliability • Diversity of supply (i.e., # of companies that use natural gas and diesel just in case something happens to one of the sources) • Estimated costs of failure or disruptions of source • Price (deviances from international markets and trends) • Reserve ratio • Price volatility • Money spent on replacement vs. new infrastructure • Time it takes to get new energy project permitted and built • R&D spending on energy sources • Age of systems • Reliability • Ratio of domestic vs. imported sources • Price spread nationally
Energy: Electricity	• Power machinery such as computers and office infrastructure • Industrial processes • Municipal uses • Support emergency services, such as hospitals • Heating and cooling • Lighting • Power commercial transactions (such as credit cards, financial trading)	• Generally reliable • Essential to everything that businesses do (from power computers, turning on lights, to running machines) • Important to all service and financial sector businesses	• Number of small businesses that have generators in case supply is disrupted. • Total cost of hidden costs (i.e., backup systems) • GDP • Price volatility • Money spent on replacement vs. new infrastructure • Stability of electrical grid • Age of systems

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Energy transmission & storage (pipes, lines, ships, trucks, rail)	• To get from source to end user	•	• Maintenance dollars • Pipeline throughput • Age of infrastructure • Time it takes to get from source to end user
Broadband data capacity & security	• Track supplies, shipments, & vehicle fleets • GPS • Automation • Entertainment • Share increasingly large amounts of data with clients and internal stakeholders • Support SAP and Oracle systems for multinationals • Share health care data & facilitate the way health providers interact with their patients • Access to education	• Security is a big concern. It causes significant disruptions if a system is hacked. Security prevention strategies also slow how fast a company can transfer data or access the Internet. • Broadband can provide equal access and opportunities (i.e., Access to education) • Broadband is what allows multinational corporations to operate effectively. • Broadband is generally reliable. If it is not, most companies have satellite back up.	• # credit card transactions • # of ID theft incidents • Cost of cyber defense systems to businesses • Consumer confidence in security • Speed that financial transactions can be made over the Internet (i.e., Stock trades) • Total volume of trades • How often systems reach capacity • Speed • Availability in rural areas • Our services vs. other countries • Bits of information transmitted per population • Emergency rescue time

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Broadband: Wireless towers, wires, satellites	• Teleconference with internal or satellite offices • Teleconference with clients • Support commercial transactions (such as credit cards) • Roadside assistance and emergency services	• Reliability of broadband can impact the service time of AAA roadside assistance.	• # of towers • Distance of lines • # of businesses with satellite back-up systems • Productivity lost to broadband outages • # of dropped calls • Geographic distribution of fiber optics • Prevalence of different types of technology (i.e., G3) • #, location, age of servers • Storage capacity • Location of central servers • Our ability to interact with other grid systems (i.e., Communication with hubs in Canada)

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Transportation: Waterways: Locks, Dams, Bridges, Ports, Rivers; railways; airports; highways; public safety	• Move goods and products • Tourism (i.e., Cruise ships) • Move people • Link transportation systems (i.e., Multimodal) • Support business & economic development	• Aging infrastructure • Congestion is a big problem • Weight limits are not enough to support heavier loads • Public safety is a concern on highways • Ports are essential to economic development in the Houston area • Congestion around the port is problematic • Businesses opt for the most reliable and cost effective mode of transportation • Companies are exploring new ways to bypass congestion on the highways, such as short-distance freight rail	• Weight limits • Delay (hours and speed) • Reliability • # hours in congestion • Locations and miles of congestion • Investment in new infrastructure • # of railcars and types in use • Crashes, death, injuries, property damages, and delays to due to safety issues • # jobs per commuter shed • # employees in x driving time to businesses • # TEUs moving through ports • Jobs linked to ports • # warehouses businesses have (i.e., Proxy for their ability to do Just In Time delivery) • Willingness to commute • Air quality • # of modes available to people • Changes in BTUs/ton mile • # passengers & freight moved • Transit & passenger ridership • Flight and duration of delays • % goods moved by any source of transportation • Conditions • Quality of technology used • # of new people entering transportation workforce • Velocity • Total volume

San Jose, CA – May 20, 2010

Key Issues for infrastructure

- Water infrastructure is especially important for this region and is likely to be a growing concern for other U.S. regions as well, as droughts, demand, and stricter wastewater regulations increase.
- U.S. infrastructure must be able to meet current demands but also be flexible enough to meet future, unknown uses and demands (i.e., new Internet based applications, uncertain water supply situations, new transportation technologies, etc.)
- Consider tracking demand as well as supply.
- Security and safety concerns are found in all types of infrastructure, and functioning infrastructure is key to providing for emergency services and security during crises of various kinds.
- Benchmarking U.S. performance against other countries is one way to mark our progress or lack thereof.
- Infrastructure should be a priority for the country. Increasing funding for less exciting activities like maintaining existing infrastructure is key, as is promoting appropriate pricing to encourage investment and conservation of resources. Right now investment tends to be almost exclusively crisis driven.
- Regulatory issues slow investment and projects, especially in broadband.

Examples/Stories

- Water: Water infrastructure is essential for this region's economy. Access to and cost of water is an important factor in all industrial and large scale businesses decisions.
- Water: Water quality is important in high tech manufacturing. Many processes require very clean, particulate free water, so the quality of water (or cost to clean it if it is not pure enough) is important.
- Water: Availability of water and its cost influence agricultural decisions. Some farmers keep their lands fallow from time to time if it is more profitable to sell water rights than agricultural crops.
- Water: Historically, the high tech industry was able to thrive in this area because they moved into areas/buildings that already had water infrastructure (sewage, pipes, etc.). It would be harder for companies to move into new areas today because the water access/treatment infrastructure required would be too onerous.
- Water: A thousand miles of levees near San Jose are now acting as dams and keeping salt water/the bay out of the landscape. An earthquake or damage to those levees would cause untold damage to businesses and communities.
- Water: if you don't have water in your business, employees must be sent home due to lack of facilities, which can shut some businesses down.

- Water: A business' treated wastewater is sold back to the community for use because it is cleaner leaving the plant than it was coming into the plant.
- Water: Some companies have costly desalinization (water treatment) back-up systems in case of drought or higher water costs.
- Energy: Many areas rely on "peaker plants," which are small scale electricity generators that kick in when demand for energy is high and exceeds current capacity. Electricity from these plants is very expensive, but firms need to know that they have 24/7 access to electricity.
- Energy: A lot of energy in CA is dedicated to moving water from places that have it to places that don't. For example, agricultural processes require water, which is pumped using electric pumping systems.
- Energy: When the power goes out, people die from heat or cold. There are also vandalism and other breaches in security when there is no electricity.
- Energy: A water supply company has a backup generator for moving water (their product) if the power goes out.
- Energy: If the power goes out, many businesses have to send their employees home because all their work requires machinery that uses electricity.
- Connections between types of infrastructure: Most municipalities have diesel generators as a backup. These then require that roads be in good condition so they can get fuel to the generators for power for the municipalities.
- Broadband: During earthquakes, since many no longer have land lines, communication via cell phones halts because of overload, which can be an issue of safety and survival during the first hours of a crisis.
- Broadband: Marvell transmits all product orders to Asia via Internet, so when the Internet was down for several days, all orders ceased, at huge cost to the company. They did not place orders another way, just waited for the problem to be fixed.
- Connections between types of infrastructure: The more teleconferencing possible, the less travel needed, which decreases costs and carbon emissions for businesses.
- Transportation: There is a link between air quality, energy, and transportation. Many trucking companies located out of state because of CA's stringent air quality regulations.

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Water Systems: treatment facilities, sewers, & reuse	• Office and home use including toilets • Ecosystem needs • Aesthetics • Safety • Manufacturing (high-tech)	• Waterborne illnesses transmitted • Need water pressure for water cleanliness • High tech processes need highly purified water. • Wastewater treatment is energy intensive.	• Cases of waterborne illnesses • Water quality (dirt in, dirt out) • Cost to purify • # of communities using metering • % of businesses with their own water treatment facilities • Water quality (contaminants, solids, or particulates in source water) • # of water sources that meet EPA water quality standards • Acres dedicated to storm water treatment
Water Systems: pipes, towers, and sourcing	• Manufacturing (cooling, as a component) • Office and home use • Agricultural crops, to feed people • Urban irrigation • Drinking water • Fire protection • Makes life possible • Ecosystem needs • Aesthetics • Cooling/misters • To generate power	• Currently overused because underpriced • Droughts make water availability (and cost) unpredictable • CA relies heavily on moving water from areas that have water to areas that don't. Without functioning infrastructure, many businesses would suffer.	• Are ecosystem-appropriate crops thriving and receiving adequate water? • In times of drought, is there enough water for hydropower, agriculture, urban use, etc.? • Public investment in water infrastructure • Water loss across pipes or aqueducts
Water Systems: flood and drought protection (levees & floodwalls)	• Hydro power • Protect infrastructure	• Droughts are destabilizing to regional businesses (agriculture, high tech, and others) and are a growing concern. • Some farmers leave fields fallow if they know that they cannot pay for water and that it is more profitable to sell their water rights.	• Is the government proactively investing in levee infrastructure, or responding to crisis? • What are the anticipated costs of levee failure? • Is there adequate maintenance of the levees? • Lost productivity due to drought.

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Energy: Sources & production (nuclear, hydro, natural gas, diesel, coal, renewables,)	• Comfort/climate (heat, A/C) • Run industrial processes • Treat water • Assist with flood control • Cooking • Powering public transit	• Consumers pay for inefficiencies, so policies should encourage conservation • Want more options for sources/generation	• Measure employees per customer, which shows a company's efficiency. • Energy use per capita • Variety of sources/portfolio • Capacity vs. demand
Energy: Electricity	• Cell phones, communication, computers • Safety / emergency vehicles • Machinery • Run transportation systems (traffic signals) • Comfort/climate • Run security systems • Refrigeration • Powering Internet • Distribute water from areas with water to areas that need it (by use of pumps)	• Type of energy has impact on air quality • "Peaker plants" are needed in many urban areas to generate and sell electricity during periods of high demand – even though this is an expensive option • A lot of energy is used to transport clean water. • A lot of energy is used to clean water and to treat wastewater.	• Ease of selling back electricity to the grid, as this increases our resilience, decreases foreign dependence. • Air quality • Location of power sources (are most local, far away) • Number of electricity "peaker plants" • End of life process- pollution and unintended consequences
Energy transmission & storage (pipes, lines, ships, trucks, rail)	• Back-up power (generators)		

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Broadband data capacity & security	• Telecommuting, communication with staff and clients • Sharing and transferring information and data • Moving money/transactions	• When Internet is down, many online and credit or debit transactions cease. • Internet security is a growing concern. We assume that our information will be secure, but businesses would suffer if there were ever a major cyber security threat.	• Speed (for downloading video, IM, etc.) • Awareness of what next generation technology is up and coming. • Security • Compare our performance to that of other countries, and international rankings. • % of residents who know how to use the Internet • # of people with access to the Internet • Breaches in security • # of security software updates businesses need • Online purchases (as a proxy for consumer confidence)
Broadband: Wireless towers, wires, satellites	• Keeping people in touch constantly • Track supplies, fleets, products • Emergency services • Investments draw new business • Entertainment • Social media and related business marketing	• It can be difficult for businesses and others to anticipate adoption/use rates of new technologies • Needs to be able to support future applications and technologies. We don't know now if it can. • Companies want to be able to have the flexibility to use more/less broadband as they need it.	• Do regulations encourage companies to make major investments & improve their systems? • Public investment in broadband • Miles covered • Reliability • # people with access to 1.5 mbits/second • Time it takes to deploy new technologies • # of electronic medical records • # options for flexible use by companies

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Transportation: Roads, Highways, Bridges	• Moving goods • Moving people • Connecting modes	• Valued because of flexibility, because investing in roads leads to private investment nearby	• Congestion: Duration, stress, pollution, safety incidents, resources lost, quality of life decreased, • Throughput • American Society of Civil Engineers' Annual Report Card • Are we meeting FTA and FHWWA annual standards? • Cargo movement • Travel time • Pricing/costs • Safety records, bridges, accidents • Time it takes for emergency vehicles to get on site • Maintenance: number of potholes, pavement condition index • Level of funding • American Consulting Engineers Council • How long the backlog of unfunded maintenance is, e.g., CA's SHOPP and STIP programs are both underfunded • Pricing of toll roads • # imports through ports • # jobs created • Quality
Transportation: Rail	• Moving goods – moves most large goods in the U.S. • Moving people • Connecting modes	• Less efficient for moving people than rail in other countries because it shares cargo track.	• Safety records • Investment: total dollars, ration of maintenance vs. new (need both), private dollars leveraged

Priority Infrastructure	Uses	Conditions/Impacts	Indicators
Transportation: Air	• Moving goods • Moving people • Connecting modes		• Are regulations increasing airports' ability to fly or not? (e.g., noise regulations sometimes prevent flights during certain times of day) • Number of flights • Number of hours per day planes can fly • Added time, cost, frustration for travelers because of the TSA security requirements • Passenger experience: ease of flying vs. other modes
Transportation: public transit, pedestrian	• Moving goods • Moving people • Connecting modes		

APPENDIX B: SUMMARY: TRANSPORTATION EXPERTS MEETING (CHICAGO, MARCH 26, 2010)

Experts

James Corbett, University of Delaware
Mark Hanson, University of California, Berkeley
Ashish Sen, University of Illinois at Chicago

Agenda

- Welcome and Introduction
- Review of project objectives – Janet Kavinoky, U.S. Chamber
- Overview of the project and progress to date – Sue McNeil
- Review of areas of expertise
- Discussion
- Observations
- Recommendations
- Areas for future work

General Comments and Observations

Departments of Transportation have invested in measurement of performance. However, there remains much work to be done. It is futile to try to find the perfect measure. The concept is to get a measure out there, and then set as a goal to make the measure better. Also, care must be taken in deciding which variables are endogenous and which are exogenous, for example, usage and capacity.

Previous work

The experts identified some previous and ongoing work that is relevant to this exercise. Specifically:

- Garrison, William and Duane Marble, "Factor Analytic Study of the Connectivity of Urban Transportation Networks," *Papers in Regional Science,* Volume 12, Number 1, December 1964.
- Garrison and Marble's work critiqued the use of graph theoretic measures of transportation linked to GDP. The work focused on the NE Corridor and categorized MSAs using factor and cluster analysis and the related prosperity to transportation infrastructure. The work looked at the form of cities and the relative values of collection costs vs. line-haul costs.
- Munnell, Alicia, Editor, Is There a Shortfall in Public Capital Investment? Conference Series; Federal Reserve Bank of Boston, June, 1991. (Proceedings of a Conference Held in June 1990)
- Munnell, Alicia, Policy Watch: Infrastructure Investment and Economic Growth, Journal of Economic Perspectives, Volume 6, Number 4, Fall 1992, pp 189-198.

- Aschauer, David, "Is Public Expenditure Really Productive?"Journal of Monetary Economics, Volume 23, Issue 2, March 1989, pp 177-200.
- Gramlich, Edward, Infrastructure Investment: A Review Essay, Journal of Economic Literature, Volume XXXII, September 1994, pp 1176-1196.
- Transportation Services Indicator – see http://www.bts.gov/programs/economics_and_finance/transportation_services_index/tsi_related_research/html/paper_01/
- See Readers Digest for Highway index article
- Sledge, Gary, Fixing America's Infrastructure: Our bridges, roads and tunnels are crumbling. Time for an extreme makeover. Reader's Digest, October 2006.
- Crouch, Michelle, The Best, Worst and Deadliest Roads in America, Reader's Digest, April 2010.

Discussion

The discussion loosely followed the agenda outlined above. This summary of the discussion is organized around specific modes or types of transportation, related measures, and the general discussion of existing measures.

Freight

The discussion related to freight focused on four indicators and related measures – port capacity, delay, cost, and more generally, impedance. These indicators cover significant gaps in the demonstration transportation index.

Port capacity is an important element of supply. Throughput can be used to capture port capacity – at least in terms of a lower bound. The most commonly available data are revenue TEUs. However, the problem is that revenue TEUs ignore empty containers. Ton miles are also not a good measure. Port throughput data are available from states and Metropolitan Planning Organizations (MPOs). For example, see:

- Wilmapco
- NYSDOT

An ideal measure might be the number of berths times the number of hours to turn over a berth. A small sample of data might be collected, correlated to a widely available measure and then forecast[5].

Delay is an important element of quality of service. One taxonomy of freight delay disaggregates delay as follows:

- Route selection
- Segment speed reduction
- Intermodal transfer time
- Dwell time

[5] Despite searching many sources, consistent data are not available. A preliminary review of throughput data showed that year to year changes are significant and are related to changes in infrastructure, efficiency or productivity.

All the disaggregated components of delay have implications for in-transit labor costs and ultimately, quality of service and efficiency. The challenge lies in trying to identify a measure that captures this indicator. A reasonable proxy would be ton hours but then determining the appropriate spatial distribution creates a new challenge. Furthermore, this new challenge underscores the importance of thinking of the system and how the configuration of the system relates to the behavior of the system.

Cost is an important element of efficiency. Efficiency can then be captured using measures such as:

- Cost % commodity value
- Business expenditures as % logistics

Published freight rates are available from

- USDA
- Journal of Commerce (TEU)
- Baltic Freight Index

Measures – Freight

Ideas for several interesting performance measures came to light:

- # cars/days/capacity
    - Capacity comes from Waybill
- Freight facilities – unimodal/multimodal
- Impedance factors –
    - Water channel depth
    - Miles of maintenance dredging - < 50 ft draught – David Greer – Institute for Water Resources, U.S. Army Corps of Engineers

Air

The discussion began by focusing on delay and the presentation of a flight delay taxonomy:

- Difference from ideal flight
- Schedule padding
- Capacity increased schedule delay
- Delay against schedule

These delays result in

- Airline costs
- Passenger costs (delays, disruptions, less convenient schedules)
- Passenger schedule adjustment cost
- Lost demand
- Indirect economic impacts

Estimates for 2007[6] are as follows:

[6] See https://afs.berkeley.edu/group/nextor/www/6_TRB_DelayWorkshop_Hansen.ppt for a 2009 presentation of the methodology.

- Cost to airlines - $16.7m
- Cost to passengers - $18.0m
- Lost demand - $4.5m

The discussion then moved to costs and efficiency. Airlines do a 10% ticket survey that can be used to provide a sense of costs.

Potential measures and data sources include:

- TSA - Flights/day, Passengers/day => load factor
- Airport Council International
- Airport Acceptance Rates serve as a measure of runway capacity (data available for 2000-2007).
- Operating revenue data are available but this data only captures a performance concept that is narrower than infrastructure efficiency. Air travel price index – 20 cities from ticket sample
- Also see Airline Service Index (K-State)

As a word of caution it is important to distinguish airport categories vs. the category the airport was designed for.

Measures - Air

Measures for air transportation need to distinguish between the infrastructure and the system. Discussion initially focused on the preliminary list of indicators:

- Supply/ accessibility - % population with access to major airport. (Major airports are defined by FAA)

Efficiency

  - Av fare/mile (includes infrastructure, TAFE, PC's and tax)
- Quality of service
  - Delay
  - Safety – runway incursions – available since the later 1990's. Not going to be a lot of change.
- Utilization
  - Flights/capacity.

Intercity passenger rail/transit

The experts recognized that this is a political issue and does not account for movement of people. However it needs to be included. Intercity rail is the most challenging. Measures could capture the number of destinations within 12 hours travel but this requires defining what is meant by a destination.

Safety

- FARS/VMT – may want to break out grade crossing data. In general finding the right units for analysis of crash information is challenging. For example, , accidents/ton mile will show that waterways are the safest freight mode but accidents/employee show problems. Also, the number of grade crossing, and miles of grade separated infrastructure is important.

- Measures need to relate to where you want to make investments.

Weighting

In general the experts believed supply is not important, as there are different perspectives (users vs. providers). Users will optimize in the short term. Providers have a longer time frame.

Sampling

The following observations were made:

- Consistency across the different types of indices (transportation, water, energy and broadband) is NOT necessary.
- Specifics are not important. Objective is to reduce noise and capture meaningful changes. May want to pay attention to the 1st and 2nd derivatives.
- Trade label is confusing.

Scale

A 0-100 scale is fine. However, a one-sentence explanation is needed.

Pipeline

Why is it missing? Pipelines have traditionally been considered a mode of transportation[7].

Recommendations

The expert group made the following recommendations:

- Relationships are actually quite non-linear[8]. Also need to think about where we need step functions rather than trends.
- Efficiency is a difficult measure -- e.g., high prices are good for some businesses and bad for others. Conclusion is to leave efficiency out of the index.

Areas for future work

The most important area for future work is to relate measures to actions.

[7] Given that most commodities moved by pipeline are energy related, pipelines are considered part of the energy index.

[8] Some explanatory analysis suggests that a log scale may be more appropriate for some indicators.

APPENDIX C – TRANSPORTATION INDICATORS – NATIONAL INDEX

This appendix summarizes the indicators used to develop the Transportation Index, databases explored, and alternative indicators considered.

Indicator Summaries – National Index

Summary tables are provided for the twenty-one transportation indicators used to develop a national transportation index. The following data are included in each summary:

- Definition: an explanation of the short name used in the text and tables
- Why it is important: relevance to transportation infrastructure performance
- Criteria metric: relevant criterion (supply, quality of service, or utilization)
- Historical and current values: average data by MSA type
- Observations: relevant notes related to the data
- Contribution to the transportation sub-index: relative weight
- Primary data sources: URLs for websites, where applicable
- Data issues and opportunities: descriptions of problems, solutions, and ideas for improvements in source data.

The indicators are based on the three categories of criteria:

- Supply
    - Highway Density - Route Miles per 10,000 Population
    - Transit Density - Miles of Transit per 10,000 Population
    - Airport Access - % Population Within 50 Miles of Major Airport(s)
    - Airport Capacity - Average (AAR + ADR) per Hour
    - Rail Density - Route Miles per 10,000 Population
    - Waterway Density - Miles of Waterways per 10,000 population
    - Port Access - Distance from the Center of MSA to the Closest International Container Port
    - Intermodal Connectivity - # Ramps per 10, 000 Population
- Quality of Service
    - Highway Congestion - Travel Time Reliability (TTI)
    - Highway Safety - Fatalities per 100 Million VMTs
    - Road Roughness - % of Lane Miles with IRI Greater Than 170 in./mi.
    - Bridge Integrity - % of Bridges Structurally Deficient or Functionally Obsolete
    - Air Congestion - % of On-Time Departures
    - Air Safety – Runway Incursions per Million Operations
    - Rail Safety – # Incidents per Million Train Miles

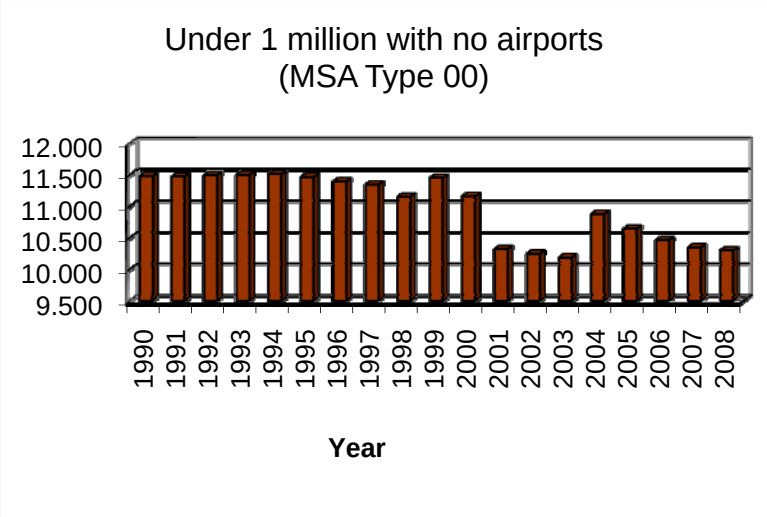
    - Waterway Congestion – Average Lock Delay per Tow (Hrs.)
    - Transit Safety - # Incidents per Million PMT
- Utilization
    - Uncongested Roads - % of Lane Miles at LOS C or Better
    - Air Utilization - % Capacity Used between 7amand 9pm
    - Transit Utilization - PMT per Capacity (Standing + Seating)
    - Rail Utilization - Million Ton Miles of Freight per Track Miles

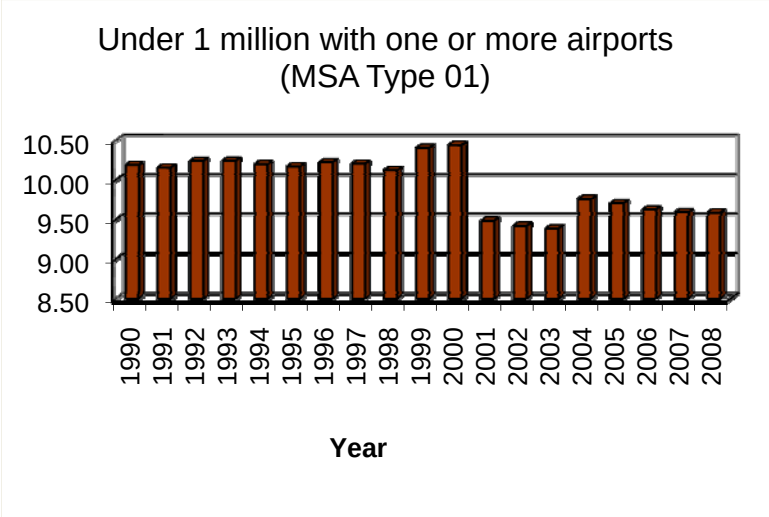
For each indicator the following data are provided:

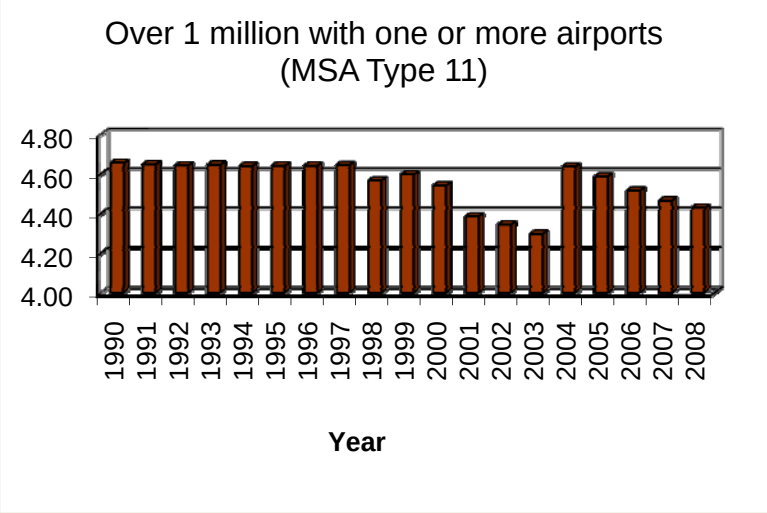
- Definition
- Why it's important
- Criteria metric
- Observations
- Contribution to the transportation sub-index
- Primary data sources
- Data issues and opportunities
- Historical and projected values (from 1990 to 2007)

Indicator #1	**Highway Density**
Definition:	Route Miles per 10,000 Population
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
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.099* *MSA type 01 (population under 1 million with primary airport(s)) – 0.093* *MSA type 11 (population over 1 million with primary airport(s)) – 0.085* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transportation Atlas Database (NTAD) (http://www.bts.gov/publications/national_transportation_atlas_database/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	(1) The NTAD data are available on CD from Bureau of Transportation Statistics (BTS) since 1996. (2) It is assumed that the indicator keeps constant from 1990 to 1996 using the 1997 data. The 1996 data were not consistent comparing to other years and were excluded from the data sets. (3) The data are obtained only for major highways (with highway functional classes of 1, 2, 6, 11, 12, 14, and 16). However, from 1996 to 2000, functional class data was missing in the data sets. Adjustments are made based on the portion of major highways in the total system in 2001.
Observations: • Generally highway route miles per capita decrease from 1990 to 2008. • The biggest decreases occur after 2000, especially in 2001, 2002, and 2003. Then in 2004, 2005, and 2006 the indicators slightly increase.	

Historical Values:

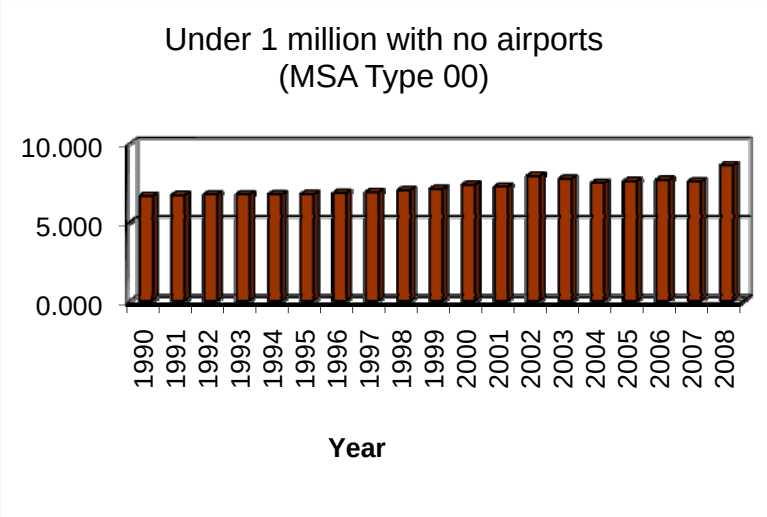


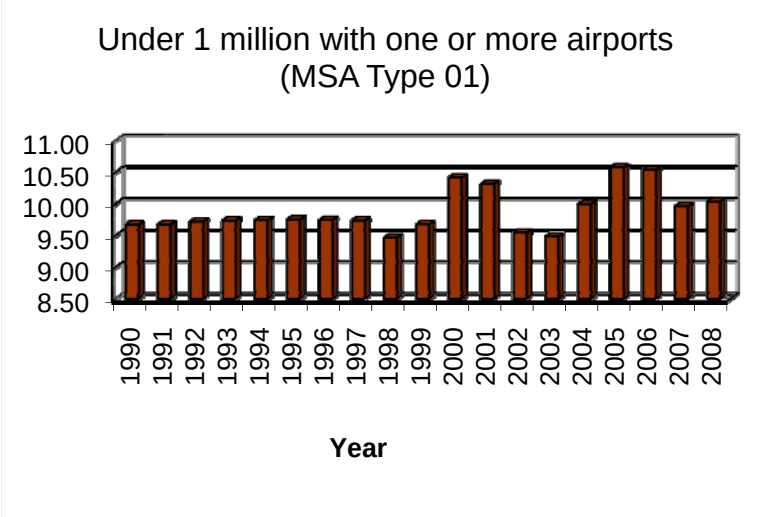


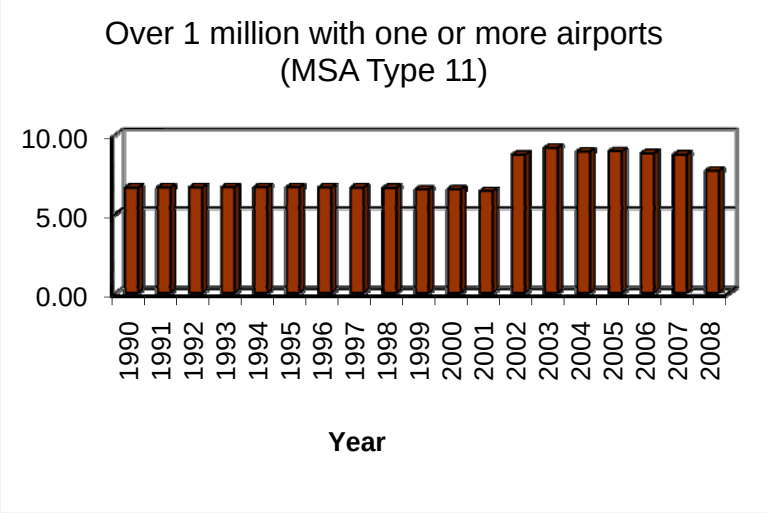


Indicator #2	**Transit Density**
Definition:	Miles of Transit per 10,000 Population
Why it's important:	Public transit is an essential transportation option that can cut through congestion to provide access to job markets and remove auto trips from the highway system, thereby helping to maintain highway capacity for the shipment of goods and materials.
Criteria metric:	Supply
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.052* *MSA type 01 (population under 1 million with primary airport(s)) – 0.049* *MSA type 11 (population over 1 million with primary airport(s)) – 0.045* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transit Database (NTD) (http://www.ntdprogram.gov/ntdprogram/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	The NTD data are available from Federal Transit Administration since 1997. It is assumed that the indicator keeps constant from 1990 to 1997 using the 1997 data.
Observations: • Transit density keep increasing in MSA types 00 and 11, especially in 2002. • Transit density for MSA type 01 various from year to year without a clear trend.	

Historical Values:

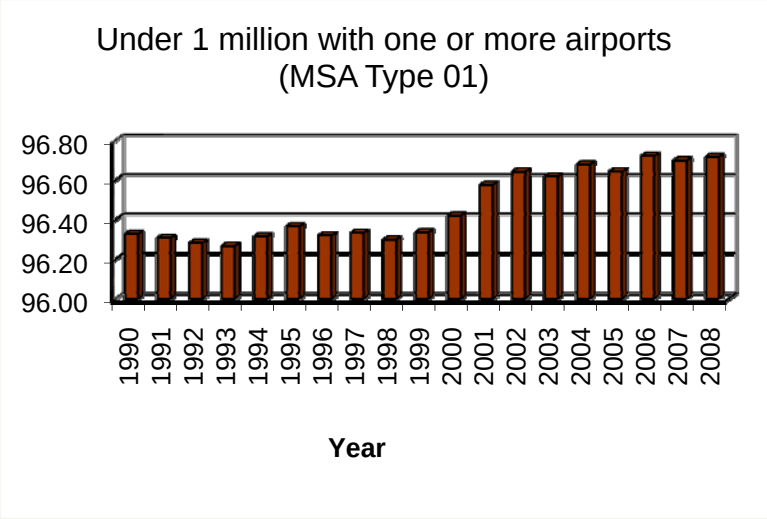


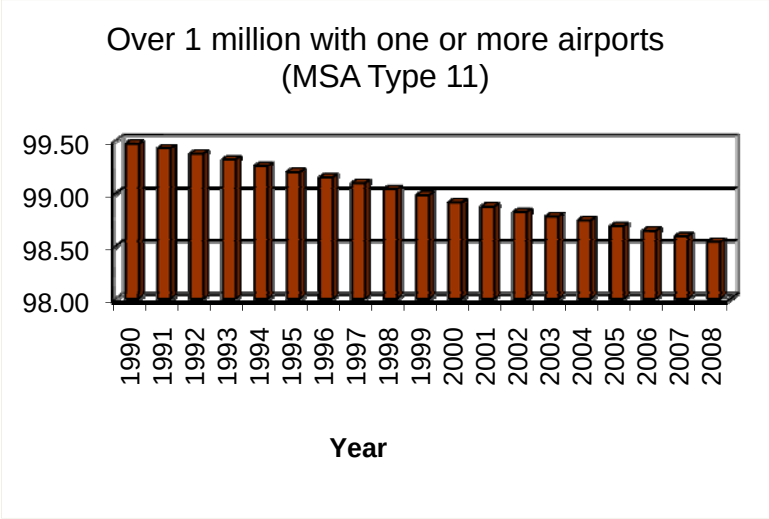




Indicator #3	**Airport Access**
Definition:	Percent of population in statistical area within a fifty mile radius of major airport(s)
Why it's important:	The airport access indicates the supply of air transportation facilities available to the population in the statistical area.
Criteria metric:	Supply
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.000* *MSA type 01 (population under 1 million with primary airport(s)) – 0.018* *MSA type 11 (population over 1 million with primary airport(s)) – 0.016* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transportation Atlas Database (NTAD) (http://www.bts.gov/publications/national_transportation_atlas_database/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	The census tracts data were available only in 1990 and 2000. Other data sets are extrapolated or interpolated based on these two data points.
Observations: • From 1990 to 2008, people tend to move towards the airports in the MSA type 01, while people move away from the airports for MSA type 11.	

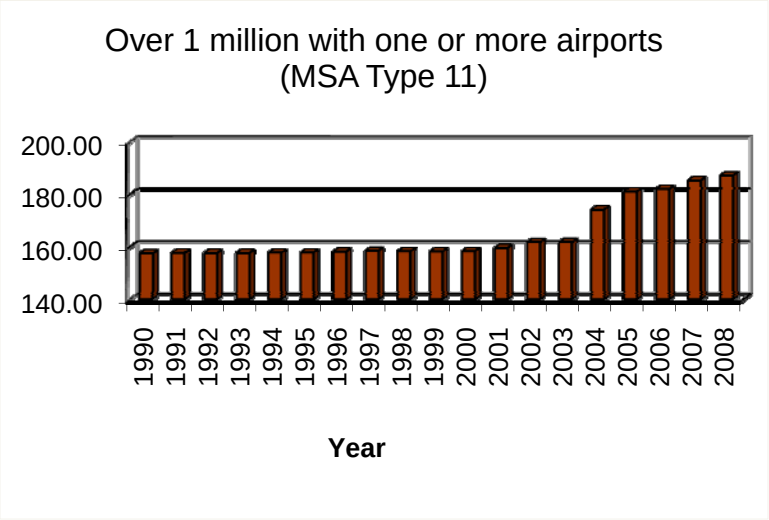
Historical Values:





Indicator #4	**Airport Capacity**
Definition:	Average Airport Arrival Rate (AAR) and Departure Rate (ADR) per Hour
Why it's important:	Airport capacity is the number of airport operations (arrivals/departures) an airport can support per unit of time under specified conditions (e.g., aerodrome layout, aircraft mix, weather conditions, facilities, aircraft parking, etc.)
Criteria metric:	Supply

Historical Values:



Observations:

- The airport capacity keeps growing from 1990 to 2008.

Contribution to Index:

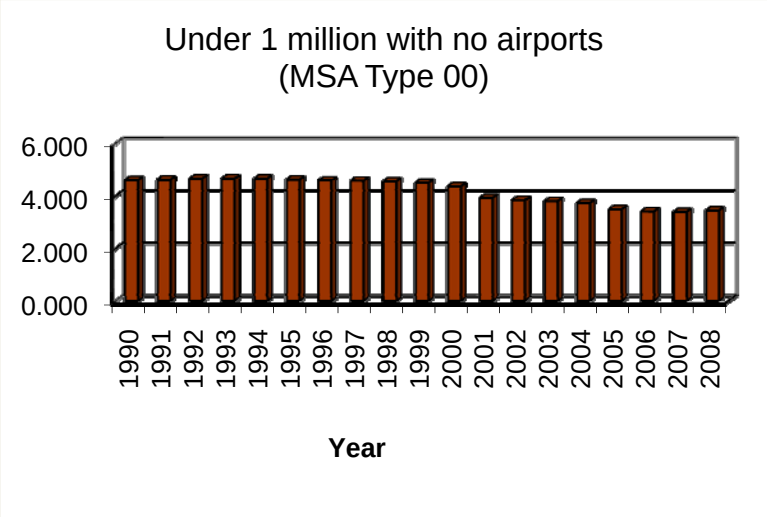
MSA type 00 (population under 1 million without primary airport) – 0.000
MSA type 01 (population under 1 million with primary airport(s)) – 0.000
MSA type 11 (population over 1 million with primary airport(s)) – 0.028

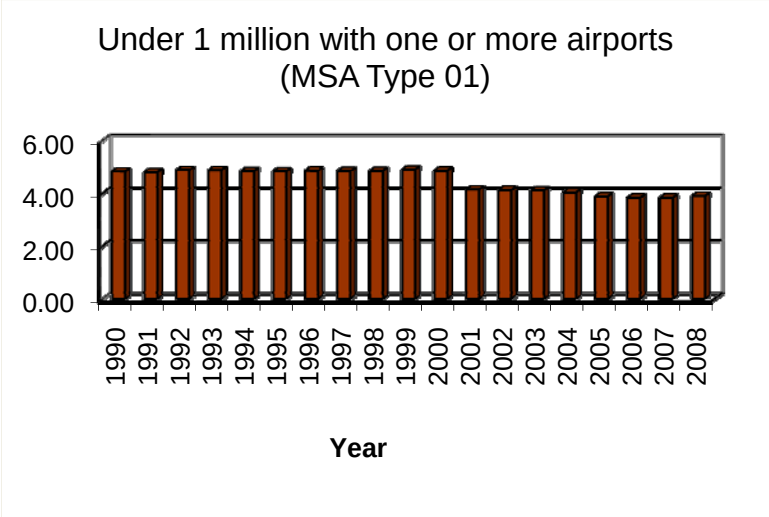
The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.

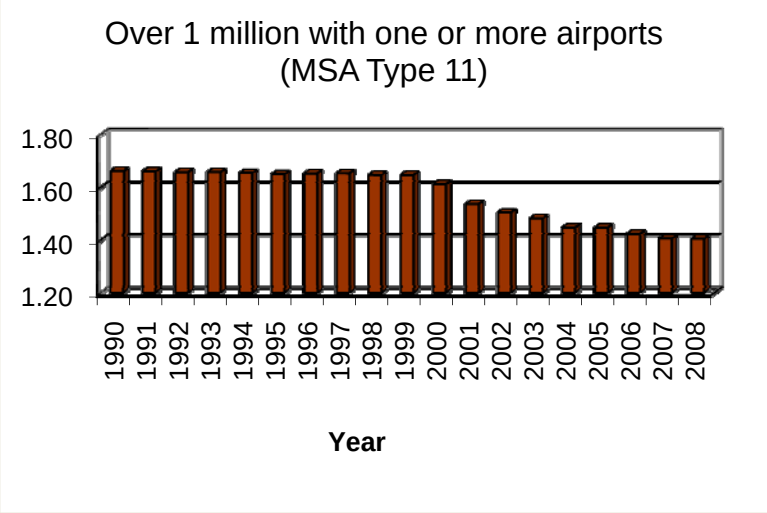
Primary data sources:	Aviation System Performance Metrics (ASPM) (http://aspm.faa.gov/aspm/entryASPM.asp) of the Federal Aviation Administration (FAA)
Data issues & opportunities	The ASPM data are available only for carriers at 75 ASPM airports started from 2000. It is assumed that the indicator keeps constant from 1990 to 2000 using the 2000 data.

Indicator #5	**Rail Density**
Definition:	Track Miles per 10,000 Population 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, which has a unique importance to U.S. competitiveness in the world economy, and the impact that forced access could have on U.S. export/import capabilities.
Criteria metric:	Supply
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.055* *MSA type 01 (population under 1 million with primary airport(s)) – 0.052* *MSA type 11 (population over 1 million with primary airport(s)) – 0.047* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transportation Atlas Database (NTAD) (http://www.bts.gov/publications/national_transportation_atlas_database/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	(1) The NTAD data are available on CD from Bureau of Transportation Statistics (BTS) since 1996. It is assumed that the indicator keeps constant from 1990 to 1996 using the 1997 data. (2) The data are obtained only for Class I railroads. However, from 1996 to 2000, functional class data were missing in the data sets. Adjustments are made based on the portion of Class I railroads in the total system in 2001.
Observations: • From 1990 to 2008, rail density keeps decreasing.	

Historical Values:

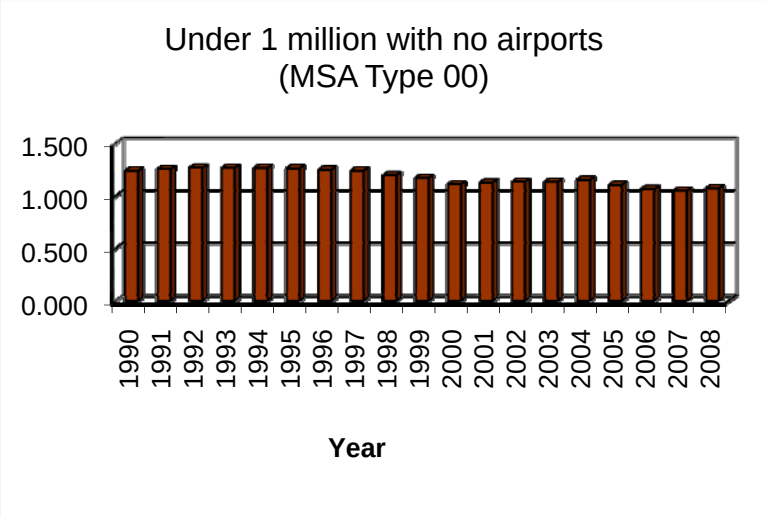


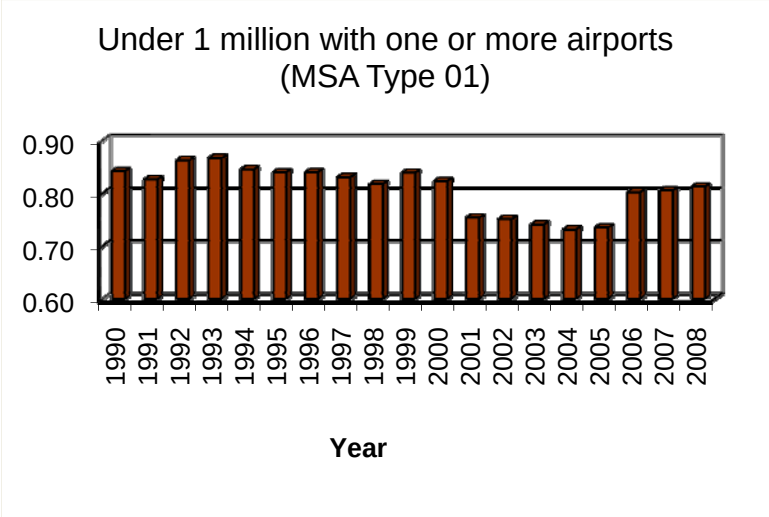


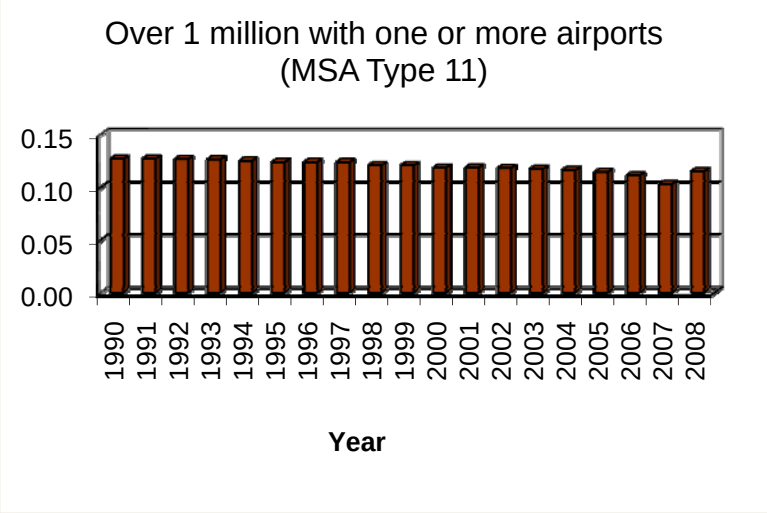


Indicator #6	**Waterway Density**
Definition:	Miles of Waterways per 10,000 population
Why it's important:	The waterway density indicates the supply of waterway services.
Criteria metric:	Supply
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.017* *MSA type 01 (population under 1 million with primary airport(s)) – 0.016* *MSA type 11 (population over 1 million with primary airport(s)) – 0.015* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transportation Atlas Database (NTAD) (http://www.bts.gov/publications/national_transportation_atlas_database/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	The NTAD data are available on CD from Bureau of Transportation Statistics (BTS) since 1996. It is assumed that the indicator keeps constant from 1990 to 1996 using the 1997 data.
Observations: • Miles of inland waterway remained fairly constant from 1990 to 2008, with a slight decrease.	

Historical Values:

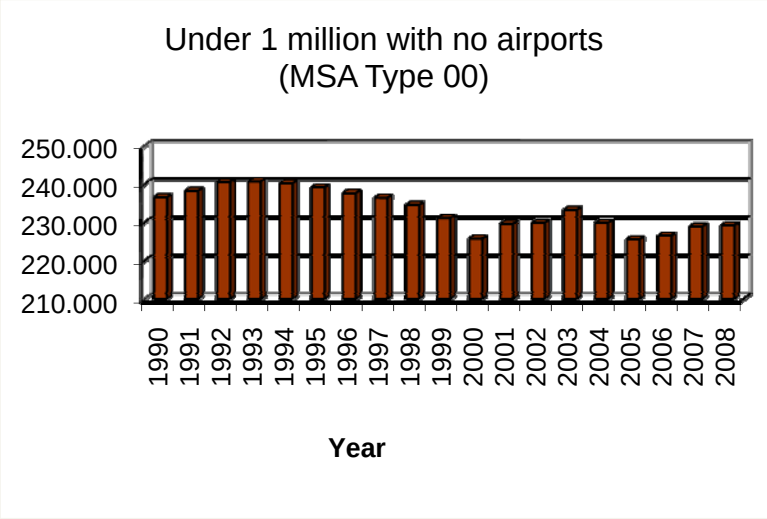


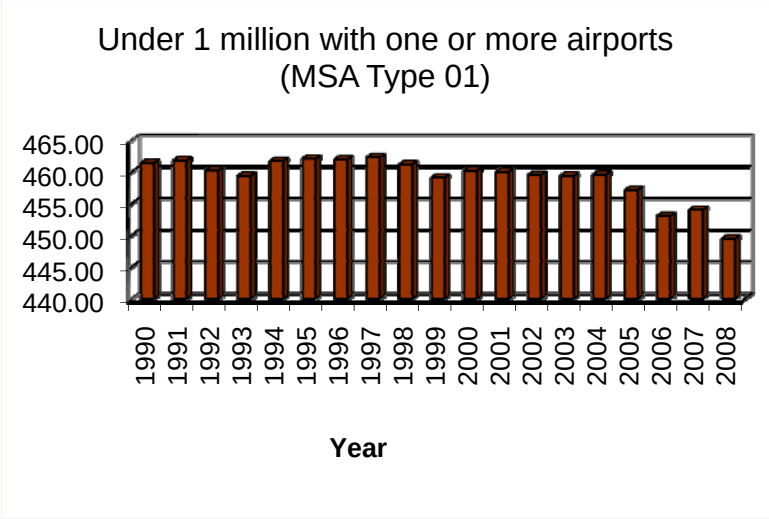


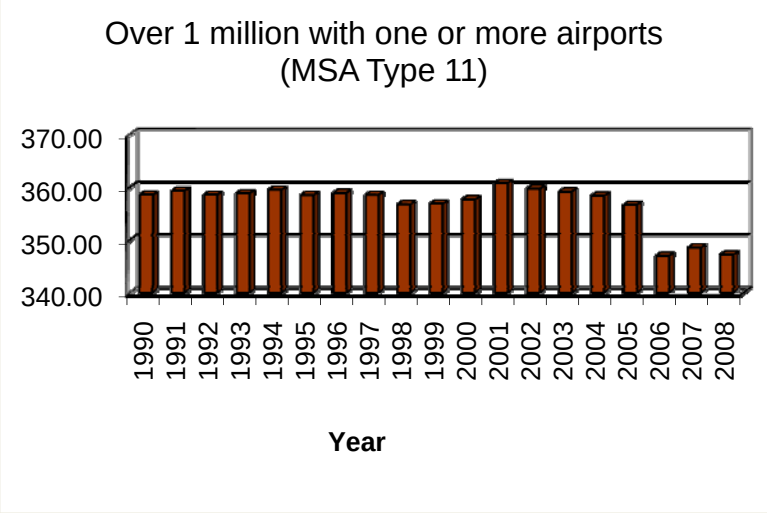


Indicator #7	**Port Access**
Definition:	Distance from the Center of MSA to the Closest International Container Port
Why it's important:	Port access indicates the accessibility of port services within the statistical area.
Criteria metric:	Supply
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.038* *MSA type 01 (population under 1 million with primary airport(s)) – 0.036* *MSA type 11 (population over 1 million with primary airport(s)) – 0.033* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transportation Atlas Database (NTAD) (http://www.bts.gov/publications/national_transportation_atlas_database/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	The NTAD data are available on CD from Bureau of Transportation Statistics (BTS) since 1996. It is assumed that the indicator keeps constant from 1990 to 1996 using the 1997 data.
Observations: • The distance from the center of a MSA to international ports has slightly decreased from 1990 to 2008.	

Historical Values:

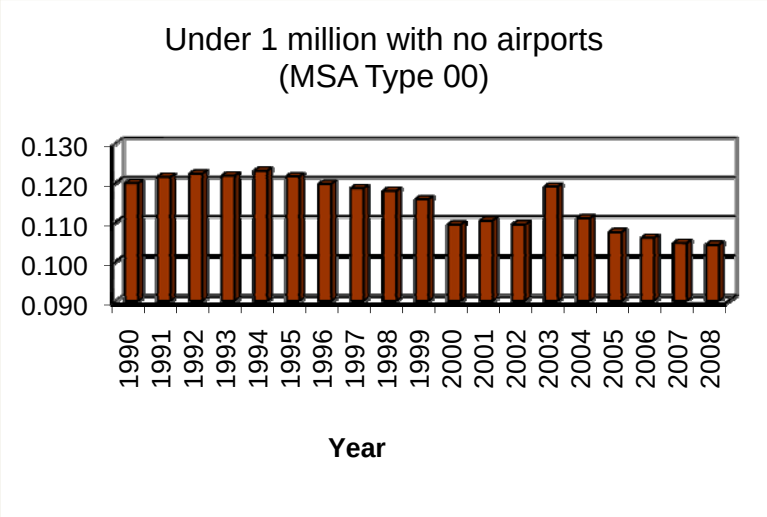


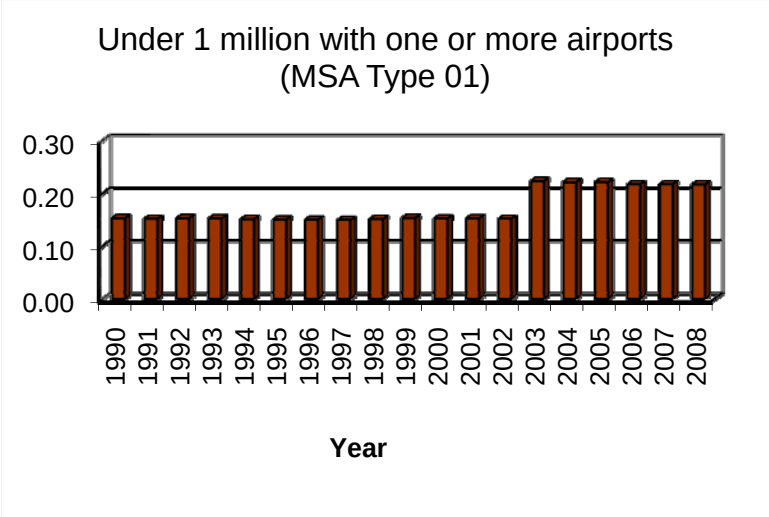


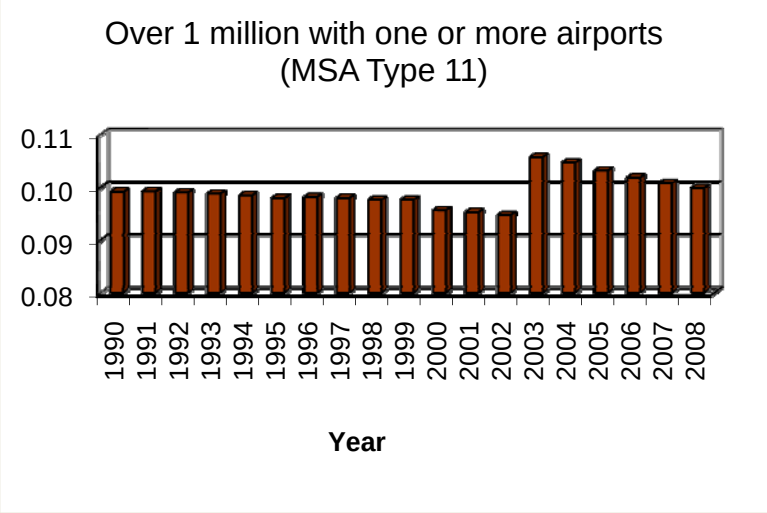


Indicator #8	**Intermodal Connectivity**
Definition:	Number of Ramps per 10, 000 Population
Why it's important:	Intermodal transport refers to the shipment of goods that involves two or more modes of transport in a single journey. The best attributes of each mode of transport are combined in a system that yields the lowest cost of transportation for the supply chain. Efficiency is the prime rationale for intermodal transport, but accessibility is a further reason for using two or more modes of transport.
Criteria metric:	Supply
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.052* *MSA type 01 (population under 1 million with primary airport(s)) – 0.049* *MSA type 11 (population over 1 million with primary airport(s)) – 0.045* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transportation Atlas Database (NTAD) (http://www.bts.gov/publications/national_transportation_atlas_database/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	(1) The NTAD data are available on CD from Bureau of Transportation Statistics (BTS) since 1996. It is assumed that the indicator keeps constant from 1990 to 1996 using the 1997 data. (2) The definitions for intermodal facilities keep changing. From 1996 to 1998, the data are stored in "TOFC/COFC" (Trailer on Flat Car/Container on Flat Car transfer facilities which contain auto loading facilities) and "Autoramps" (Highway/rail transfer facilities which contain auto loading facilities). From 1999 to 2002, they are called "Terminals," while after 2003 they changed to "Facilities."
Observations: • More intermodal facilities have been used from 1990 to 2008 for MSA type 01 and 11, while for MSA type 00 the number of intermodal facilities per capita decreases from 1990 to 2008.	

Historical Values:

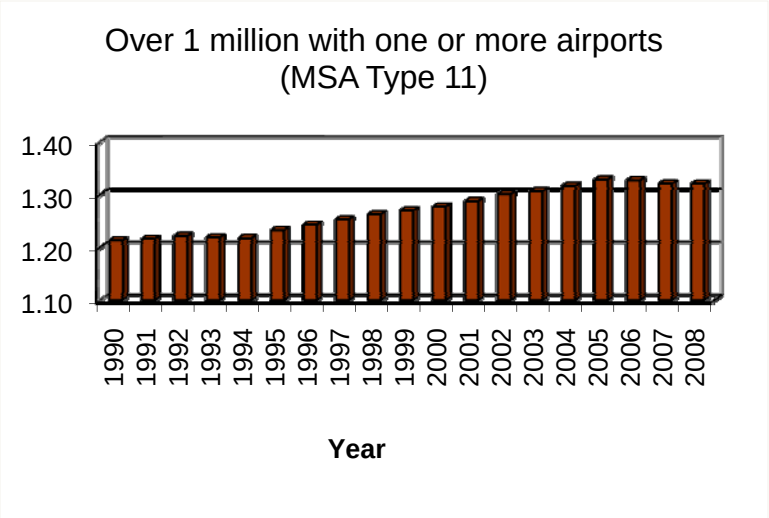






Indicator #9	**Highway Congestion**
Definition:	The travel time reliability is measured by the Travel Time Index (TTI) which is the ratio of peak period travel time to free flow travel time.
Why it's important:	The TTI expresses the average amount of extra time it takes to travel during peak hours relative 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.
Criteria metric:	Quality of Service

Historical Values:



Observations:

- Congestion problems tended to be more severe from 1990 to 2007 in large urban areas. The average increase in the travel time was about 10% during this period.
- As economy goes down, travel time indices slightly decrease in 2006 and 2007, probably due to less traffic on the highways.

Contribution to Index:

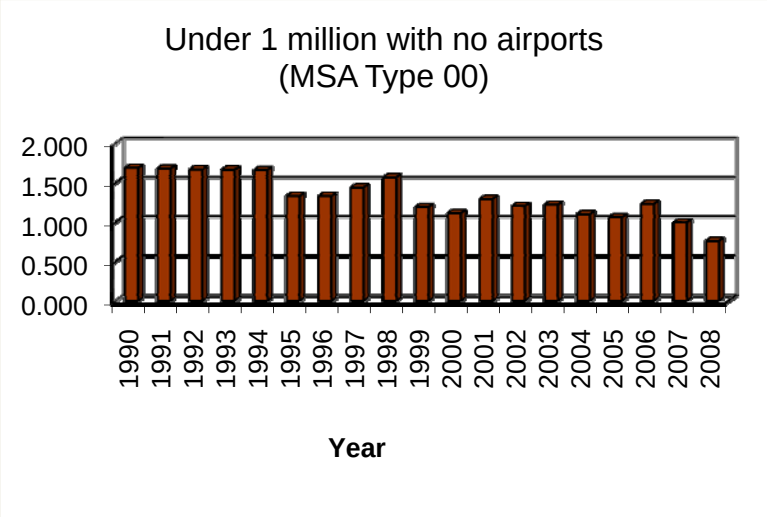
MSA type 00 (population under 1 million without primary airport) – 0.000
MSA type 01 (population under 1 million with primary airport(s)) – 0.000
MSA type 11 (population over 1 million with primary airport(s)) – 0.113

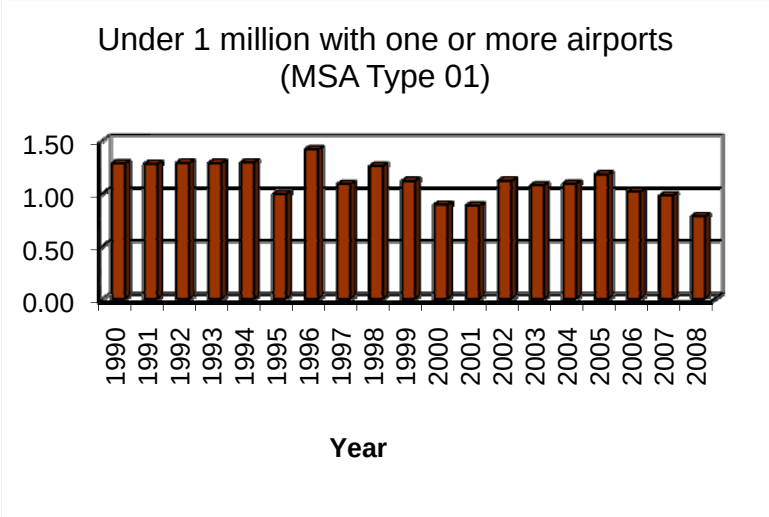
The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.

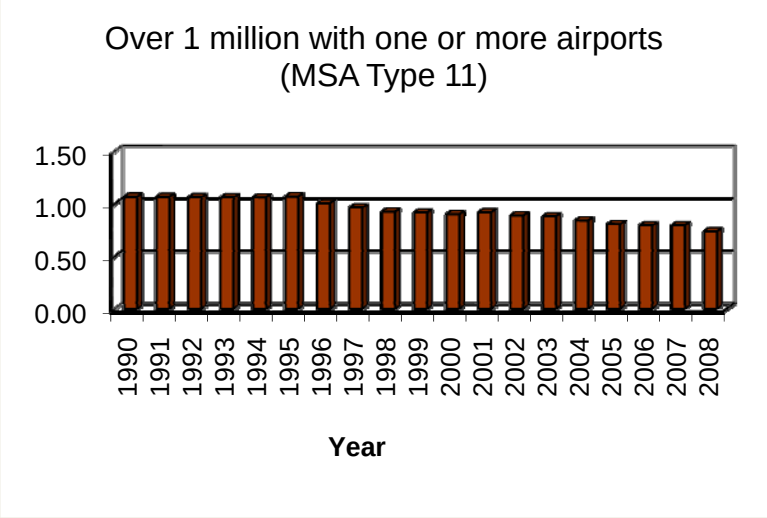
Primary data sources:	Texas Transportation Institute, The Annual Urban Mobility Report, available at http://mobility.tamu.edu, currently available from 1982 to 2007.
Data issues & opportunities	Detailed data are available only for most urbanized areas over 1 million population based on the availability of data provided.

Indicator #10	**Highway 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
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.112* *MSA type 01 (population under 1 million with primary airport(s)) – 0.089* *MSA type 11 (population over 1 million with primary airport(s)) – 0.068* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	The number of fatalities data are from the Fatality Analysis Reporting System (FARS) (http://www-fars.nhtsa.dot.gov/Main/index.aspx). VMT data are obtained from the Highway Performance Monitoring System (HPMS) data.
Data issues & opportunities	The fatality data are available from 1994 to 2008. It is assumed that the indicator keeps constant from 1990 to 1994 using the 1994 data.
Observations: • The number of deaths due to motor vehicle crashes keeps dropping from 1990 to 2008.	

Historical Values:

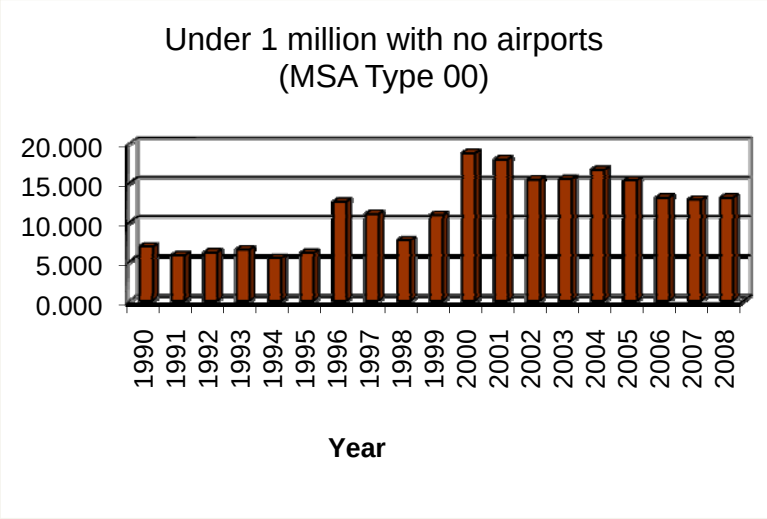


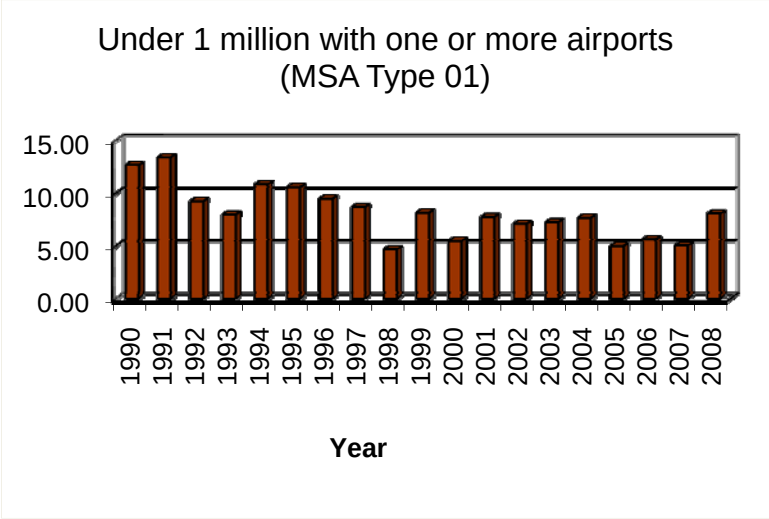


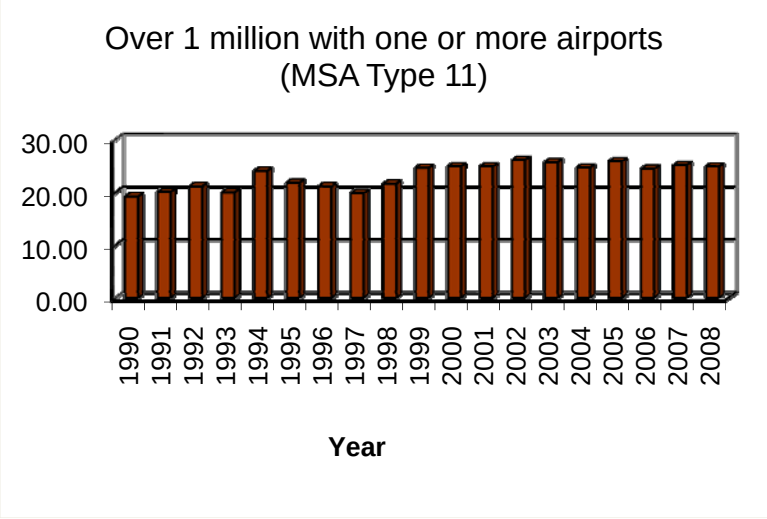


Indicator #11	**Road Roughness**
Definition:	Road roughness is measured by the percentage of lane miles that have IRI roughness values greater than 170 in/mi.
Why it's important:	International Roughness Index (IRI) is a dimensionless quantity used for measuring road roughness (ride quality) and proposed as a world standard by the World Bank.
Criteria metric:	Quality of Service
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.043* *MSA type 01 (population under 1 million with primary airport(s)) – 0.034* *MSA type 11 (population over 1 million with primary airport(s)) – 0.026* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	The IRI data are obtained from the Highway Performance Monitoring System (HPMS) data. The threshold for "Acceptable" ride quality used is set as 170 in/mi.
Data issues & opportunities	FHWA needs either an IRI or a PSR value coded for every sample section. On sample sections where IRI is not available, a PSR value smaller than 2.5 is used for the indicator.
Observations: • Road condition tends to deteriorate for MSA type 00 and 11, while there is no consistent trend for MSA type 01.	

Historical Values:

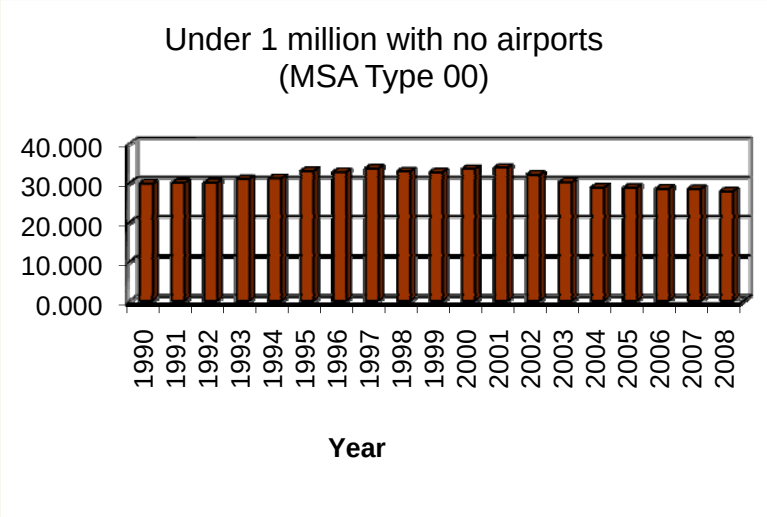


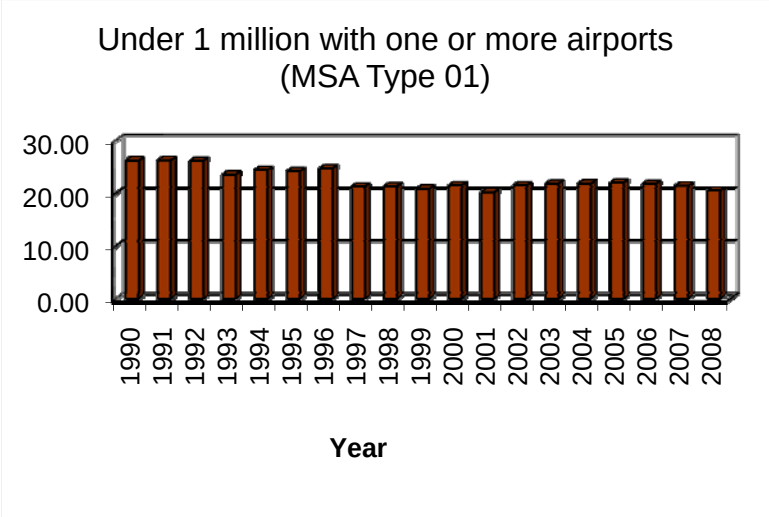


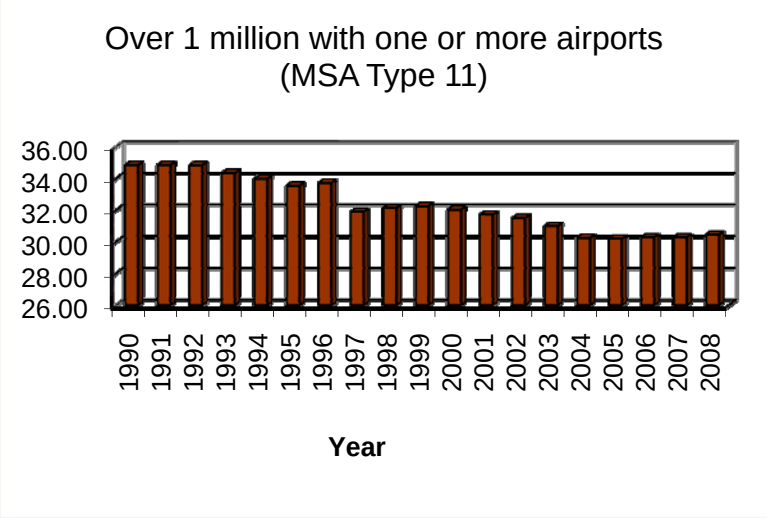


Indicator #12	**Bridge Integrity**
Definition:	Bridge integrity is measured by the percent of bridges (out of total) which are functionally obsolete or structurally deficient.
Why it's important:	Structurally deficient means there are elements of the bridge that need to be monitored and/or repaired. 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
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.121* *MSA type 01 (population under 1 million with primary airport(s)) – 0.096* *MSA type 11 (population over 1 million with primary airport(s)) – 0.073* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Bridge Inventory (NBI) from Federal Highway Administration (FHWA).
Data issues & opportunities	The NBI data are available from 1992. It is assumed that the indicator keeps constant from 1990 to 1992.
Observations: • The percentage of deficient bridges has been declining from 1990 to 2008.	

Historical Values:

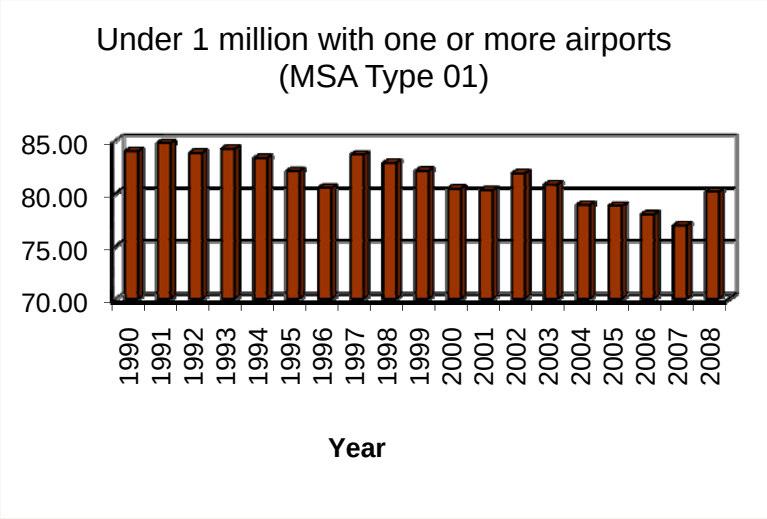


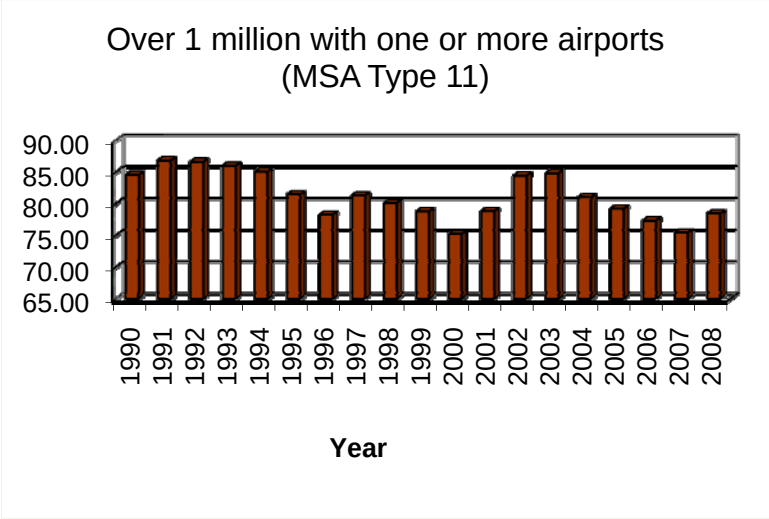




Indicator #13	**Air Congestion**
Definition:	Percent of On-Time Departures
Why it's important:	Air Passenger Congestion indicates the utilization of the airport facility and congestion that may be occurring at an airport facility that is in high demand.
Criteria metric:	Quality of Service
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.000* *MSA type 01 (population under 1 million with primary airport(s)) – 0.029* *MSA type 11 (population over 1 million with primary airport(s)) – 0.022* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	The data is obtained from the Office of Airline Information, Bureau of Transportation Statistics (BTS) (http://www.transtats.bts.gov/OT_Delay/OT_DelayCause1.asp).
Data issues & opportunities	Flights are on-time if they depart from the gate or arrive at the gate less than 15 minutes after their scheduled departure or arrival times.
Observations: • The general trend of air on-time performance has declined, with exceptions in some specific years.	

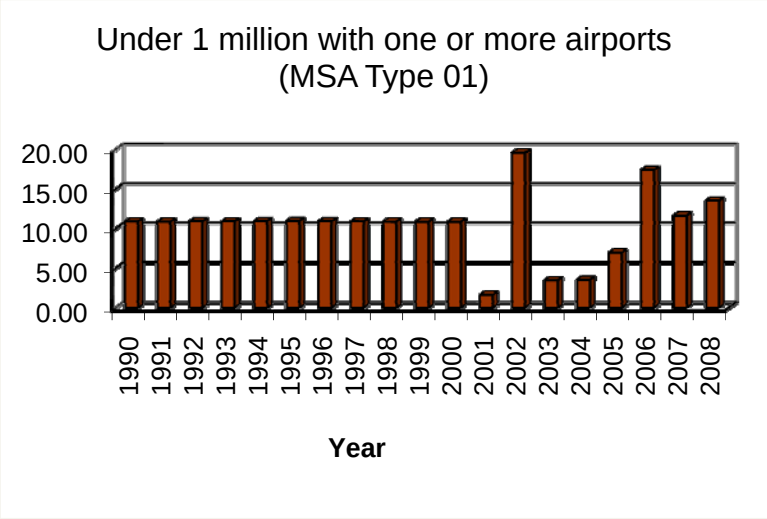
Historical Values:

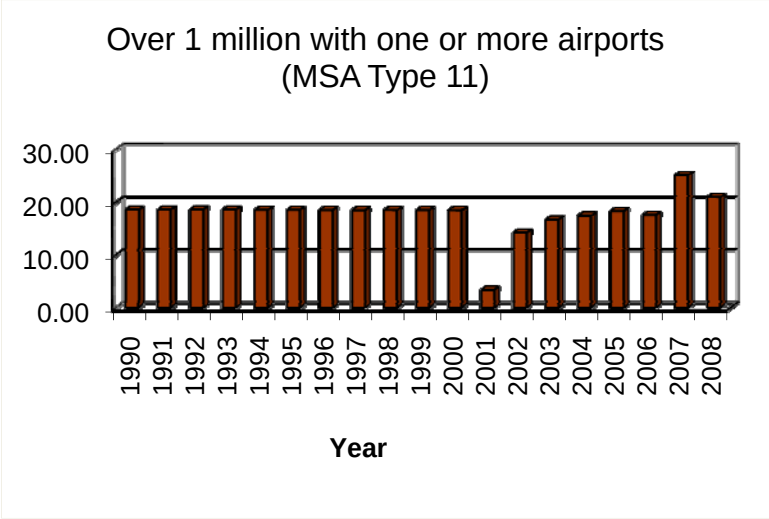




Indicator #14	**Air Safety**
Definition:	Runway Incursions per Million Operations
Why it's important:	A runway incursion occurs any time an airplane, vehicle, person or object on the ground creates a collision hazard with an airplane that is taking off or landing at an airport under the supervision of Air Traffic Control (ATC).
Criteria metric:	Quality of Service
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.000* *MSA type 01 (population under 1 million with primary airport(s)) – 0.067* *MSA type 11 (population over 1 million with primary airport(s)) – 0.051* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	Runway Safety Office Runway Incursion Database (http://www.asias.faa.gov/portal/page/portal/ASIAS_PAGES/ASIAS_HOME/WELCOME_TAB) maintained by the FAA Office of Runway Safety; # of operations are obtained from the Terminal Area Forecast (TAF) (http://aspm.faa.gov/main/taf.asp) system from FAA.
Data issues & opportunities	The runway incursion data are available after 2001. The average values from 2001 to 2008 are used to represent those for 1990 to 2000.
Observations: • Air safety varies significantly from year to year. • In 2001, very few incursions have been observed because of the significant decrease of operations.	

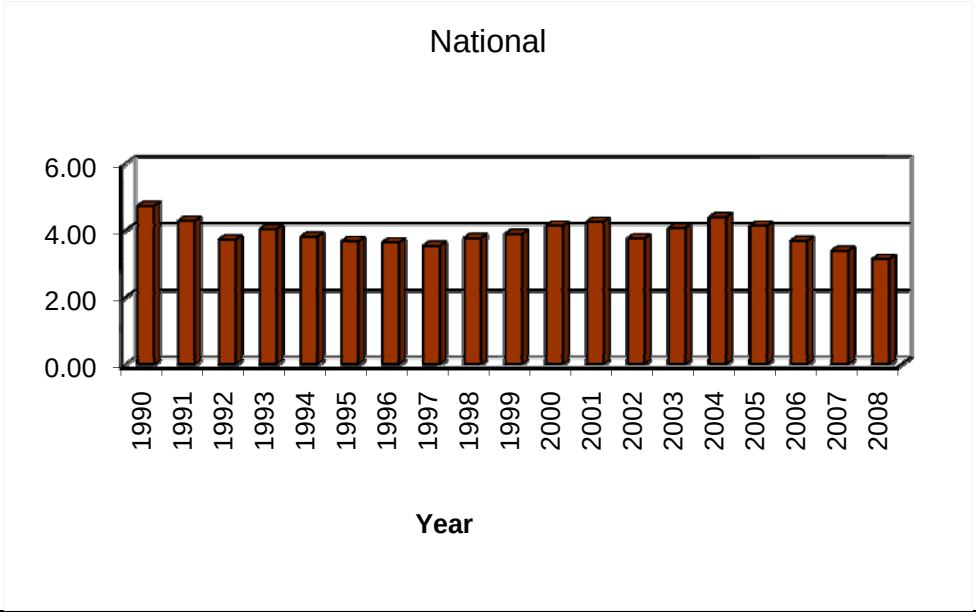
Historical Values:





Indicator #15	**Rail Safety**
Definition:	Number of Incidents per Million Train Miles
Why it's important:	The "Highest Priority of the Federal Railroad Administration is the Safety of the U.S. railroad system."
Criteria metric:	Quality of Service

Historical Values:



Observations:

- Rail safety tends to decrease in the middle 1990s, slightly increase until 2004, and then decrease.

Contribution to Index:

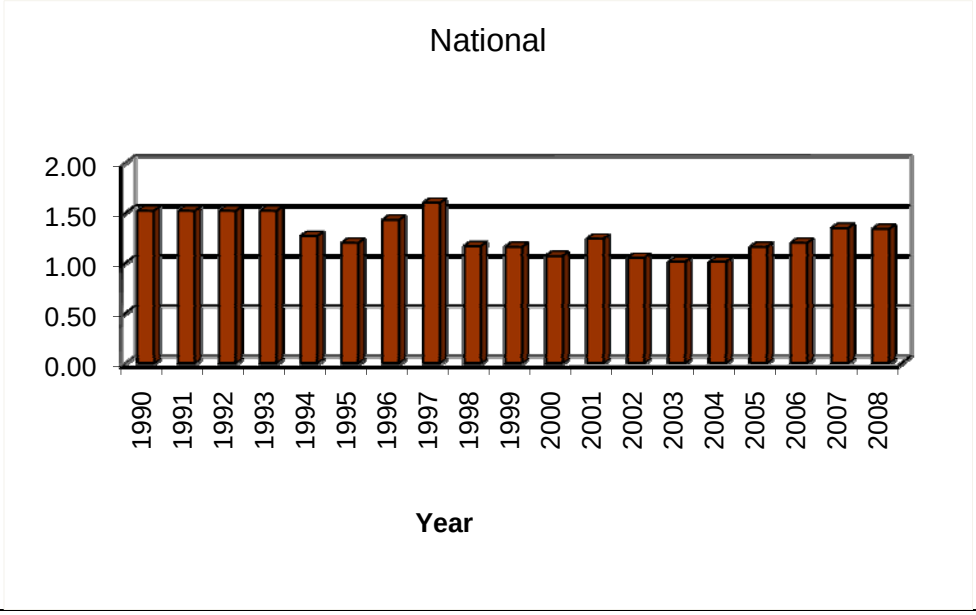
MSA type 00 (population under 1 million without primary airport) – 0.059
MSA type 01 (population under 1 million with primary airport(s)) – 0.047
MSA type 11 (population over 1 million with primary airport(s)) – 0.036

The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.

Primary data sources:	National Transportation Statistics (http://www.bts.gov/publications/national_transportation_statistics/).
Data issues & opportunities	Only national data are available for this indicator.

Indicator #16	**Waterway Congestion**
Definition:	Average Lock Delay per Tow (Hrs)
Why it's important:	Barge traffic congestion on U.S. inland waterways occurs primarily at locks, which has a big impact on barge transportation rates as well as other costs associated with the predetermined lock chokepoints.
Criteria metric:	Quality of Service

Historical Values:



Observations:

- Waterway congestion varies from year to year without a clear trend.

Contribution to Index:

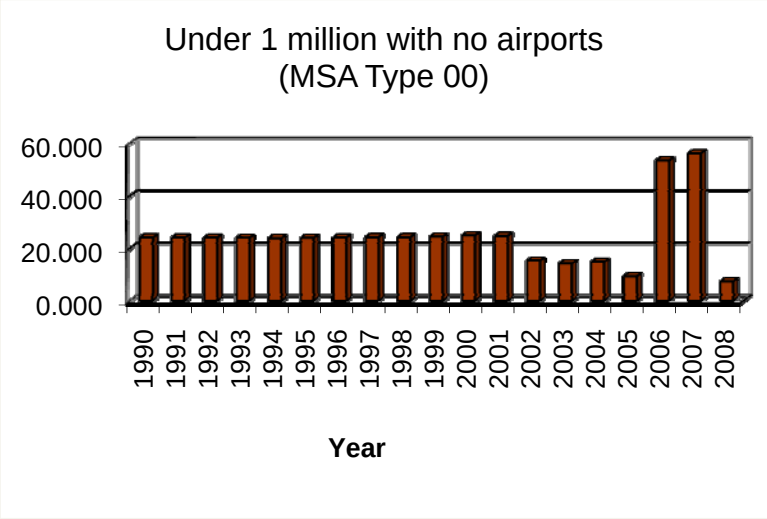
MSA type 00 (population under 1 million without primary airport) – 0.033
MSA type 01 (population under 1 million with primary airport(s)) – 0.026
MSA type 11 (population over 1 million with primary airport(s)) – 0.020

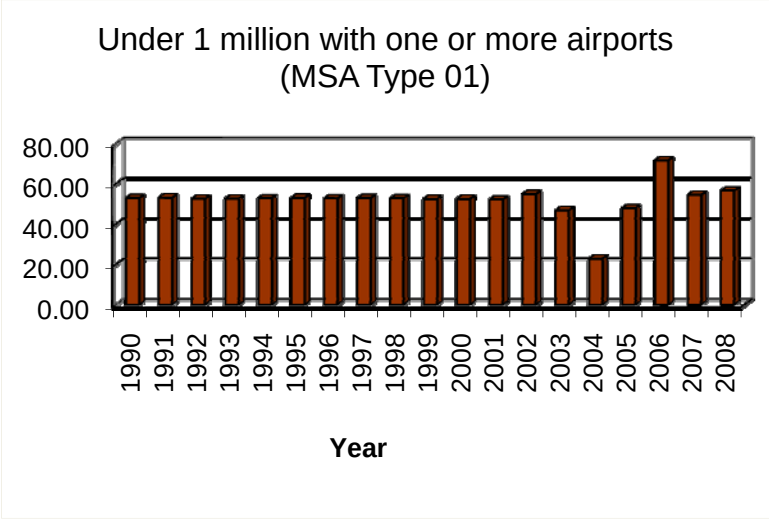
The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.

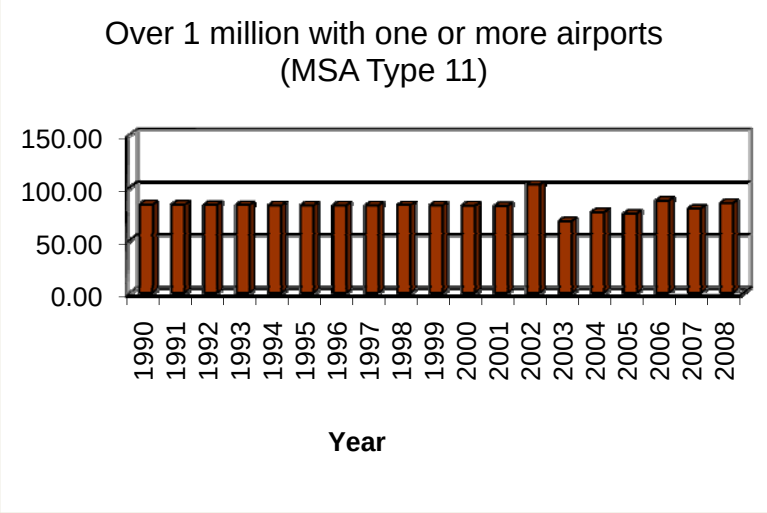
Primary data sources:	The Lock Performance Monitoring System (LPMS) and Lock Characteristics database (http://www.ndc.iwr.usace.army.mil/lpms/lpms.htm) maintained by the U.S Army Corps of Engineers.
Data issues & opportunities	Only national data are available for this indicator.

Indicator #17	**Transit Safety**
Definition:	Number of Incidents per 100 Million PMT
Why it's important:	A situation, such as a fire, the presence of smoke, fuel leak, electrical or other hazard, crashes, that constitutes an imminent danger to passengers, employees, contractors, or other persons.
Criteria metric:	Quality of Service
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.102* *MSA type 01 (population under 1 million with primary airport(s)) – 0.082* *MSA type 11 (population over 1 million with primary airport(s)) – 0.062* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transit Database (NTD) (http://www.ntdprogram.gov/ntdprogram/).
Data issues & opportunities	The NTD safety data are available from Federal Transit Administration since 2002. It is assumed that the indicator takes the average value of the available data from 1990 to 2001.
Observations: • Transit safety varies from year to year.	

Historical Values:

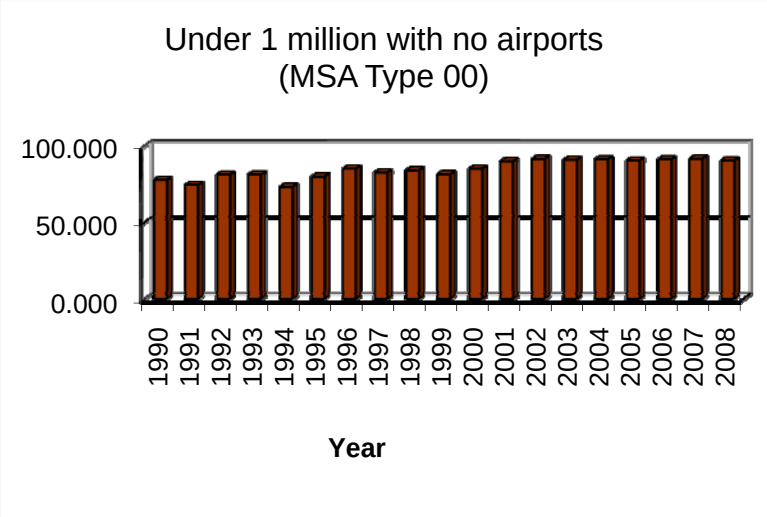


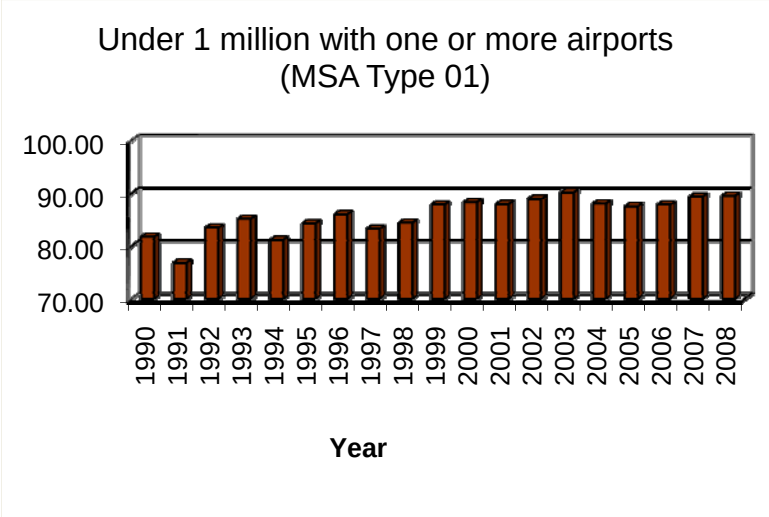


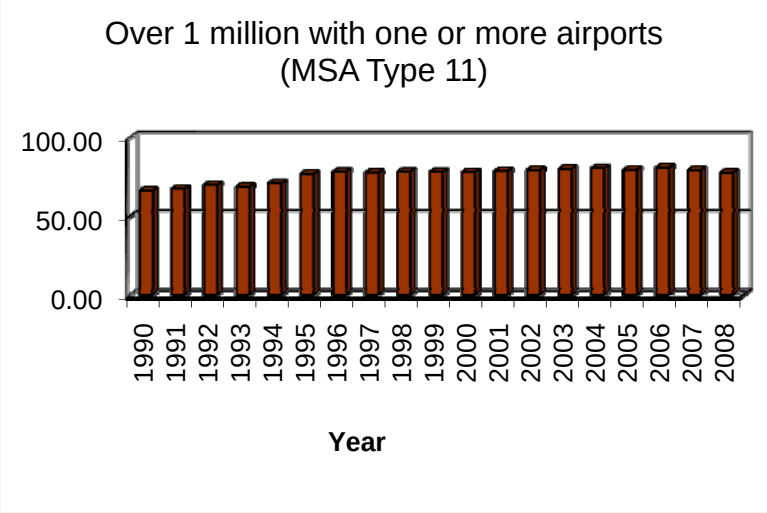


Indicator #18	**Uncongested Roads**
Definition:	Road congestion is measured by the percentage of lane miles with Level of Service (LOS) at C or better.
Why it's important:	The Highway Capacity Manual (HCM) and AASHTO Geometric Design of Highways and Streets ("Green Book") classify the transportation 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.
Criteria metric:	Utilization
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.132* *MSA type 01 (population under 1 million with primary airport(s)) – 0.132* *MSA type 11 (population over 1 million with primary airport(s)) – 0.117* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	Highway Performance Monitoring System (HPMS) data.
Data issues & opportunities	A level of 0.80 of Volume-to-service flow (V/SF) ratio 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).
Observations: • Road congestion problem keeps improving in the 1990s, and remains a constant level after 2000.	

Historical Values:

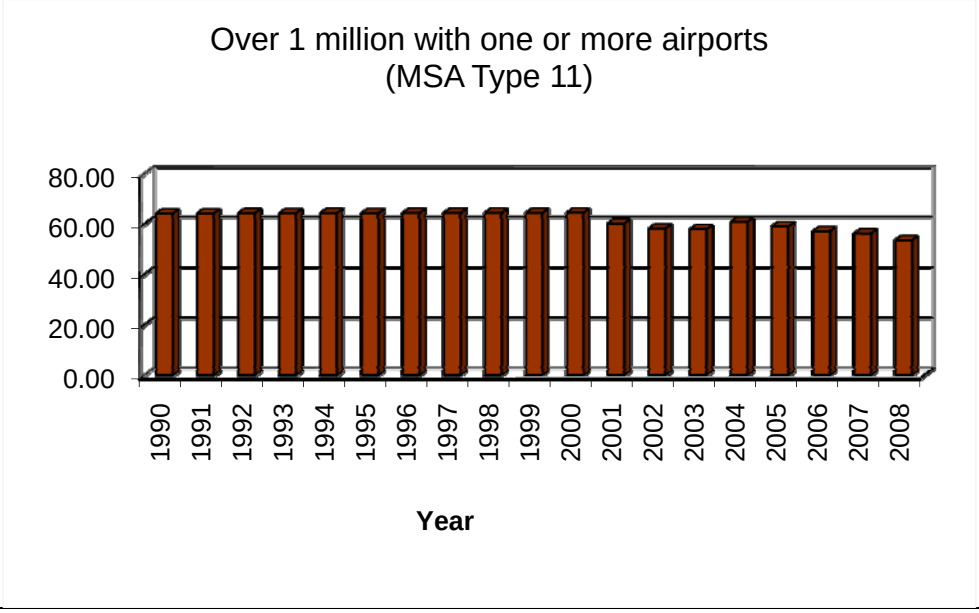






Indicator #19	Percent of Air Capacity Utilized
Definition:	Percent of Capacity Used between 7am and 9pm
Why it's important:	The indicator captures the potential future air capacity growth.
Criteria metric:	Utilization

Historical Values:



Observations:

- The utilization of air capacity is decreasing, probably is due to the airport capacity expansion, as shown in Indicator 4.

Contribution to Index:

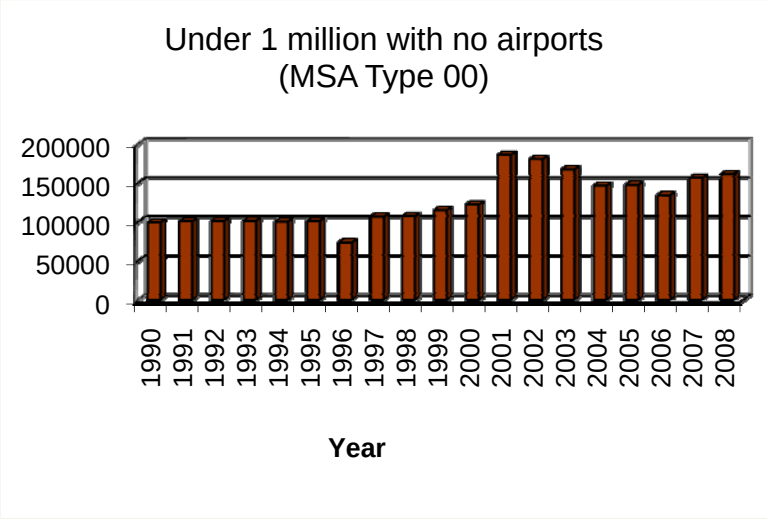
MSA type 00 (population under 1 million without primary airport) – 0.000
MSA type 01 (population under 1 million with primary airport(s)) – 0.000
MSA type 11 (population over 1 million with primary airport(s)) – 0.024

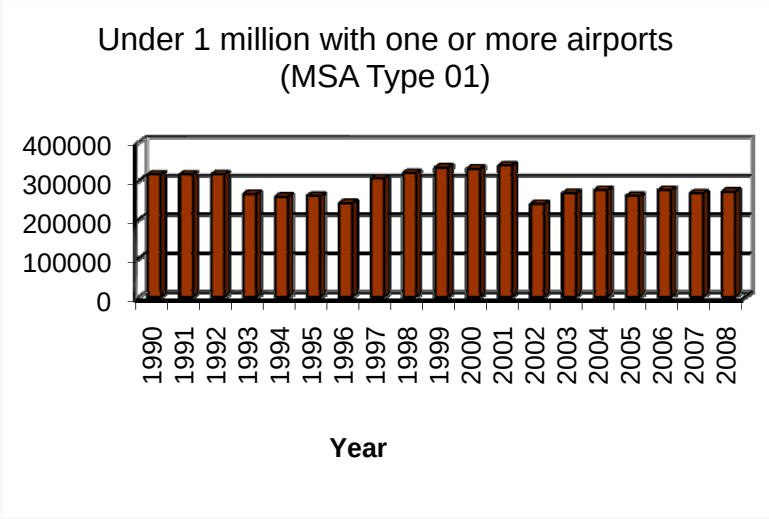
The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.

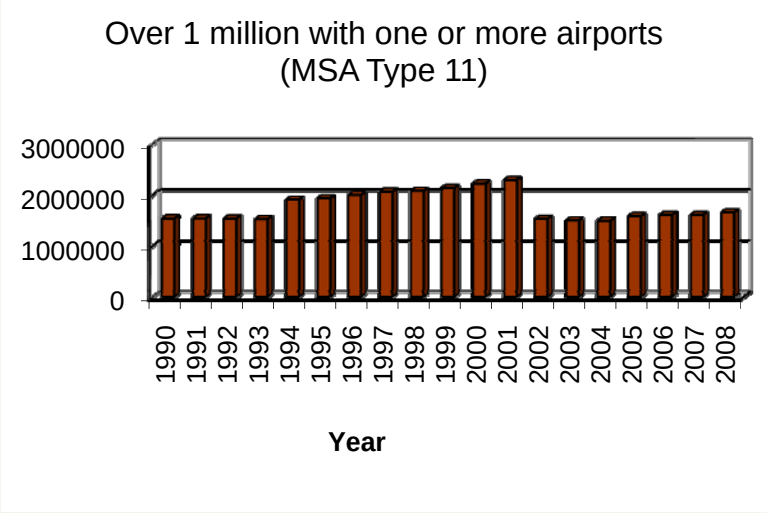
Primary data sources:	Aviation System Performance Metrics (ASPM) (http://aspm.faa.gov/aspm/entryASPM.asp) of the Federal Aviation Administration (FAA)
Data issues & opportunities	The ASPM data are available only for carriers at 75 ASPM airports started from 2000. It is assumed that the indicator keeps constant from 1990 to 2000 using the 2000 data.

Indicator #20	**Transit Utilization**
Definition:	Passenger Miles Traveled (PMT) per Capacity (Standing + Seating)
Why it's important:	The indicator captures the utilization of public transit, cumulative sum of the distances ridden by each passenger, comparing the capacity provided.
Criteria metric:	Utilization
Contribution to Index: *MSA type 00 (population under 1 million without primary airport) – 0.044* *MSA type 01 (population under 1 million with primary airport(s)) – 0.044* *MSA type 11 (population over 1 million with primary airport(s)) – 0.039* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transit Database (NTD) (http://www.ntdprogram.gov/ntdprogram/).
Data issues & opportunities	The NTD utilization data are available from Federal Transit Administration since 1992. It is assumed that the indicator keeps constant from 1990 to 1992.
Observations: • The utilization of transit was increasing until it reached its peak around 2001. Since then, it started to decrease.	

Historical Values:

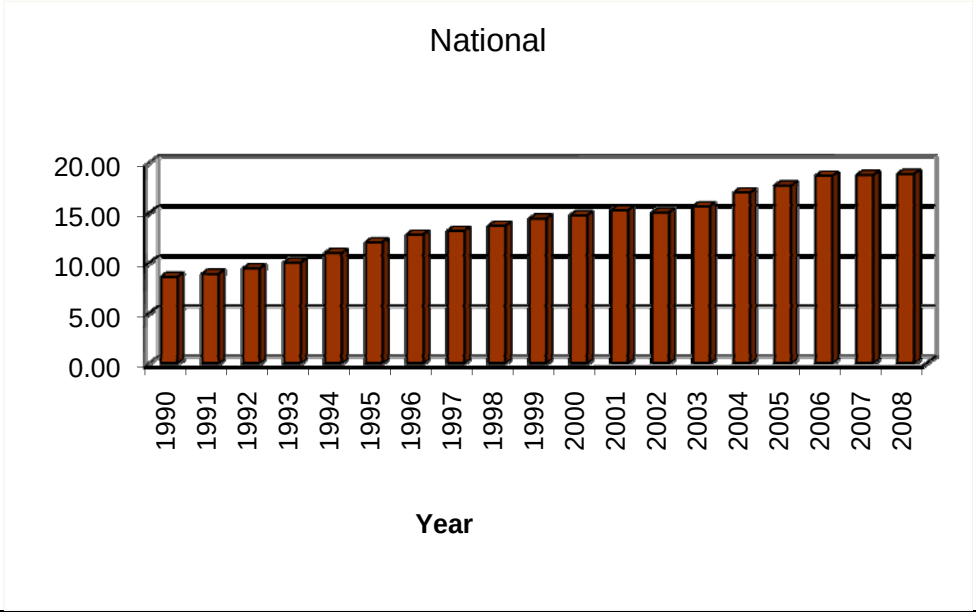






Indicator #21	**Rail Usage for Freight**
Definition:	Million Ton Miles of Freight per Track Miles
Why it's important:	Freight railroads play an important role in the United States' economy. They connect businesses with each other across the country and with markets overseas.
Criteria metric:	Utilization

Historical Values:



Observations:

- Rail utilization in freight movement keeps rising from 1990 to 2008.

Contribution to Index:

MSA type 00 (population under 1 million without primary airport) – 0.042
MSA type 01 (population under 1 million with primary airport(s)) – 0.042
MSA type 11 (population over 1 million with primary airport(s)) – 0.037

The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.

Primary data sources:	National Transportation Statistics (http://www.bts.gov/publications/national_transportation_statistics/).
Data issues & opportunities	Only national data are available for this indicator.

Public Data Sources for Transportation Indicators

Highway

National Highway Planning Network (NHPN): The NHPN is a geospatial data set for planning that is consistent with other data sets 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 major purpose of the HPMS is to support a data driven decision process within FHWA, the DOT, and the Congress. The HPMS data are used extensively in the analysis of highway system condition, performance, and investment needs that make up the biennial Condition and Performance Reports to Congress. These Reports are used by the Congress in establishing both authorization and appropriation legislation, activities that ultimately determine the scope and size of the Federal-aid Highway Program, and determine the level of Federal highway taxation.

The Highway Performance Monitoring System (HPMS) is to provide data that reflect the extent, condition, performance, use, and operating characteristics of U.S. highways. In general, the HPMS contains administrative and extent of system information on all public roads, while information on other characteristics is represented in HPMS as a mix of universe and sample data for arterial and collector functional systems. Limited information on travel and paved miles is included in summary form for the lowest functional systems.

National Bridge Inventory (NBI): The NBI is a collection of information (database) covering just under 600,000 of the Nation's bridges located on public roads, including Interstate Highways, U.S. highways, State and county roads, as well as publicly-accessible bridges on Federal lands. It presents a State by State summary analysis of the number, location, bridge types and specifications, operational conditions, bridge data including geometric data and functional description, inspection data, etc., of highway bridges within each State. The data are often used to analyze bridges and judge their conditions.

Fatality Analysis Reporting System (FARS): The Fatality Analysis Reporting System (FARS) was created by the National Highway Traffic Safety Administration (NHTSA) in 1975. The FARS database contains information on all fatal motor vehicle crashes in the United States. Data on fatal motor vehicle traffic crashes are gathered from each state's source documents and are coded on standard FARS forms. FARS data are usually available around Memorial Day. (U.S. Department of Transportation, 2010)

Highway Congestion (Urban Mobility Study): The Urban Mobility Study, developed by the Texas Transportation Institute, uses statistics from available traffic data in 68 urban areas across the United States to provide information on trends in levels of mobility and congestion. Available data series include 1) driver-hours of delay per year, 2) traffic rate index, 3) wasted fuel per year, and 4) congestion cost per year. The areas included were chosen based on which state DOTs were able to provide necessary information.

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 (Oak Ridge National Laboratory, 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

Aviation

Aviation System Performance Metrics (ASPM): The ASPM online access system provides detailed data on IFR flights to and from only the ASPM airports (select airports tracked in ASPM, currently 77); and all flights by only the ASPM carriers (select carriers tracked in ASPM, currently 22). ASPM also includes airport weather, runway configuration, and airport arrival and departure rates (AAR/ADR).

ASPM flight records fall into two groupings: Efficiency Counts and Metrics Counts. ASPM Efficiency Counts include the full set of ASPM records, including those that are missing one or more pieces of key data. In contrast, ASPM Metrics Counts include only complete records and records for which accurate estimates are possible for the few pieces of missing data. Metrics Counts exclude most General Aviation and Military flights, as well as records for international flights that include only data associated with the arrival or departure to/from the U.S. airport. Flight cancellations and diversions are excluded from both Efficiency and Metrics Counts.

Data are available from January 2000 to present for 55 airports. Data for additional 22 airports are available from October 2004 to present. Arrival/departure rates and runway configuration data are available from January 1, 2000 to present.

ASPM is not publicly available. A login is required and can be requested with a legitimate reason. Once a user has a login, he can access ASPM data through GUI or download raw data in DBF format.

ASPM data are used by the FAA for monitoring of airport efficiency and other aspects of system performance, retrospective trend analysis, and targeted studies.

Terminal Area Forecast (TAF) system: The Terminal Area Forecast (TAF) system is the official forecast of aviation activity at FAA facilities. The Internet interface also allows users to create summary reports and user-defined forecasts. These forecasts are prepared to meet the budget and planning needs of FAA and provide information for use by state, industry, and the public.

Airline On-Time Performance Data: This database contains scheduled and actual departure and arrival times reported by certified U.S. air carriers that account for at least one percent of domestic scheduled passenger revenues. The data are collected by the Office of Airline Information, Bureau of Transportation Statistics (BTS). The data are available from 1987 on a monthly basis. The On-Time Performance table contains on-time arrival data for non-stop domestic flights by major air carriers, and provides such additional items as departure and arrival delays, origin and destination airports, flight numbers, scheduled and actual departure and arrival times, cancelled or diverted flights, taxi-out and taxi-in times, air time, and non-stop distance.

Aviation Safety Information Analysis and Sharing (ASIAS) System: The Aviation Safety Information Analysis and Sharing (ASIAS) system has connected several dozens of safety databases across the industry and is integrated into the Commercial Aviation Safety Team (CAST) process. The aviation infrastructure performance related databases in ASIAS include:

- **FAA Accident /Incident Data System (AIDS)**: contains data records for general aviation and commercial air carrier incidents since 1978 using the National Transportation Safety Board (NTSB) accident database as the primary source for accident information. The information contained in AIDS is gathered from several sources including incident reports on FAA Form 8020-5.
- **Aviation Safety Reporting System (ASRS)**: receives, processes, and analyzes reports of unsafe occurrences and hazardous situations that are voluntarily submitted by pilots, air traffic controllers, and others to identify hazards and safety discrepancies in the National Airspace System.
- **Bureau of Transportation Statistics (BTS)**: contains traffic and capacity statistics on individual Air Carrier operations.
- **Runway Safety Office Runway Incursion**: contains records of events involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take-off of aircraft.

The runway incursion database is maintained by the FAA Office of Runway Safety.

The FAA plans to increase the numbers and types of participants following a phased expansion plan to include other parts of the aviation community. ASIAS will include more regional aircraft, domestic corporate general aviation, military, helicopter, manufacturers, and other government agencies.

Transit

National Transit Database (NTD): The Federal Transit Administration (FTA) collects and disseminates data on the state of mass transportation in the U.S. through the National Transit Database (NTD) program. Over 600 of the nation's transportation providers submit data to the NTD program annually. All NTD reporting agencies serve at least one Urbanized Area (UZA) with many serving more than one UZA and non-UZAs (rural areas). The data collected consist of selected financial and operating data that generally describe mass transportation characteristics.

The Federal Transit Administration's (FTA's) annual Safety Management Information System (SAMIS) reports provide data on transit accidents, casualties, and criminal incidents. Data are reported under FTA's National Transit Database Reporting System. Available data series include 1) the number of fatalities and injuries by transit mode, and 2) the type of accident for passengers, non-passengers and employees.

The NTD data are available since 1996 and the safety data from 2002.

Rail

FRA Office of Safety Analysis: This site was established by the Federal Railroad Administration (FRA) for the purpose of making railroad safety information readily available to a broad constituency. The data include accidents and incidents, inspections and highway-rail crossing data. From this site users can run dynamic queries, download a variety of safety database files, publications and forms, and view current statistical information on railroad safety.

Railroad Performance Measures: Six major North American freight railroads have voluntarily reported three weekly performance measures — Cars On Line, Train Speed, and Terminal Dwell to the Railroad Performance Measures website since 1999. All six railroads use the same definitions to calculate their performance data, ensuring a high degree of consistency of the measurements. However, only 53 weeks of data are kept available through this website.

Marine

U.S. Army Corps of Engineers Navigation Data Center: This data center provides information on waterborne commerce, vessel characteristics, port facilities,

dredging, and lock performance. Data can be queried and are available by state, by commodity, and by waterway.

The Lock Performance Monitoring System (LPMS) is a part of the Inland Navigation Systems Analysis (INSA) program and encompasses the collection, editing, maintenance, and analysis of data collected at all Corps-owned and operated locks. The data have been collected since March of 1975 and consist of information describing the traffic through the locks as well as the physical aspects of lockages. Available data series include 1) number of vessels, tonnage, commodity transported by lock, district, and river and 2) commercial and non-commercial vessels. (U.S. Army Corps of Engineers, 1999)

The Port Facilities database contains the physical characteristics and infrastructure data for principal port facilities. The data consists of listings of port area's waterfront facilities, including information on berthing, cranes, transit sheds, grain elevators, marine repair plants, fleeting areas, and docking and storage facilities. However, the collection of data is performed on a rotational basis at each facility.

Waterborne Commerce of the U.S.: The Maritime Administration provides detailed summaries of domestic and international waterborne freight flows, commodity tonnage, ton miles, and freight traffic of U.S. commerce shipped aboard U.S.-flag and foreign vessels. Data are available by type of waterway (the Great Lakes, inland waterways, and coastal waters), foreign/domestic commerce, and type of vessel. Foreign commerce tonnage is available by state and region.

Others

National Transportation Atlas Database (NTAD): The National Transportation Atlas Database (NTAD) is a set of transportation-related geospatial data for the United States. The data consist of transportation networks, transportation facilities, and other spatial data used as geographic reference. The NTAD is a cooperative effort throughout the U.S. Department of Transportation and other Federal agencies. The Federal Highway Administration (FHWA), the Federal Railroad Administration (FRA), the U.S. Army Corps of Engineers (USACE), the U.S. Bureau of the Census, the National Park Service (NPS), the Federal Aviation Administration (FAA), the Federal Transit Administration (FTA), and the Bureau of Economic Analysis (BEA) supplied data for this project.

Transportation Networks are topologically connected line databases depicting the locations and centerline alignments of nationally significant roads, freight network, airport runways, railroads, waterways, airways, and transitways. Nodes associated with transportation networks may represent Airports, Fuel stations, Amtrak Stations Automatic Traffic Recorder junctions such as Highway-Rail Grade Crossings, Intermodal Terminal Facilities, Bridges, National Populated Places, water Port facilities, and Weigh in Motion Stations.

Background databases (geographic entities) are typically area databases depicting administrative or statistical boundaries such as states and counties, congressional districts or military bases. These area databases are used in conjunction with transportation networks and other facilities to provide a locational frame of reference or a base for demographic or environmental information. They are represented by polygon features.

National Transportation Statistics: Compiled and published by the U.S. Department of Transportation's Bureau of Transportation Statistics (BTS), National Transportation Statistics presents information on the U.S. transportation system, including its physical components, safety record, economic performance, energy use, and environmental impacts. National Transportation Statistics is a companion document to the Transportation Statistics Annual Report, and State Transportation Statistics, which presents state-level data on many of the same topics and data items.

TRANSTATS - The Intermodal Transportation Database: The U.S. Department of Transportation (DOT), Research and Innovative Technology Administration (RITA), Bureau of Transportation Statistics (BTS) offers the TranStats website for transportation researchers and analysts, aimed at providing "one stop shopping" for transportation data. TranStats has indexed its data with a transportation thesaurus with a searchable index of over 100 transportation-related databases. Not only does it cover all modes of transportation (rail, road, air, sea, space), but also all aspects. This includes economics (imports and exports, hourly earnings of transportation workers, jet fuel prices, major air carrier on-time performance), safety and security (fatalities, incidents, piracy, alien interdiction), volume (average international flight stage length, highway vehicle miles traveled, highway and street construction) and environment (pollutant emissions).

Users can explore the data by transportation mode or by subject area, use keyword searches to find relevant data sets, and get online help. By providing easy linkages across many data sets, the time needed for data gathering is reduced and more time is available for analysis. Ultimately, this should result in more timely and more informed decisions, and a better transportation system.

Evaluation of Indicators

The U.S. Chamber asked transportation industry experts to provide feedback on the indicators. Recognizing that the selected indicators are extremely limited by the availability of publicly available time series and data, and not necessarily representative of the performance of the transportation industry or the service perceived by the industry's customers, the feedback is very useful. The suggestions point us in the right direction for developing the next generation of the transportation index and making some modifications to the current indicators.

Specifically, the experts were asked:

1. Are the indicators defensible as a representation of the performance of the nation's transportation system?

2. Are there alternative indicators given the data requirements (based on publicly available data, available consistently from 1990-2007, connected to Metropolitan Statistical Areas)?

Suggested indicators are discussed in the following subsection. General feedback included the following comments. Where appropriate, responses are included in brackets:

- The Intermodal Connector Assessment Tool (available from FHWA in 2010) will provide a better measure of access to intermodal facilities. See http://www.i95coalition.org/i95/Home/tabid/36/Default.aspx. [ICAT looks like a useful tool. The tool will not give us historical data but may provide a useful indicator in the future. We will explore this tool when released.]
- Indicators are needed that capture access to ports and facilities that handle bulk and breakbulk. [We are open to suggestions.]
- Railroad supply
    - Railroad supply indicator does not capture the substantial long term increase in rail intermodal business, availability, or traffic density and so is not useful.
    - Do not quite understand the track miles per square mile as I do not know what it tells me. I would be more concerned about having rail be where it needs to be to support the economic competitiveness of the nation and the industries that generate that competitiveness.
    - [Rail - Supply: Track miles per 10,000 population is used as an *indicator* of the "presence" of railroad track – the amount of infrastructure. However, the reviewers are looking for something to "capture long term increases in … business…," which should go to the Utilization category. The fourth indicator can capture that. More importantly, we would like to find better measures of **infrastructure** supply and are open to suggestions.]
- Highway supply – Similar issues to railroad supply. Also, this measure does not capture connectivity. [Agreed, we are open to suggestions.]

- Revenue Ton-miles is the standard measure of average traffic density and track utilization in the railroad industry. [The correlation between Revenue Ton-miles per track mile of owned and Ton-miles per track mile of owned for the period 1990-2007 is 0.996. The question is which is the more appropriate measure for this study? Revenue Ton-miles is most relevant for the railroads but Ton-miles may be a better indicator of track availability and infrastructure performance. We can use either measure.]
- Carriers are gaming "percent on-time performance" so this may not be a suitable measure.
- Like Ton-miles per track mile for rail utilization, but could also see using Car-miles per track mile in that empty cars are part of utilization too Also Car-miles per car and train miles per locomotive are measures of equipment use and not just track. [Car-miles, train miles, and # locomotives are available in BTS data and should be explored.]
- The aviation indices don't include anything on air cargo. [Agreed, we are open to suggestions.]
- How do these (indicators) stack up compared to the work of BTS? [The indicators used for the Transportation Index are far more comprehensive than the Transportation Services Index. As they focus on infrastructure the direct comparison (presented in the Results chapter) is not possible.]
- Capturing meaningful data to quantify system performance is an activity that is starting to gain traction, better late than never, but what you have to pick from now -- with the exception of safety and infrastructure condition -- is pretty sparse. I would not want to see the metrics based on what we currently have as opposed to determining what the right measures are, seeing what we have that either gets us there or not, and then figuring out how we acquire the data we need to quantify the measures we've determined are appropriate (steps). [Agreed. We have attempted to do this in the larger report.]
- The metrics we use do not necessarily have to be uniform across the system. For example, on the major freight corridors I think travel time reliability is key, those corridors need to flow smoothly. However, off the corridors I do not know if that is the right metric (forgetting for a moment how we would collect the information). Perhaps accessibility - ensuring the envelope vehicle can get to and from the points of production and consumption to the corridors - is a better metric. Then how do I turn this into an index measure? I don't know that I could take those two different metrics - travel time reliability on the network and accessibility off the network - and conjoin them into an index measure that would accurately represent the condition of the system. I suppose they could be turned into percentages - on the corridors X% of the lane miles achieved the target travel time reliability measure and off the network X% of the principal arterials met the accessibility metric. Then what? How do I combine these two, along with safety and infrastructure measures, into an overall index measure? [With unlimited resources, using measures that represent the % of the relevant

parts of the network that meets or exceeds a target is a much better way to capture performance if the data are available to support the measure. We can also use different weighting schemes for different elements of the network. We have given some thought to these kinds of measures and used them for three indicators – road roughness, deficient measures and uncongested roads.]

- Need a placeholder for passenger rail/high speed rail. [Agreed.]
- The utilization at the ports has always been difficult with the proxy of TEU lifts/crane/hour being less than satisfactory. Quality of service could be turn times for the vessel - from the time it passes the sea buoy inbound to the port to the time it passes it outbound - this would capture the channels, the harbor conditions, the pilot, the efficiency of the dock, the cranes, the ability to get goods off the dock, reloading (if done), etc. [Agreed. We welcome suggestions regarding data sources.]
- Aviation Delays: The use of the DOT Bureau of Transportation Statistics percentage on-time arrivals and departures to characterize overall system schedule performance is consistent with other widespread uses of this data and has the advantage of a long history and high levels of familiarity by the public and the press. However, it doesn't capture systemic delays that carriers build into their schedules or any delays by smaller airlines operating under contract to major airlines if they carry less than 1% of the total national passenger traffic. These limitations should be footnoted in your publication of the index. [Thanks for the comments; this is noted in the expert meeting notes.]
- Aviation Safety: This is a highly complex subject which is difficult to measure for knowledgeable professionals, much less the general public. Because of the extremely low accident rate among U.S. certificated passenger airlines, traditional measures, such as the number of fatal accidents per 100,000 flights, do not convey an easily understood sense of risk in public discussion. However, your proposed use of the number of runway incursions per million operations is particularly troubling. First, an incursion is not an accident or an incident, only an indicator of a breakdown in one of the barriers to an incident or an accident. Virtually all runway incursions for the last 20 years have had their potential risk modified by existing procedures, equipment and other measures such that no actual serious accidents have occurred. The incursions more than 20 years ago that did result in fatal accidents happened at low speeds and relatively few casualties resulted. Other risk factors have caused most of the recent fatal accidents, including: pilot fatigue, runway overruns or excursions, the use of the wrong runway, mechanical failures, and terrorism.

  In our opinion, the use of runway incursions to characterize aviation safety would be a major error, falling into the category of being sufficiently problematic to require replacement before the release of the transportation index. Despite the relative abstraction caused by the paucity of fatal accidents, we recommend using the traditional index: "number of fatal

accidents per 100,000 operations" or the slightly more relevant "number of fatalities per 100,000 operations," which accounts for the fact that some fatal accidents involve either greater or lesser numbers of fatalities. These indices, or similar ones using flights instead of operations, are readily available from FAA. Be sure to exclude the data for general aviation, charters, emergency medical flights, and other operations which have substantially higher accident rates, but are not relevant to the safety of most commercial air travelers.

[We agree that this is a highly complex topic and we want to emphasize that we are seeking infrastructure related measures. The other factors listed ("Other risk factors have caused most of the recent fatal accidents, including: pilot fatigue, runway overruns or excursions, the use of the wrong runway, mechanical failures, and terrorism.") are not directly related to the infrastructure, but on the human factor side. Incursions, to some degree, is a better indicator for infrastructure as our understanding is that infrastructure changes are often made in response to runway incursions. We believe that fatalities per 100,000 operations is NOT an appropriate measure and would consider eliminating this indicator completely.]

- Aircraft Arrival and Departure Rates: These rates are available for major airports from FAA. However, they may not be updated frequently enough to be useful in a dynamic index (mainly because they don't change unless a new runway or ATC procedure has been adopted at a given airport). We suggest limiting the reporting of these rates to those airports that carry a significant fraction of commercial passengers, perhaps FAA's 35 OEP airports. It makes little sense to include the AAR/ADR for airports that carry very few passengers. [This indicator applies only to the 75 ASPM large airports, which are reported in the FAA's ASPM database. The fact that these rates change when the infrastructure changes is exactly what we are trying to capture. We are also open to alternative suggestions.]
- Access to Commercial Passenger Air Service: The title of this index and its description do not match. Access to commercial air service could be provided at an EAS airport or a very small airport having a few flights a day. The description discusses the % of population having access to a major airport, which would exclude many smaller airport having significant levels of service (e.g., MHT or PVD both have significant levels of traffic, yet would not normally be thought of as "major" airports). Also, suggesting 50 miles as the right distance may not be useful, since the advent of low cost carriers has demonstrated that many passengers are willing to drive substantially further than that for access to low fare service. We suggest building an index based on the percentage of the population living within 100 miles of an airport with more than 50 departures per day. In any case, the index should be clear as to what it is measuring. [We have reworded the descriptions to be more precise. Including smaller airports may be a better measure. However, processing the NTAD GIS data along with tract census data may be time consuming.]

- Airport Capacity Utilization: We assume this index is intended to measure the efficiency with which airport resources are used. However, unless the set of airports chosen is specified, it is not meaningful. If you measure the ratio of scheduled flights to the capacity between 7am and 9pm of the 100 largest airports, carrying 94% of the total passengers, it would be a useful index. Another alternative would be to use only the FAA 35 OEP airports, on the theory that they carry about 75% of the passengers and are the ones FAA has identified as being most delay prone. [This indicator applies only to the 75 ASPM large airports, which are reported in the FAA's ASPM database.]
- Transit Supply: Measures of coverage in terms of percentage of population served based on zone of refusal is the best measure. Unfortunately the GIS data is generally not available for bus transit. [This data should be explored for future versions of the index.]
- Transit Safety: Number of incidents is not very reliable data. [Consideration should be given to eliminating this indicator in future versions of the index.]
- Transit Utilization: Passenger miles divided by capacity is probably a better measure. [Again, consideration should be given to including this measure in future versions.]
- Fleet Age: This serves as a proxy for quality of service (reliability). Data is available using the Transit Economic Requirements Model (TERM). [Exploration of TERM is warranted for future versions of the index.]
- Waterway and Harbor Capacity: Data is available in databases maintained by the Army Corps of Engineers. While this is not public data, it may be accessible. The Operations Maintenance Business Information Link is an internal database that includes lock specific data that could help identify choke points. The Corps also has a channel availability index. [Obtaining data directly from the Corps should be explored for future versions of the index.]

Alternative Indicators Suggested and Considered

Many excellent suggestions for indicators were received. Some of these warrant further exploration, some fail to capture the aspect of performance being considered or focus on elements of delivering service other than infrastructure, others do not have time series (1990-2007) data available, and for others data are available only nationally (not by MSA). In this section, each proposed indicator is described and comments provided.

The specific suggestions are:

- Access to commercial passenger air service – Essential Air Service
- Number of major cities accessible by air
- Passenger miles per vehicle mile or per seat mile
- Percentage of On-Time Arrivals
- Percentage VMT on roads of "good" quality
- Percentage VMT under conditions of delay
- Port Capacity Utilization

- Rail Safety
- Ratio of transportation fatal crashes to all fatal accidents
- State of good repair
- Train Speed (average); Terminal Dwell Time; Cars On Line (measure of congestion)
- "Transit time" or "unscheduled outages"

For each indicator proposed, the indicator is briefly described, the relevant existing indicator, criteria and applicable mode(s) identified, and comments on the relevance and availability added.

Proposed Indicator: Access to commercial passenger air service – Essential Air Service

Existing indicator: % Population Within 50 Miles of Major Airport(s)

Applicable Criteria: Supply

Applicable Mode(s): Air

Comments: The Essential Air Service program is for rural airports: http://ostpxweb.dot.gov/aviation/x-0%20role_files/essentialairservice.htm. This website provides the EAS list and the distance to closest large hubs. How can it be used? This could be combined with the proposed "Number of major cities accessible" indicator.

Proposed Indicator: Number of major cities accessible by air

Using the top 100 cities, the number of cities accessible by non-stop flights could serve as a measure of aviation supply.

Existing indicator: Average Number of Arrivals and Departures

Applicable Criteria: Supply

Applicable Mode(s): Air

Comments: This is an interesting measure warranting further exploration. This will require identifying the top 100 cities and then getting access to historical airline schedules. Presumably, historical copies of the Official Airline Guide (OAG) are available for past years.

Proposed Indicator: Passenger miles per vehicle mile or per seat mile

Existing indicator: PMT per Capacity

Applicable Criteria: Utilization

Applicable Mode(s): Transit

Comments: Data are available in the NTD and should be explored.

Proposed Indicator: Percentage of On-Time Arrivals

Use on-time arrivals. If you get there on time you almost have to depart on time. Besides they measure departure time by the time the aircraft closes the door and pulls back from the gate, not takeoff.

Existing indicator: Percentage of on-time arrivals and departures.

Applicable Criteria: Quality of Service

Applicable Mode(s): Air

Comments: This is a reasonable argument.

Proposed Indicator: Percentage VMT under conditions of delay

Existing indicator: % of Lane miles at LOS C or better

Applicable Criteria: Utilization

Applicable Mode(s): Highway

Comments: This is a logical measure. However, VMT data are estimated and thus the accuracy of the proposed indicator might be an issue if we use VMT rather than lane miles.

Proposed Indicator: Percentage VMT on roads of "good" quality

Existing indicator: % of Lane Miles with IRI Greater Than 170 in./mi.

Applicable Criteria: Quality of service

Applicable Mode(s): Highway

Comments: This is also a logical measure. However, again, VMT data are estimated and accuracy is of concern.

Proposed Indicator: Port Capacity Utilization

Examples include "number of harbors/channels dredged to their authorized depths and then maintained at their authorized depths" combined with "berth occupancy" or "volume of containers per port."

Existing indicator: None

Applicable Criteria: Utilization/Quality of Service

Applicable Mode(s): Waterway

Comments: Interesting indicators, however, we have been unable to find consistent data that we can assemble for each of the required years and each relevant MSA.

Proposed Indicator: Rail Safety

- FRA-reportable train accidents per million train miles
- FRA-reportable employee-on-duty casualties per 200,000 employee-hours

- Highway-rail collisions per million train miles

Existing indicator: Safety – Number of Incidents per Million Train Miles

Applicable Criteria: Quality of Service

Applicable Mode(s): Rail

Comments: This indicator warrants further consideration. The first step is to review the safety data and explore correlations among safety indicators to determine how closely these indicators track each other and whether all three, two or one indicator should be included. Our methodology assumes that indicators are **not** highly correlated. The three indicators proposed warrant further investigation

As we stated, the input from the railroad industry is extremely valuable. The input reinforces our sense of the areas that need further work, and provides ideas for improvement of the index. We look forward to an opportunity for further interaction.

Proposed Indicator: Ratio of transportation fatal crashes to all fatal accidents

This measure has run at about 50% despite improvements in transportation safety over several decades. CDC shows this for 2005 so transportation is more like 40% currently:

All accidents	117,809
All transportation accidents	48,411

Existing indicator: Fatalities/100 million VMT

Applicable Criteria: Quality of Service

Applicable Mode(s): Highway

Comments: Data are available only on a national basis and do not distinguish by mode..

Proposed Indicator: State-of-good repair (SGR)

Suggested measures include:

- Current % of transportation assets at SGR, by asset class (measured in terms of current replacement value, lane-miles, number of bridges)
- Backlog of investment needed to bring all assets to SGR, by asset class
- Worsened % of assets at SGR if current annual investment levels continue
- Higher annual investment required to maintain current % of assets at SGR
- Even higher annual investment required to bring all assets to SGR (i.e., zero backlog) by a certain date

Existing indicator: None

Applicable Criteria: Supply/ Quality of service

Applicable Mode(s): All modes

Comments: These are important indicators for "Rebuilding America." However, the data needed to support this indicator are not readily available. Possible sources include the new HPMS data and TERM.

Proposed Indicator: Train Speed (average); Terminal Dwell Time; Cars On Line (measure of congestion)

These data are available by major North American railroad for the latest 53 weeks from a website maintained by the Association of American Railroads (http://www.railroadpm.org/).

Existing indicator: None

Applicable Criteria: Quality of Service

Applicable Mode(s): Rail

Comments: Historical data are not available. This indicator should be included beginning in 2010 (the first year for which complete data will be available. This will require downloading data in a timely manner and developing a strategy to aggregate data across railroads. Input on the aggregation of the data should be obtained from the railroad industry.

Proposed Indicator: "Transit time" or "unscheduled outages"

Existing indicator: Average Lock Delay

Applicable Criteria: Quality of Service

Applicable Mode(s): Waterway

Comments: These measures are provided by river or division. To aggregate them to a national value we need to weight each by the traffic but we do not have access to traffic data.

APPENDIX D – TRANSPORTATION INDICATORS – STATE BY STATE INDEX

This appendix summarizes the seventeen transportation indicators used to develop a state-by-state transportation index, based on the three categories of criteria:

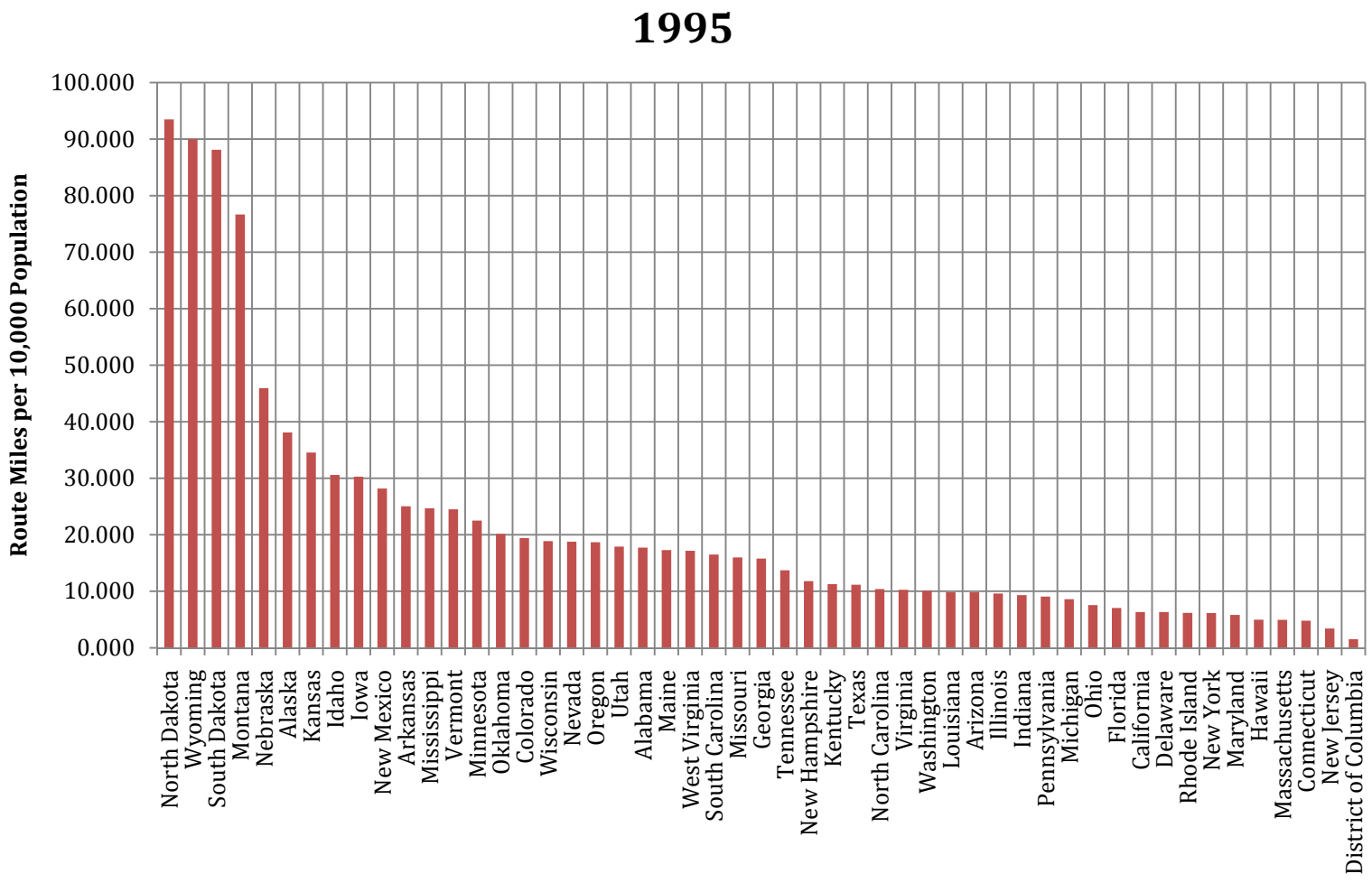
- Supply
  - Highway Density - Route Miles per 10,000 Population
  - Transit Density - Miles of Transit per 10,000 Population
  - Airport Access – Enplanements per population
  - Rail Density - Route Miles per 10,000 Population
  - Waterway Density - Miles of Waterways per 10,000 population
  - Port Access - Distance from the Center of MSA to the Closest International Container Port
  - Intermodal Connectivity - # Ramps per 10, 000 Population
- Quality of Service
  - Highway Safety - Fatalities per 100 Million VMTs
  - Road Roughness - % of Lane Miles with IRI Greater Than 170 in./mi.
  - Bridge Integrity - % of Bridges Structurally Deficient or Functionally Obsolete
  - Air Congestion - % of On-Time Departures
  - Air Safety – Runway Incursions per Million Operations
  - Rail Safety – # Incidents per Million Train Miles
  - Transit Safety - # Incidents per 100 Million PMT
- Utilization
  - Uncongested Roads - % of Lane Miles at LOS C or Better
  - Transit Utilization - PMT per Capacity (Standing + Seating)
  - Rail Utilization - Million Ton Miles of Freight per Track Miles

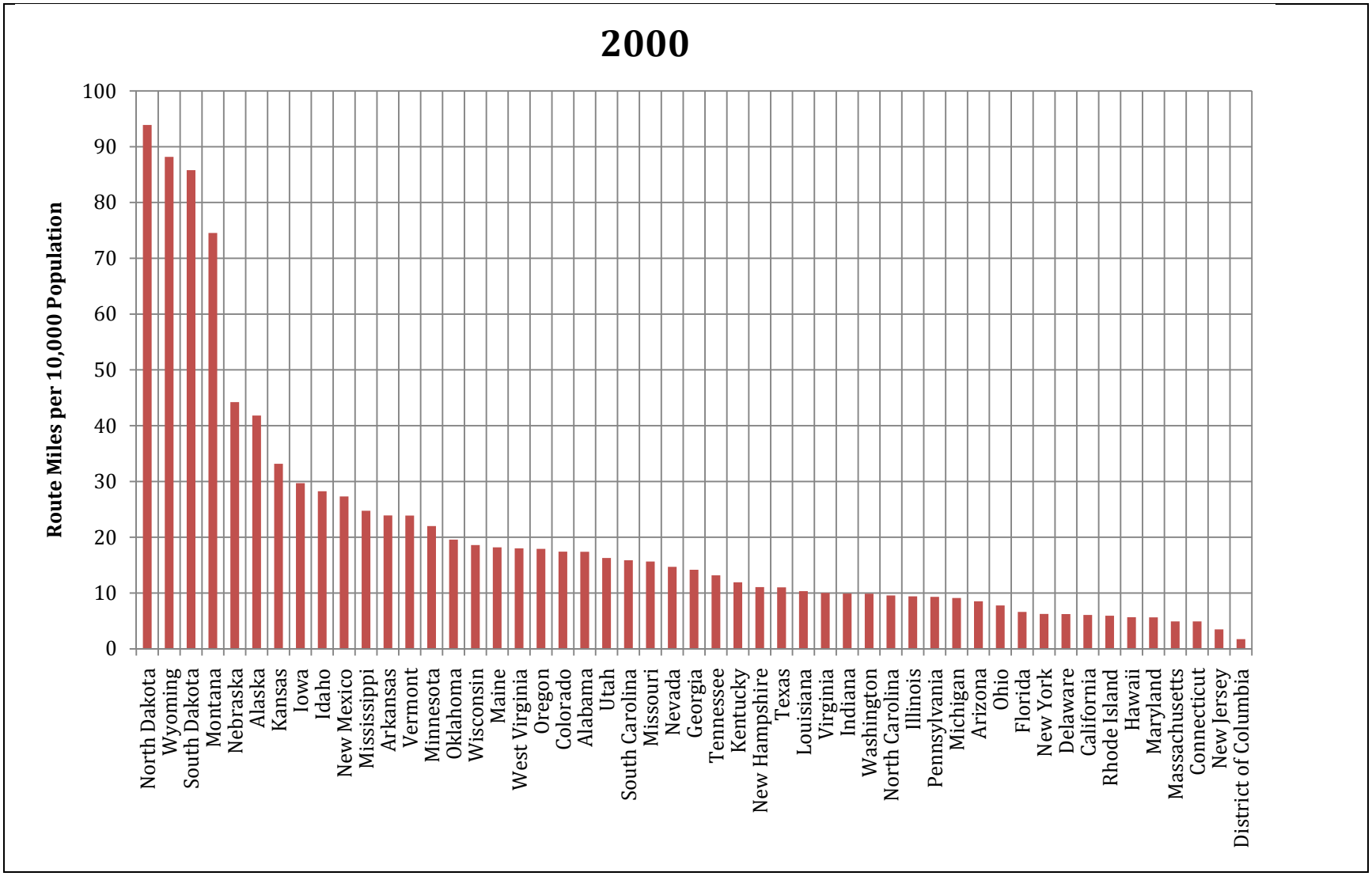
For each indicator the following data are provided:

- Definition
- Why it's important
- Criteria metric
- Contribution to Index
- Observations
- Primary data sources
- Data issues and opportunities
- Historical values (1995, 2000, and 2007)

Indicator #1	**Highway Density**
Definition:	Route Miles of Highways per 10,000 Population
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
Contribution to Index: *State-by-State – 0.093* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transportation Atlas Database (NTAD) (http://www.bts.gov/publications/national_transportation_atlas_database/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	(4) The NTAD data are available only in 2000 and 2007 from Bureau of Transportation Statistics (BTS). The data are obtained only for major highways (with highway functional classes of 1, 2, 6, 11, 12, 14, and 16). However, in 2000, functional class data were missing in the data sets. Adjustments are made based on the portion of major highways in the total system in 2002. (5) The data in 1995 are extrapolated based from those in 2000 and 2007.
Observations: • This indicator changes very little over time. • Four Plains states have significantly higher densities than the other states.	

Historical Values:




2000
Route Miles per 10,000 Population
100
90
80
70
60
50
40
30
20
10
0
North Dakota
Wyoming
South Dakota
Montana
Nebraska
Alaska
Kansas
Iowa
Idaho
New Mexico
Mississippi
Arkansas
Vermont
Minnesota
Oklahoma
Wisconsin
Maine
West Virginia
Oregon
Colorado
Alabama
Utah
South Carolina
Missouri
Nevada
Georgia
Tennessee
Kentucky
New Hampshire
Texas
Louisiana
Virginia
Indiana
Washington
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Arizona
Ohio
Florida
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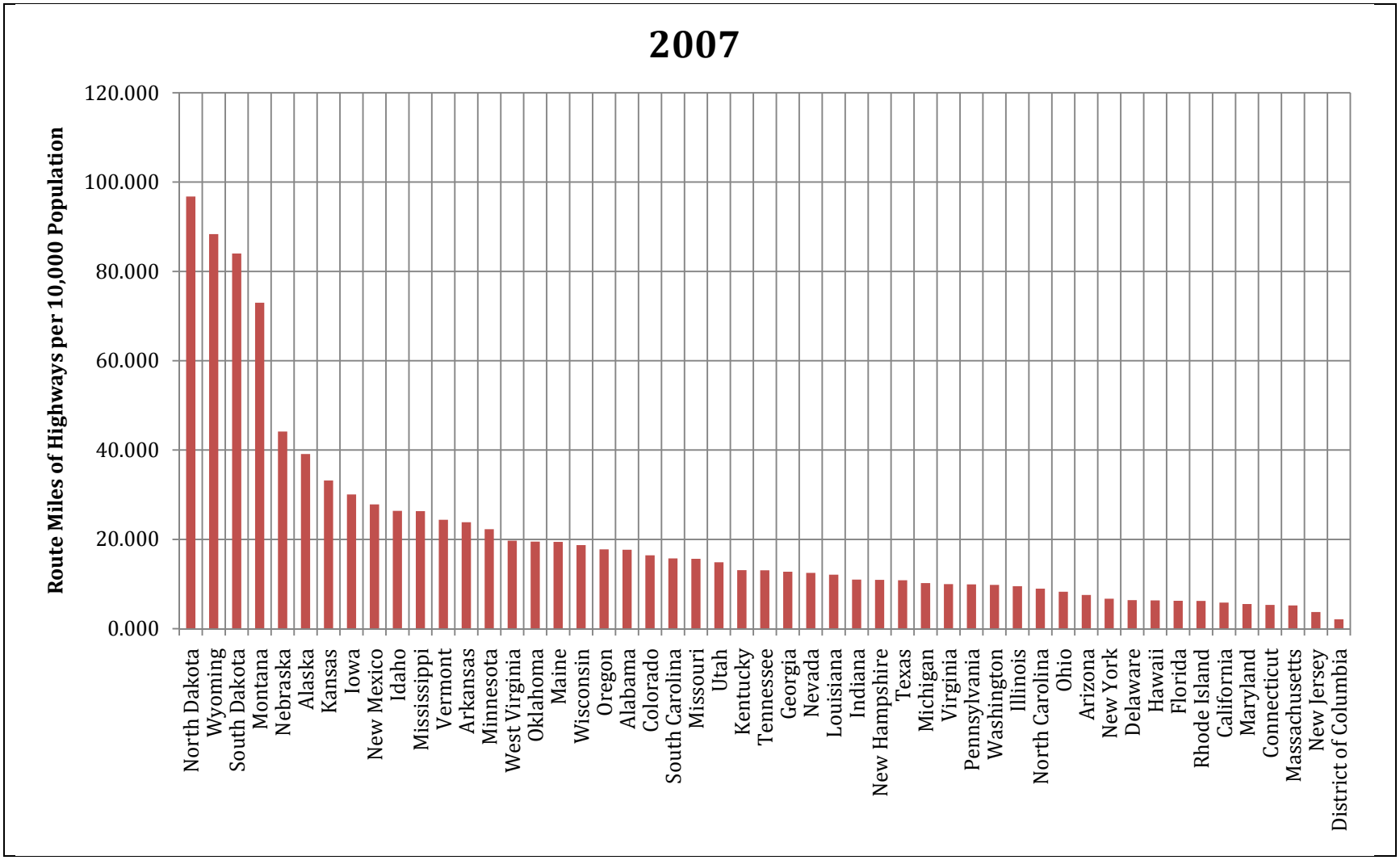
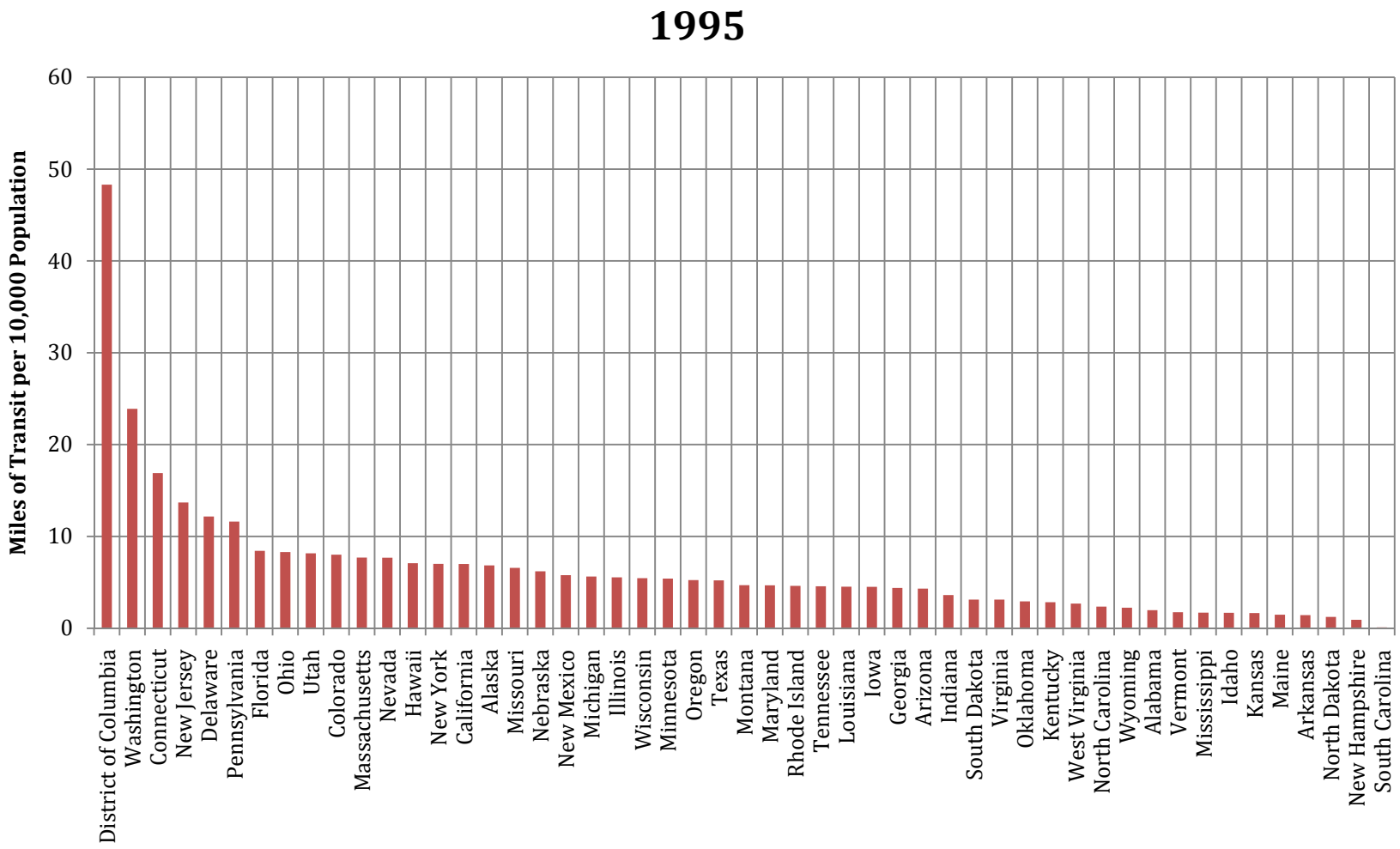
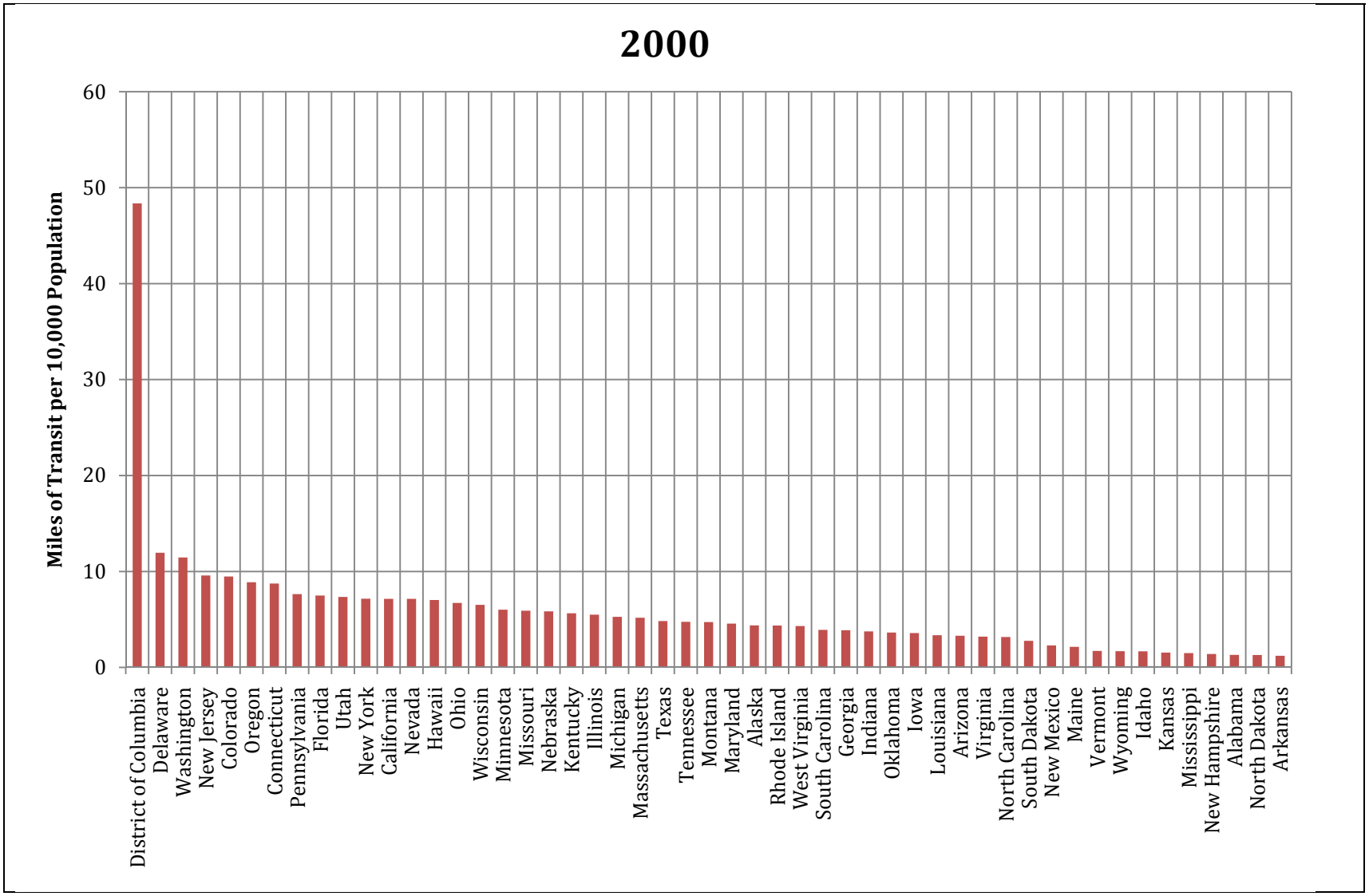
Delaware
California
Rhode Island
Hawaii
Maryland
Massachusetts
Connecticut
New Jersey
District of Columbia

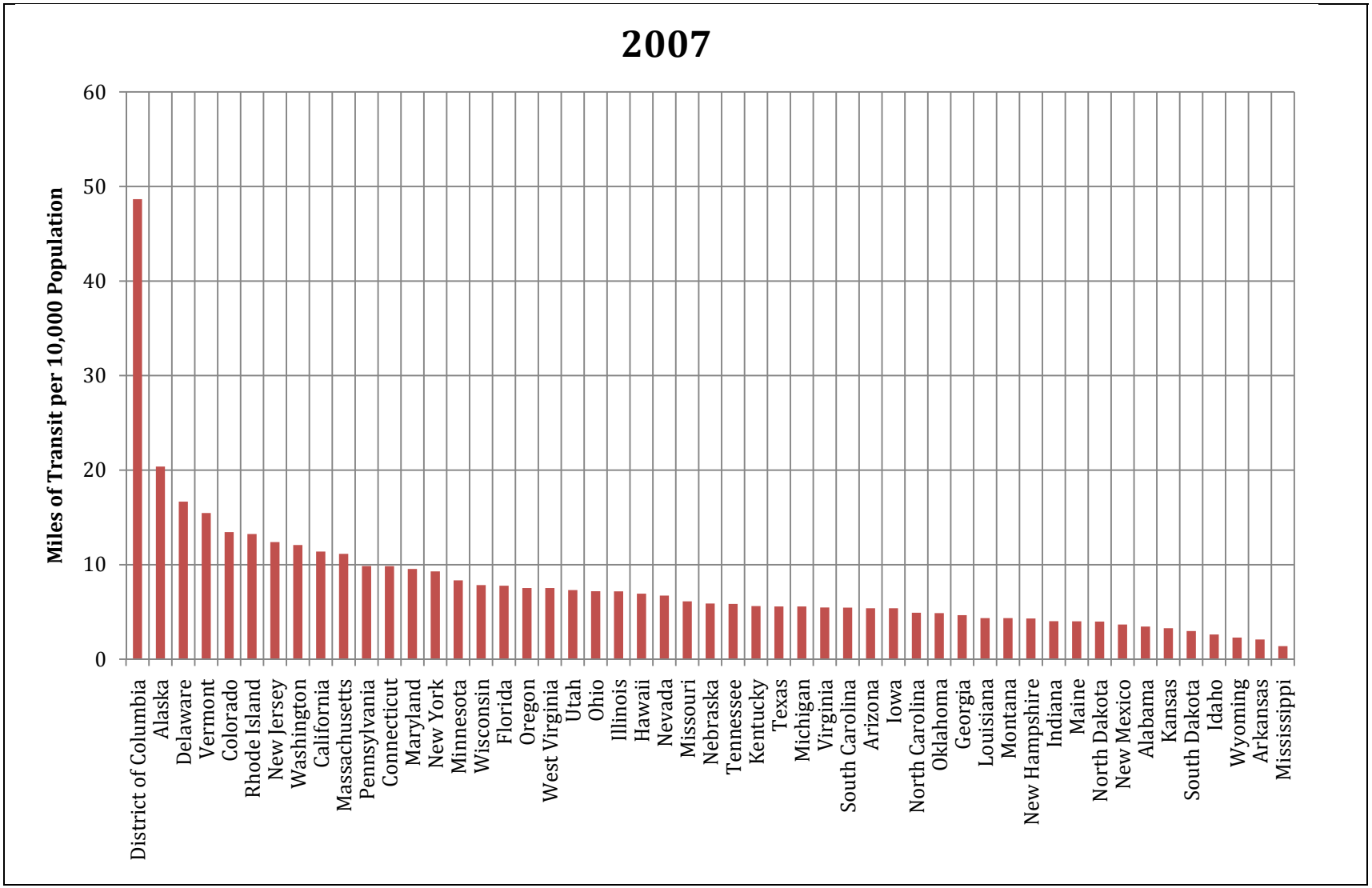

2007
Route Miles of Highways per 10,000 Population
120.000
100.000
80.000
60.000
40.000
20.000
0.000
North Dakota
Wyoming
South Dakota
Montana
Nebraska
Alaska
Kansas
Iowa
New Mexico
Idaho
Mississippi
Vermont
Arkansas
Minnesota
West Virginia
Oklahoma
Maine
Wisconsin
Oregon
Alabama
Colorado
South Carolina
Missouri
Utah
Kentucky
Tennessee
Georgia
Nevada
Louisiana
Indiana
New Hampshire
Texas
Michigan
Virginia
Pennsylvania
Washington
Illinois
North Carolina
Ohio
Arizona
New York
Delaware
Hawaii
Florida
Rhode Island
California
Maryland
Connecticut
Massachusetts
New Jersey
District of Columbia

Indicator #2	**Transit Density**
Definition:	Miles of Transit per 10,000 Population
Why it's important:	Public transit is an essential transportation option that can cut through congestion to provide access to job markets and remove auto trips from the highway system, thereby helping to maintain highway capacity for the shipment of goods and materials.
Criteria metric:	Supply
Contribution to Index: *State-by-State – 0.049* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transit Database (NTD) (http://www.ntdprogram.gov/ntdprogram/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	The NTD data are available only in 2000 and 2007 from Federal Transit Administration. The data in 1995 are extrapolated based from those in 2000 and 2007.
Observations: • Highest transit densities are in the very urban states. • District of Columbia has the highest transit density and the lowest highway density.	

Historical Values:

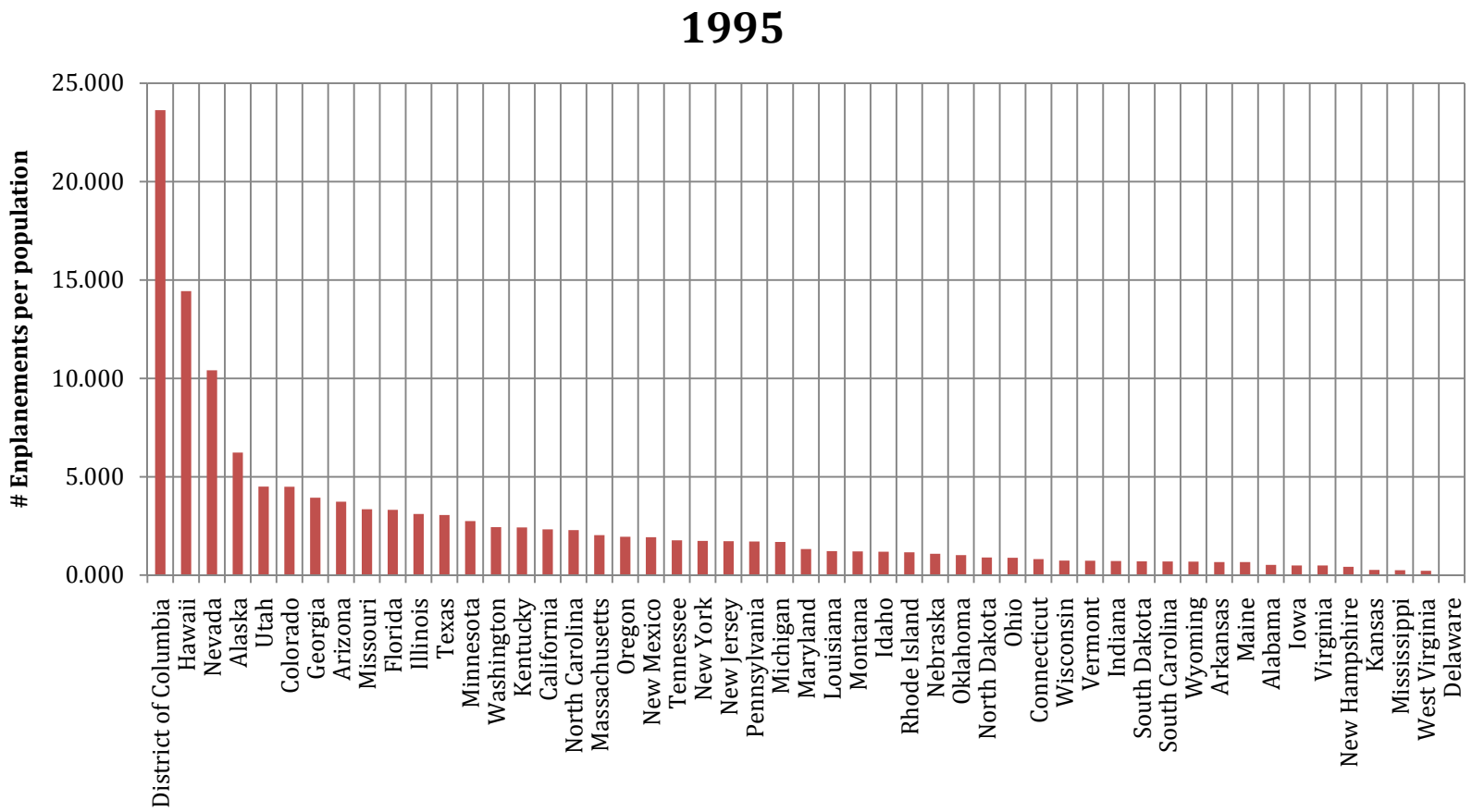


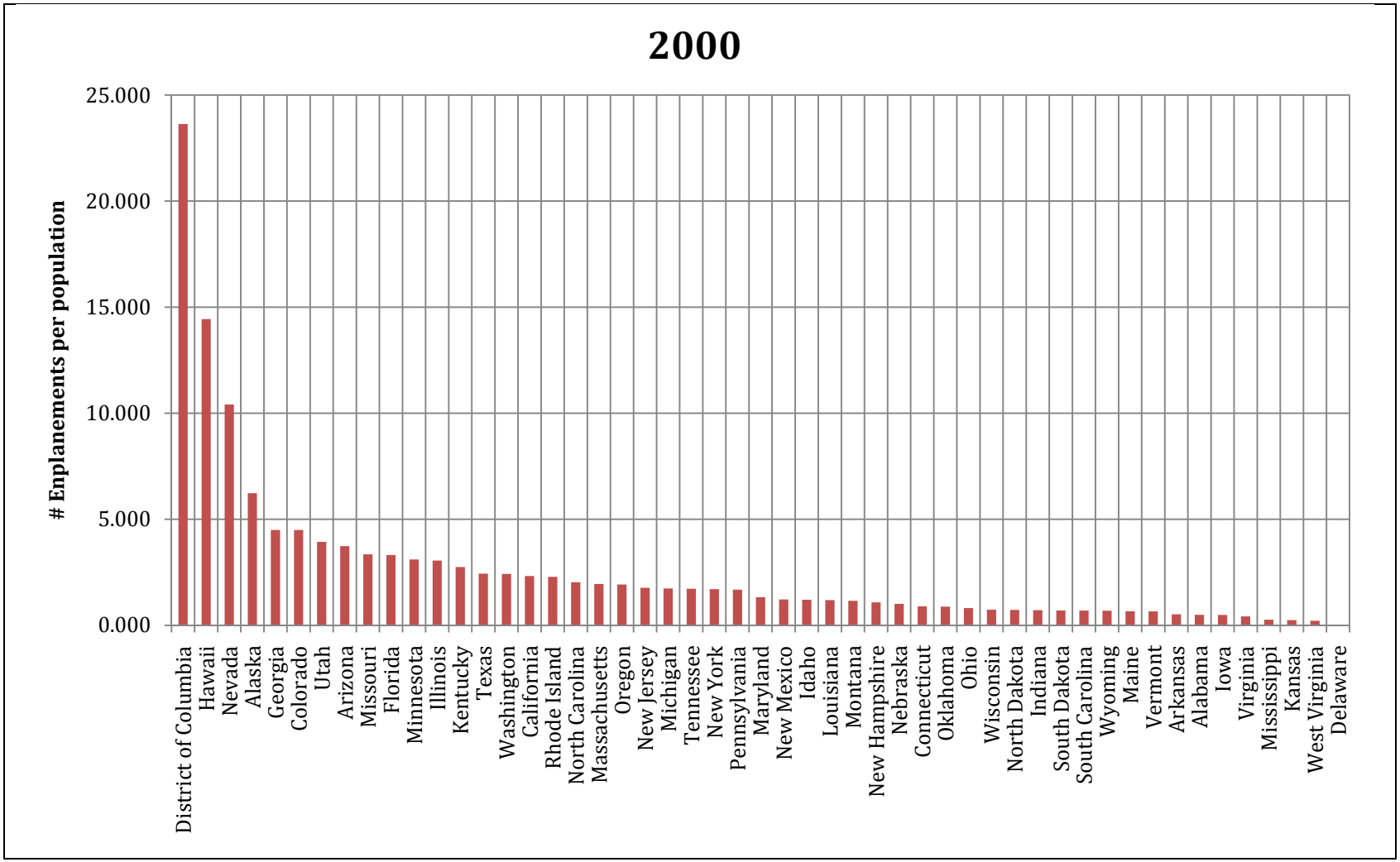

2000
Miles of Transit per 10,000 Population
60
50
40
30
20
10
0
District of Columbia
Delaware
Washington
New Jersey
Colorado
Oregon
Connecticut
Pennsylvania
Florida
Utah
New York
California
Nevada
Hawaii
Ohio
Wisconsin
Minnesota
Missouri
Nebraska
Kentucky
Illinois
Michigan
Massachusetts
Texas
Tennessee
Montana
Maryland
Alaska
Rhode Island
West Virginia
South Carolina
Georgia
Indiana
Oklahoma
Iowa
Louisiana
Arizona
Virginia
North Carolina
South Dakota
New Mexico
Maine
Vermont
Wyoming
Idaho
Kansas
Mississippi
New Hampshire
Alabama
North Dakota
Arkansas

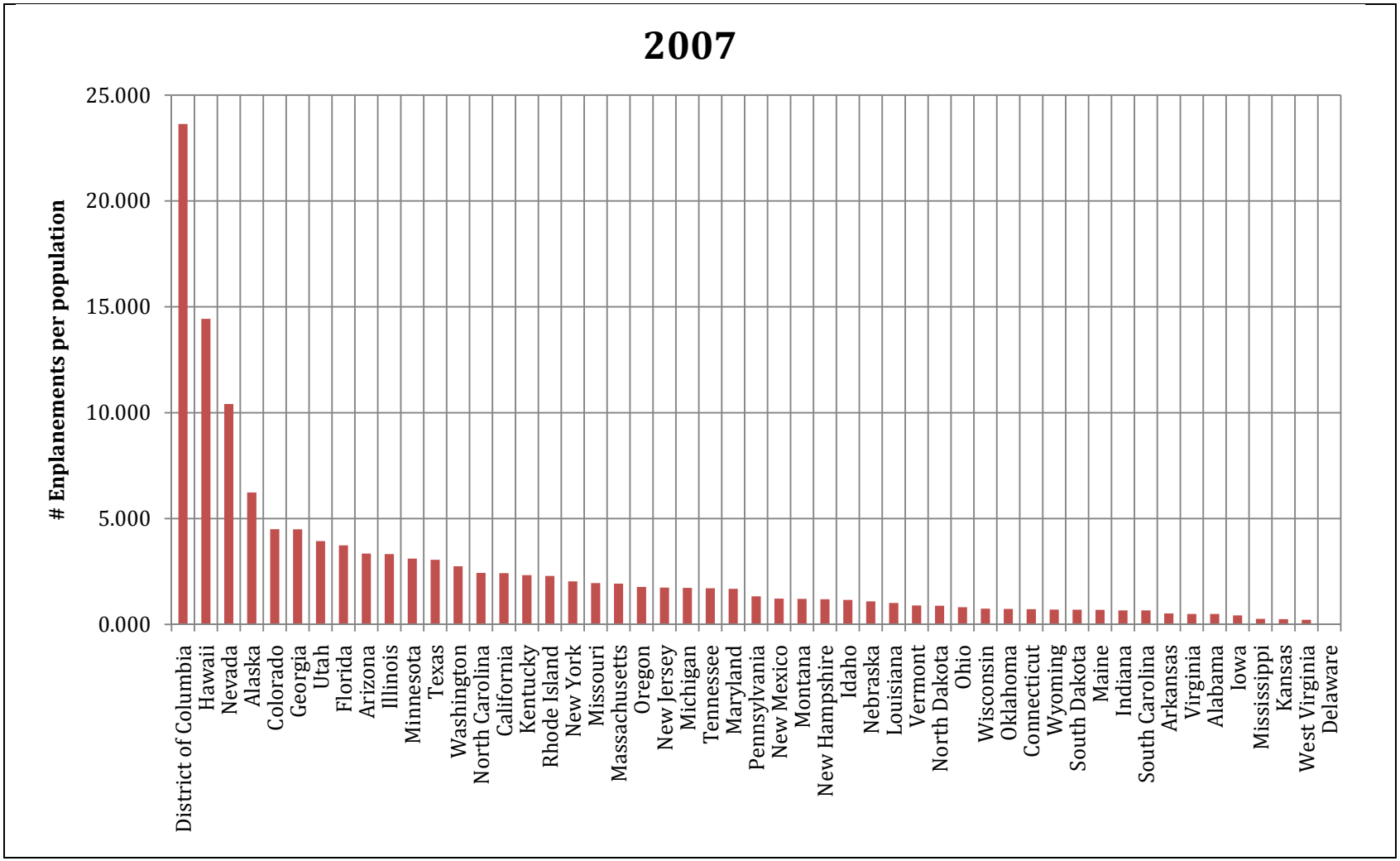

2007
Miles of Transit per 10,000 Population
60
50
40
30
20
10
0
District of Columbia
Alaska
Delaware
Vermont
Colorado
Rhode Island
New Jersey
Washington
California
Massachusetts
Pennsylvania
Connecticut
Maryland
New York
Minnesota
Wisconsin
Florida
Oregon
West Virginia
Utah
Ohio
Illinois
Hawaii
Nevada
Missouri
Nebraska
Tennessee
Kentucky
Texas
Michigan
Virginia
South Carolina
Arizona
Iowa
North Carolina
Oklahoma
Georgia
Louisiana
Montana
New Hampshire
Indiana
Maine
North Dakota
New Mexico
Alabama
Kansas
South Dakota
Idaho
Wyoming
Arkansas
Mississippi

Indicator #3	**Airport Access**
Definition:	Enplanements per Population
Why it's important:	This indicator is a surrogate for airport proximity (airport access), which indicates the supply of air transportation facilities available to the population in the state.
Criteria metric:	Supply
Contribution to Index: *State-by-State – 0.018* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	Terminal Area Forecast (http://aspm.faa.gov/main/taf.asp) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	
Observations: • Best access to air transportation is in the District of Columbia, Hawaii, Nevada and Alaska -- all	

Historical Values:

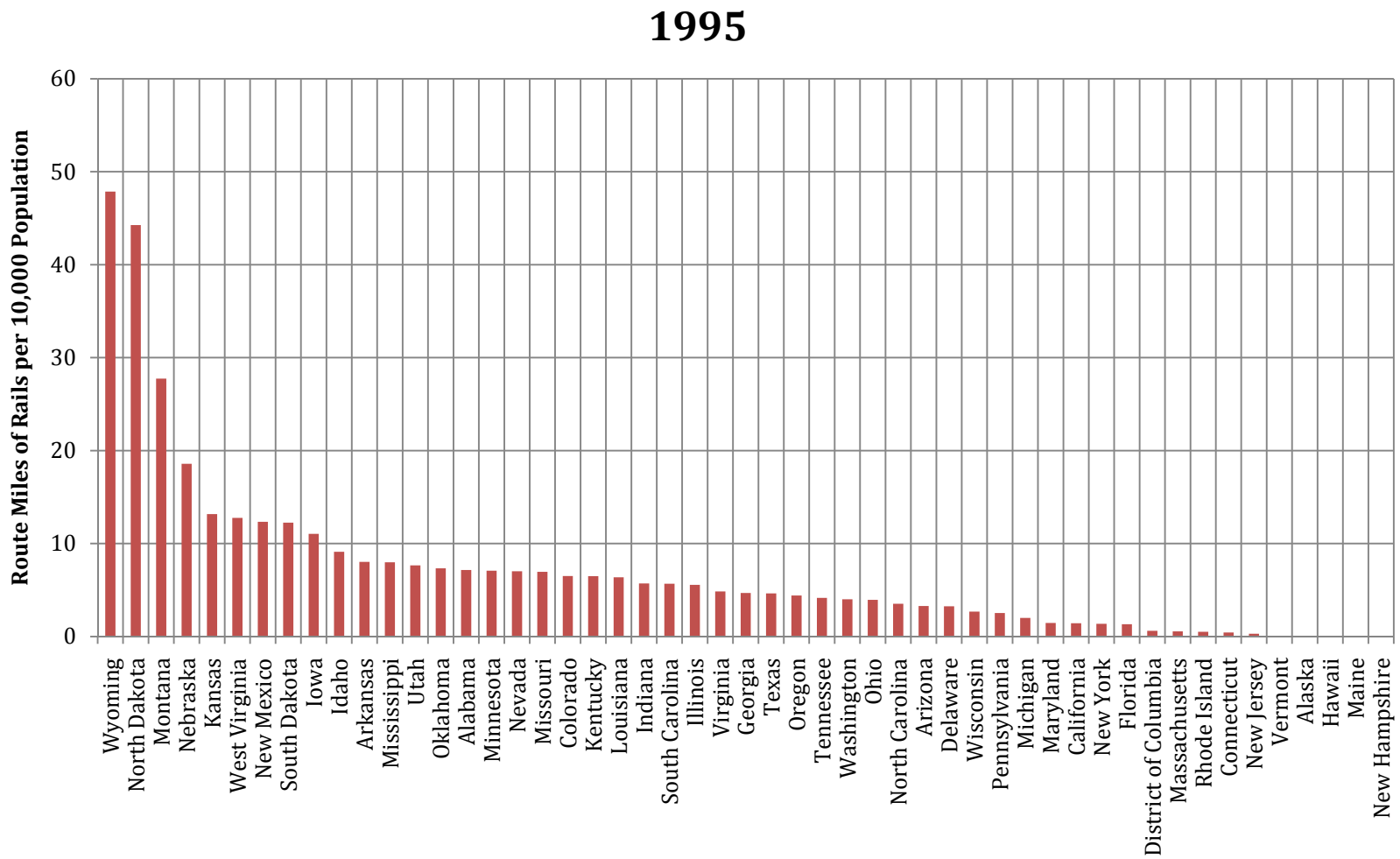


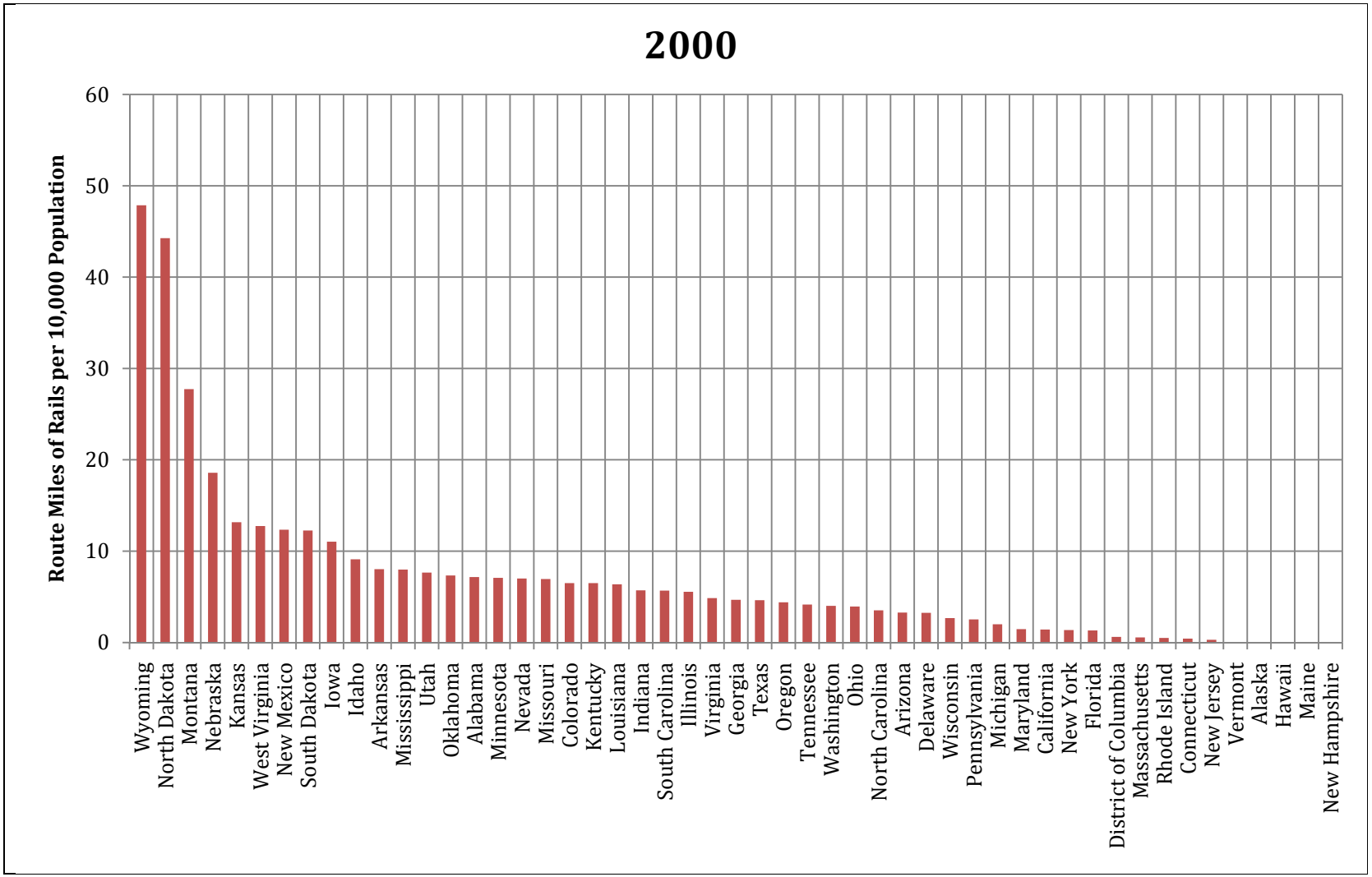

2000
Enplanements per population
25.000
20.000
15.000
10.000
5.000
0.000
District of Columbia
Hawaii
Nevada
Alaska
Georgia
Colorado
Utah
Arizona
Missouri
Florida
Minnesota
Illinois
Kentucky
Texas
Washington
California
Rhode Island
North Carolina
Massachusetts
Oregon
New Jersey
Michigan
Tennessee
New York
Pennsylvania
Maryland
New Mexico
Idaho
Louisiana
Montana
New Hampshire
Nebraska
Connecticut
Oklahoma
Ohio
Wisconsin
North Dakota
Indiana
South Dakota
South Carolina
Wyoming
Maine
Vermont
Arkansas
Alabama
Iowa
Virginia
Mississippi
Kansas
West Virginia
Delaware

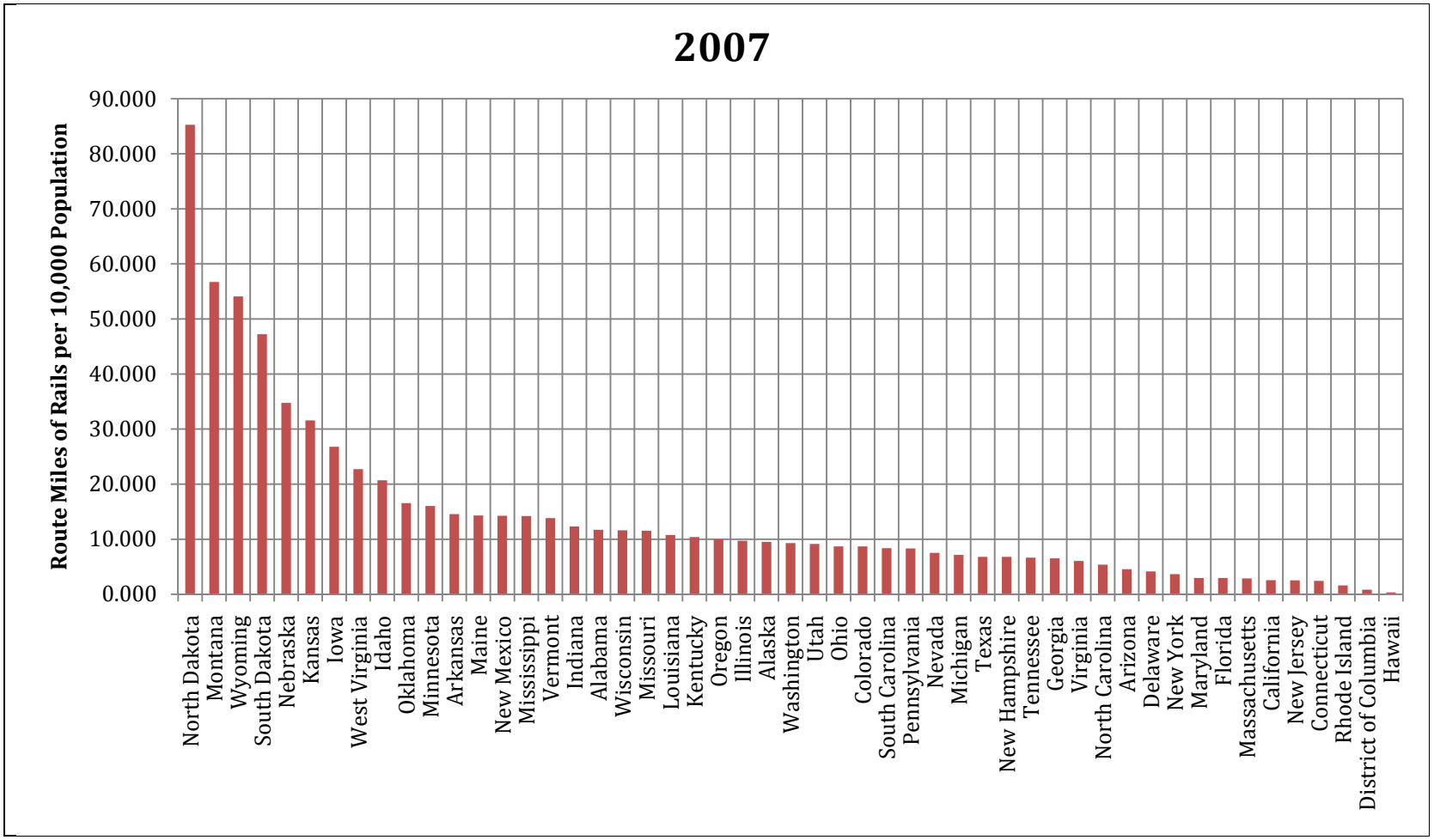

2007
Enplanements per population
25.000
20.000
15.000
10.000
5.000
0.000
District of Columbia
Hawaii
Nevada
Alaska
Colorado
Georgia
Utah
Florida
Arizona
Illinois
Minnesota
Texas
Washington
North Carolina
California
Kentucky
Rhode Island
New York
Missouri
Massachusetts
Oregon
New Jersey
Michigan
Tennessee
Maryland
Pennsylvania
New Mexico
Montana
New Hampshire
Idaho
Nebraska
Louisiana
Vermont
North Dakota
Ohio
Wisconsin
Oklahoma
Connecticut
Wyoming
South Dakota
Maine
Indiana
South Carolina
Arkansas
Virginia
Alabama
Iowa
Mississippi
Kansas
West Virginia
Delaware

Indicator #4	**Rail Density**
Definition:	Route Miles of Rails per 10,000 Population 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, which has a unique importance to U.S. competitiveness in the world economy, and the impact that forced access could have on U.S. export/import capabilities.
Criteria metric:	Supply
Contribution to Index: *State-by-State – 0.052* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transportation Atlas Database (NTAD) (http://www.bts.gov/publications/national_transportation_atlas_database/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	(3) The NTAD data are available only in 2000 and 2007 from Bureau of Transportation Statistics (BTS). The data are obtained only for Class I rails. However, in 2000, functional class data were missing in the data sets. Adjustments are made based on the portion of Class I rails in the total system in 2002. (4) The data in 1995 are assumed to be the same as those in 2000.
Observations: • Like Highway Density, the best performing states are the Plains states.	

Historical Values:

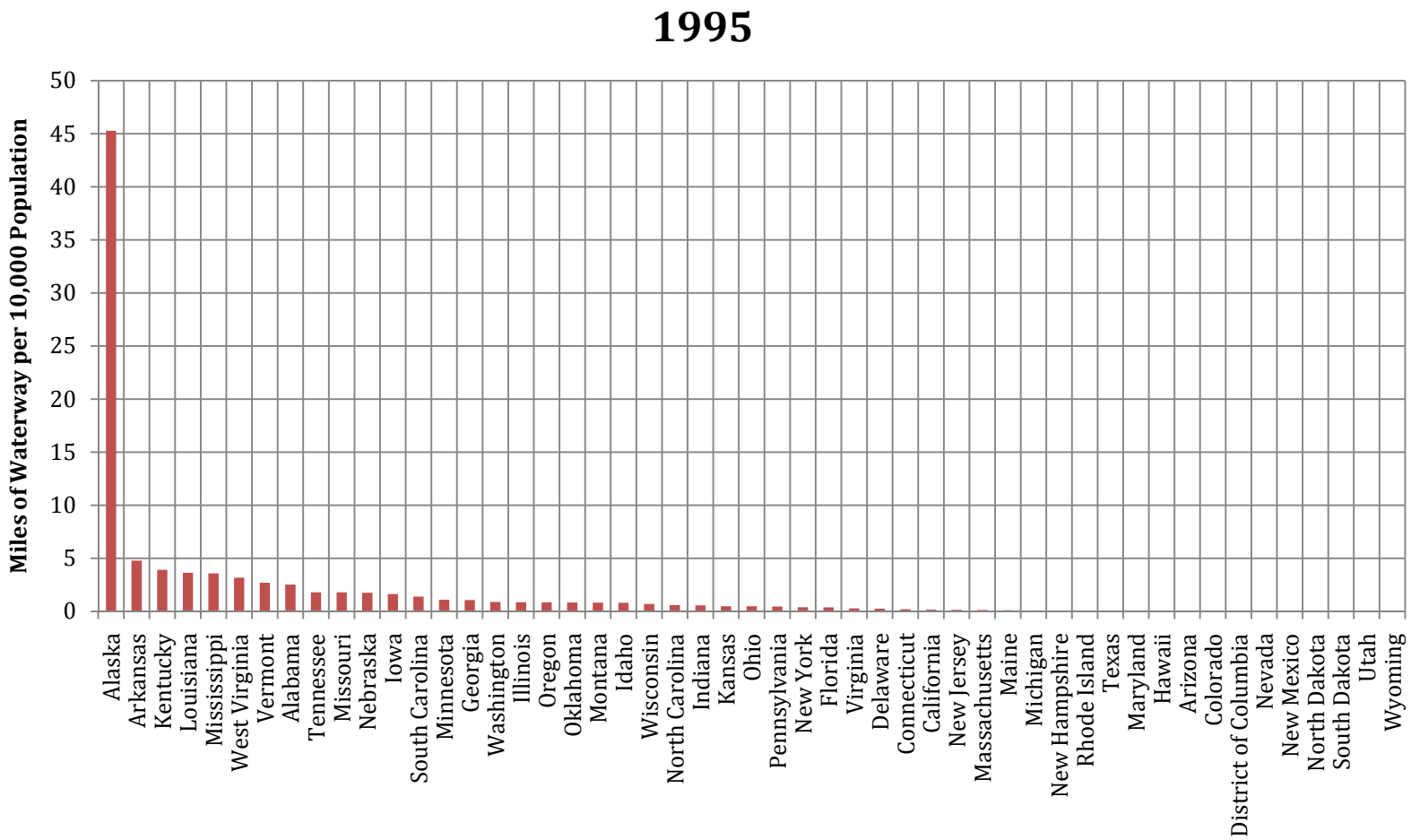


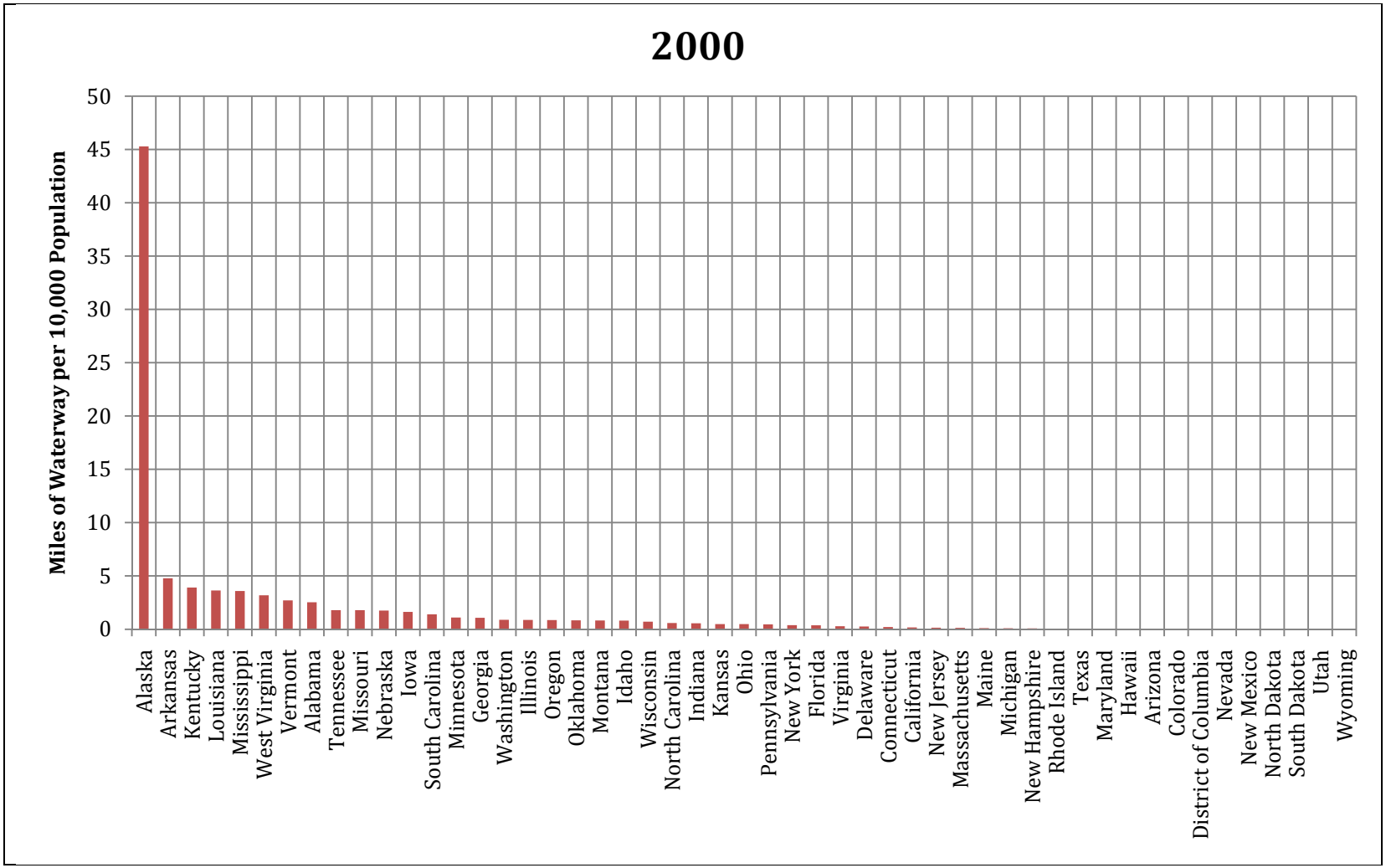

2000
Route Miles of Rails per 10,000 Population
60
50
40
30
20
10
0
Wyoming
North Dakota
Montana
Nebraska
Kansas
West Virginia
New Mexico
South Dakota
Iowa
Idaho
Arkansas
Mississippi
Utah
Oklahoma
Alabama
Minnesota
Nevada
Missouri
Colorado
Kentucky
Louisiana
Indiana
South Carolina
Illinois
Virginia
Georgia
Texas
Oregon
Tennessee
Washington
Ohio
North Carolina
Arizona
Delaware
Wisconsin
Pennsylvania
Michigan
Maryland
California
New York
Florida
District of Columbia
Massachusetts
Rhode Island
Connecticut
New Jersey
Vermont
Alaska
Hawaii
Maine
New Hampshire

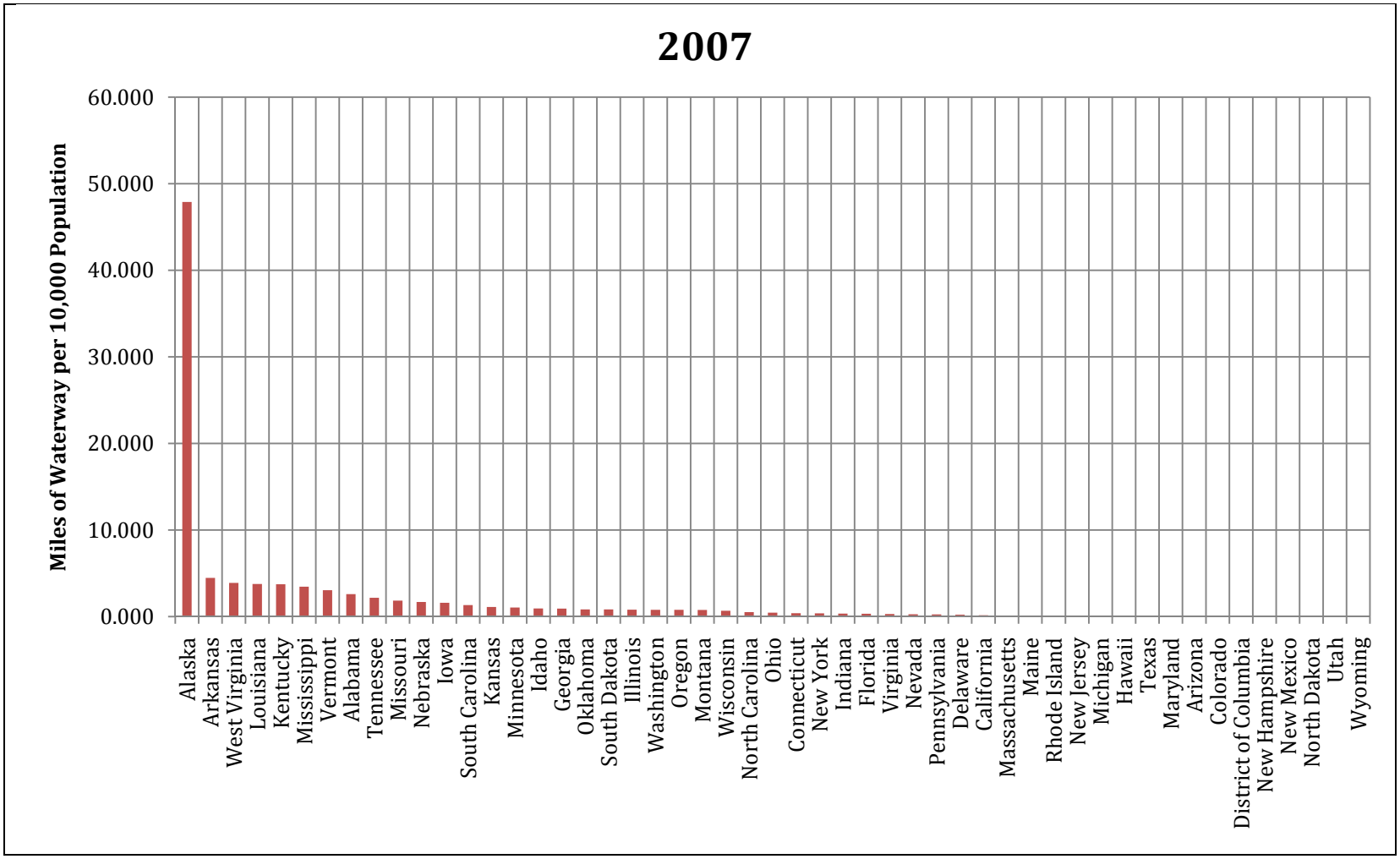

2007
Route Miles of Rails per 10,000 Population
90.000
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
North Dakota
Montana
Wyoming
South Dakota
Nebraska
Kansas
Iowa
West Virginia
Idaho
Oklahoma
Minnesota
Arkansas
Maine
New Mexico
Mississippi
Vermont
Indiana
Alabama
Wisconsin
Missouri
Louisiana
Kentucky
Oregon
Illinois
Alaska
Washington
Utah
Ohio
Colorado
South Carolina
Pennsylvania
Nevada
Michigan
Texas
New Hampshire
Tennessee
Georgia
Virginia
North Carolina
Arizona
Delaware
New York
Maryland
Florida
Massachusetts
California
New Jersey
Connecticut
Rhode Island
District of Columbia
Hawaii

Indicator #5	**Waterway Density**
Definition:	Miles of Waterways per 10,000 population
Why it's important:	The waterway density indicates the supply of waterway services.
Criteria metric:	Supply
Contribution to Index: *State-by-State – 0.016* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transportation Atlas Database (NTAD) (http://www.bts.gov/publications/national_transportation_atlas_database/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	(1) The NTAD data are available only in 2000 and 2007 from Bureau of Transportation Statistics (BTS). The data are obtained only for navigable waterways. However, in 2000, functional class data were missing in the data sets. Adjustments are made based on the portion of navigable waterways in the total system in 2003. (2) The data in 1995 are assumed to be the same as those in 2000.
Observations: • Poorest performing states have no access to waterways.	

Historical Values:

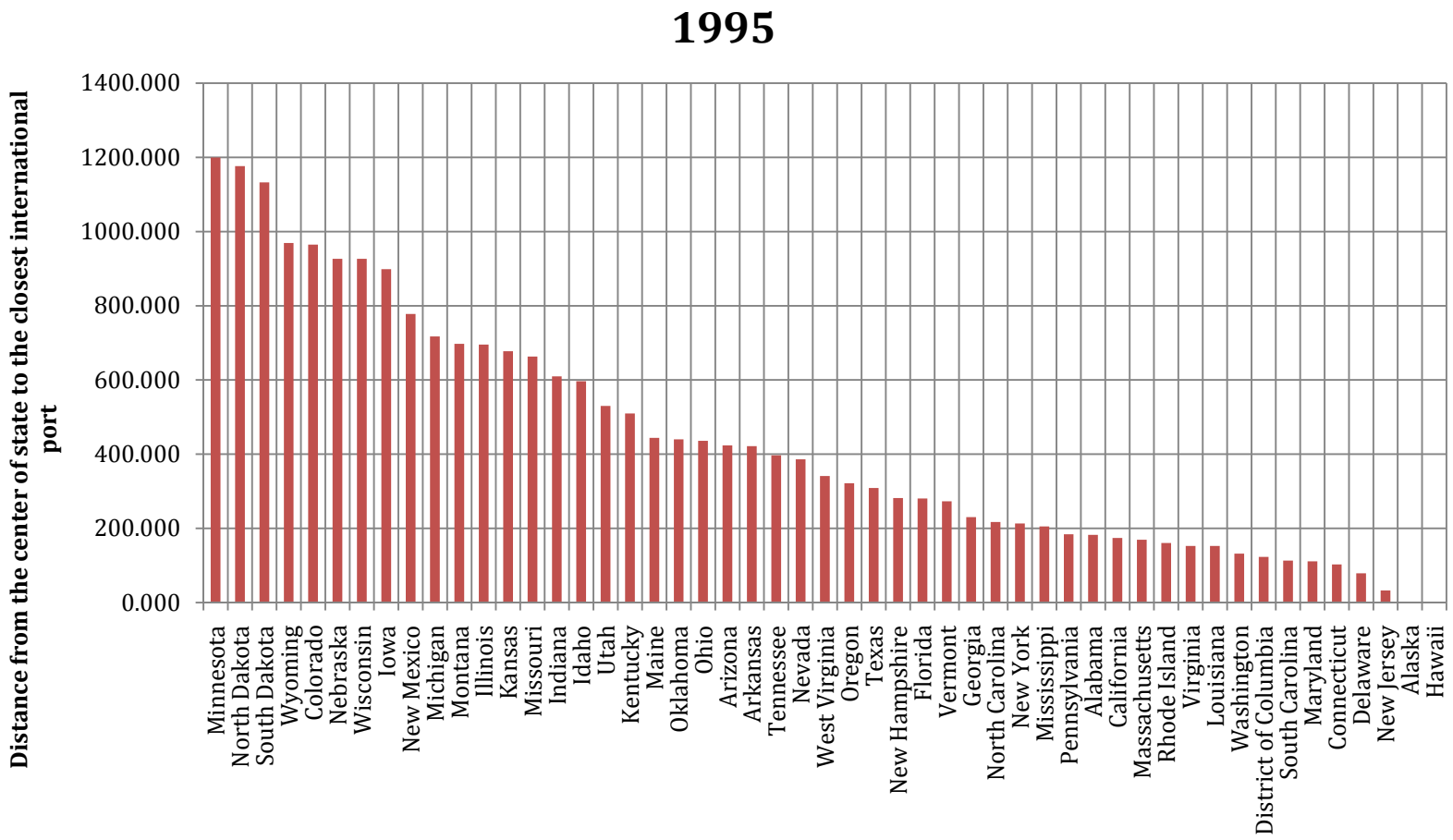


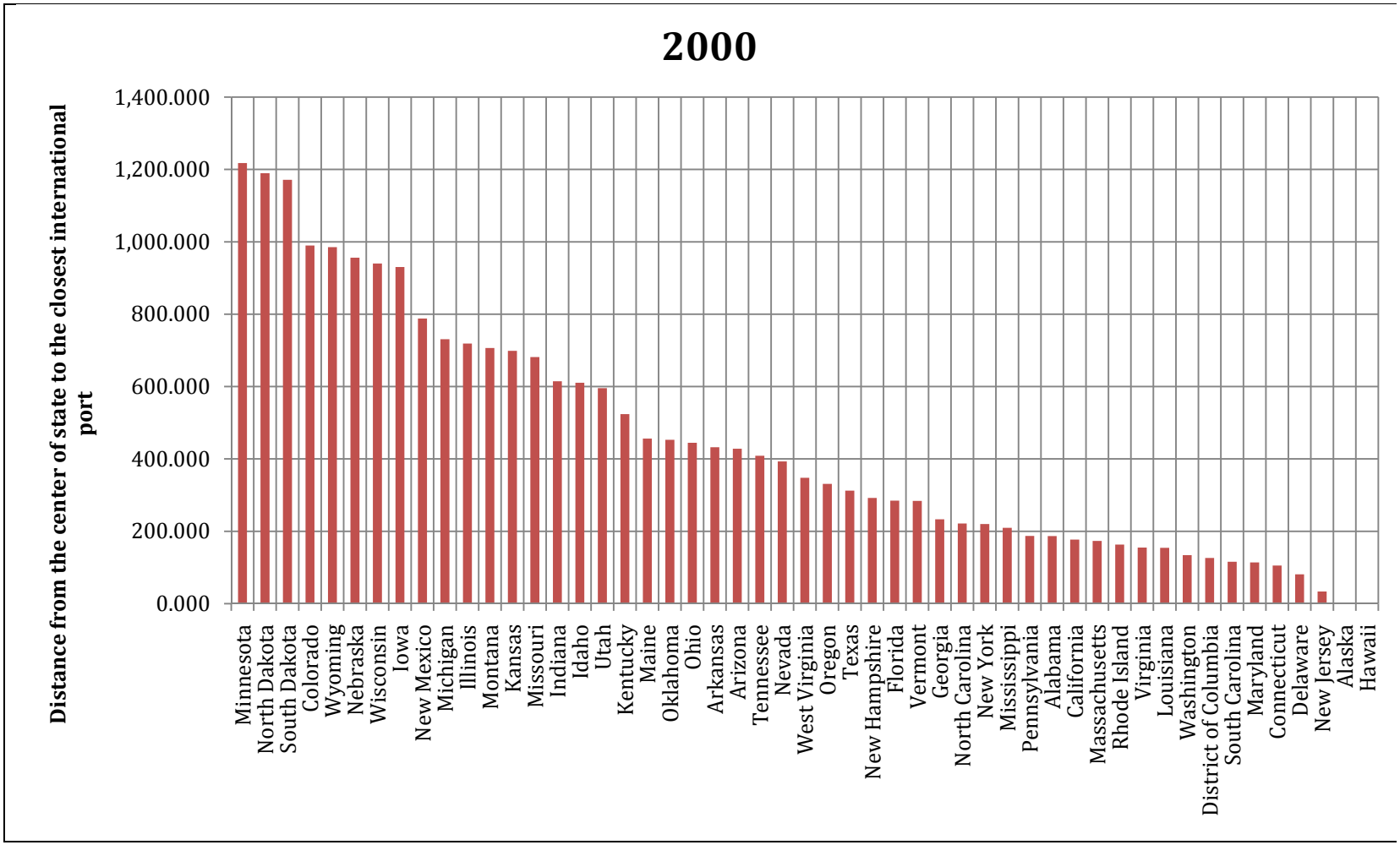

2000
Miles of Waterway per 10,000 Population
50
45
40
35
30
25
20
15
10
5
0
Alaska
Arkansas
Kentucky
Louisiana
Mississippi
West Virginia
Vermont
Alabama
Tennessee
Missouri
Nebraska
Iowa
South Carolina
Minnesota
Georgia
Washington
Illinois
Oregon
Oklahoma
Montana
Idaho
Wisconsin
North Carolina
Indiana
Kansas
Ohio
Pennsylvania
New York
Florida
Virginia
Delaware
Connecticut
California
New Jersey
Massachusetts
Maine
Michigan
New Hampshire
Rhode Island
Texas
Maryland
Hawaii
Arizona
Colorado
District of Columbia
Nevada
New Mexico
North Dakota
South Dakota
Utah
Wyoming

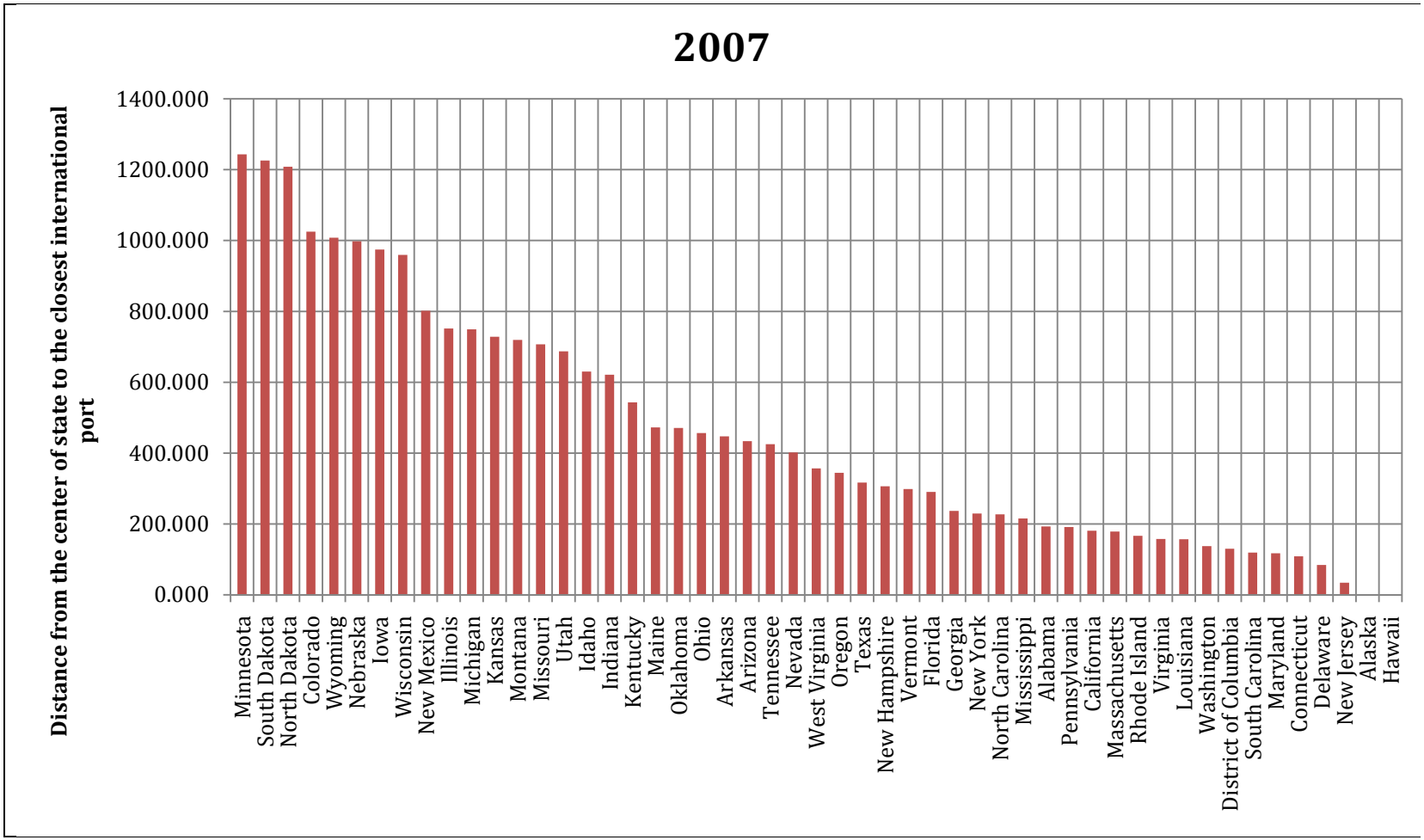

2007
Miles of Waterway per 10,000 Population
60.000
50.000
40.000
30.000
20.000
10.000
0.000
Alaska
Arkansas
West Virginia
Louisiana
Kentucky
Mississippi
Vermont
Alabama
Tennessee
Missouri
Nebraska
Iowa
South Carolina
Kansas
Minnesota
Idaho
Georgia
Oklahoma
South Dakota
Illinois
Washington
Oregon
Montana
Wisconsin
North Carolina
Ohio
Connecticut
New York
Indiana
Florida
Virginia
Nevada
Pennsylvania
Delaware
California
Massachusetts
Maine
Rhode Island
New Jersey
Michigan
Hawaii
Texas
Maryland
Arizona
Colorado
District of Columbia
New Hampshire
New Mexico
North Dakota
Utah
Wyoming

Indicator #6	**Port Access**
Definition:	Distance from the Center of MSA to the Closest International Container Port
Why it's important:	Port access indicates the accessibility of port services within the state.
Criteria metric:	Supply
Contribution to Index: *State-by-State – 0.036* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transportation Atlas Database (NTAD) (http://www.bts.gov/publications/national_transportation_atlas_database/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	(1) The NTAD data are available only in 2000 and 2007 from Bureau of Transportation Statistics (BTS). The data are obtained only for Class I rails. However, in 2000, functional class data were missing in the data sets. Adjustments are made based on the portion of Class I rails in the total system in 2002. (2) The data in 1995 are extrapolated based on those in 2000 and 2007.
Observations: • Poorest performing states are in the middle of the country.	

Historical Values:

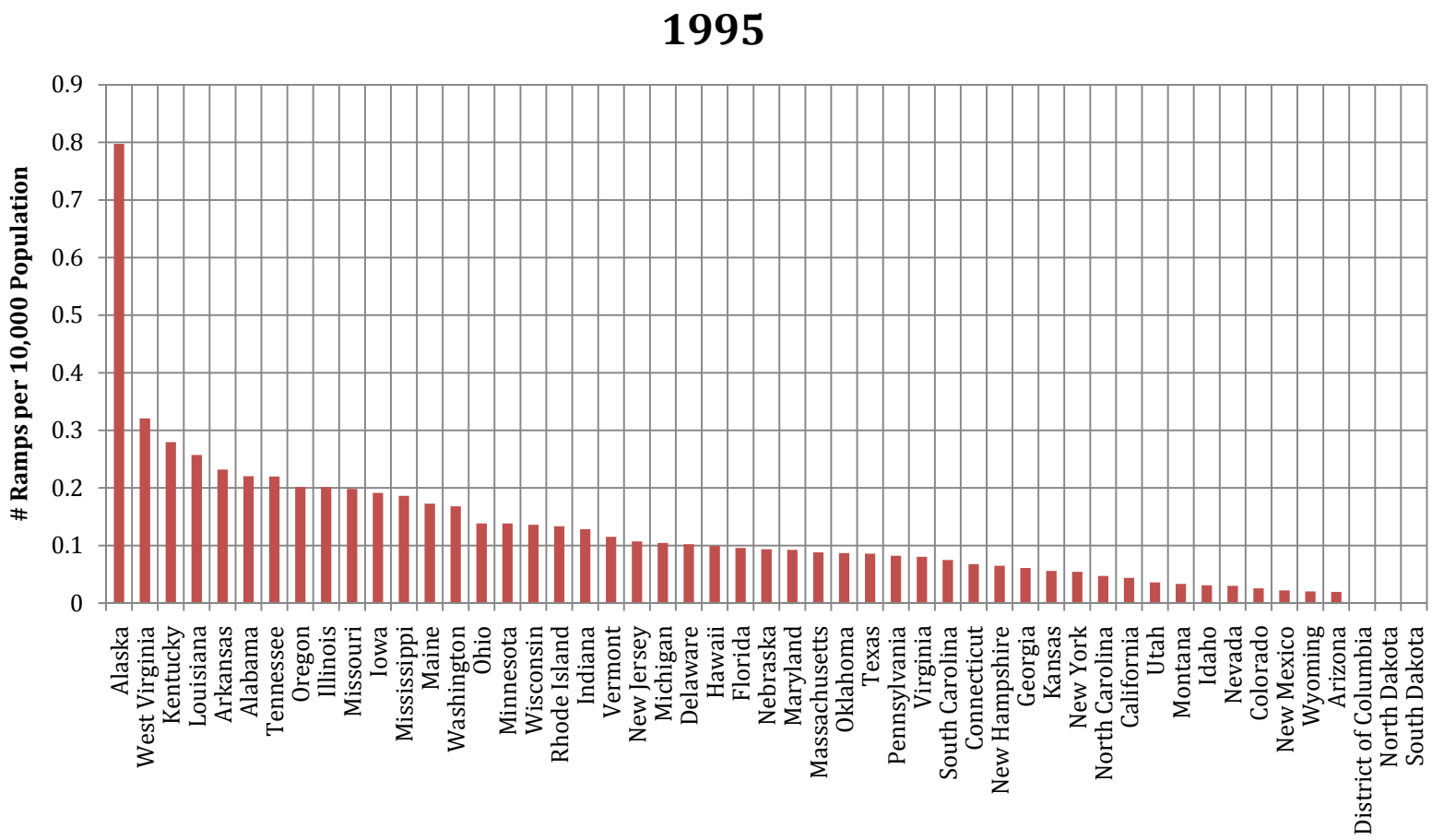


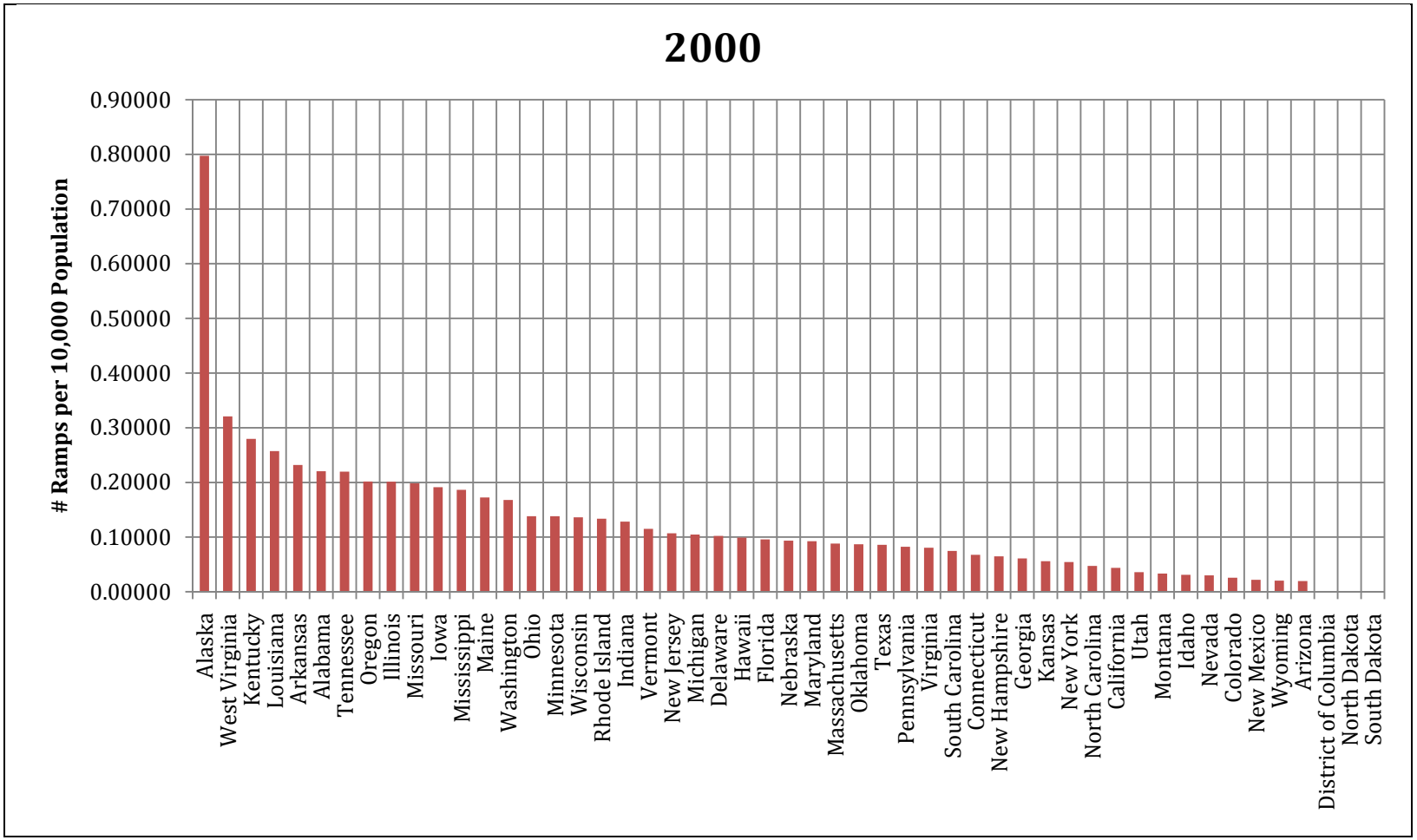

2000
Distance from the center of state to the closest international port
1,400.000
1,200.000
1,000.000
800.000
600.000
400.000
200.000
0.000
Minnesota
North Dakota
South Dakota
Colorado
Wyoming
Nebraska
Wisconsin
Iowa
New Mexico
Michigan
Illinois
Montana
Kansas
Missouri
Indiana
Idaho
Utah
Kentucky
Maine
Oklahoma
Ohio
Arkansas
Arizona
Tennessee
Nevada
West Virginia
Oregon
Texas
New Hampshire
Florida
Vermont
Georgia
North Carolina
New York
Mississippi
Pennsylvania
Alabama
California
Massachusetts
Rhode Island
Virginia
Louisiana
Washington
District of Columbia
South Carolina
Maryland
Connecticut
Delaware
New Jersey
Alaska
Hawaii

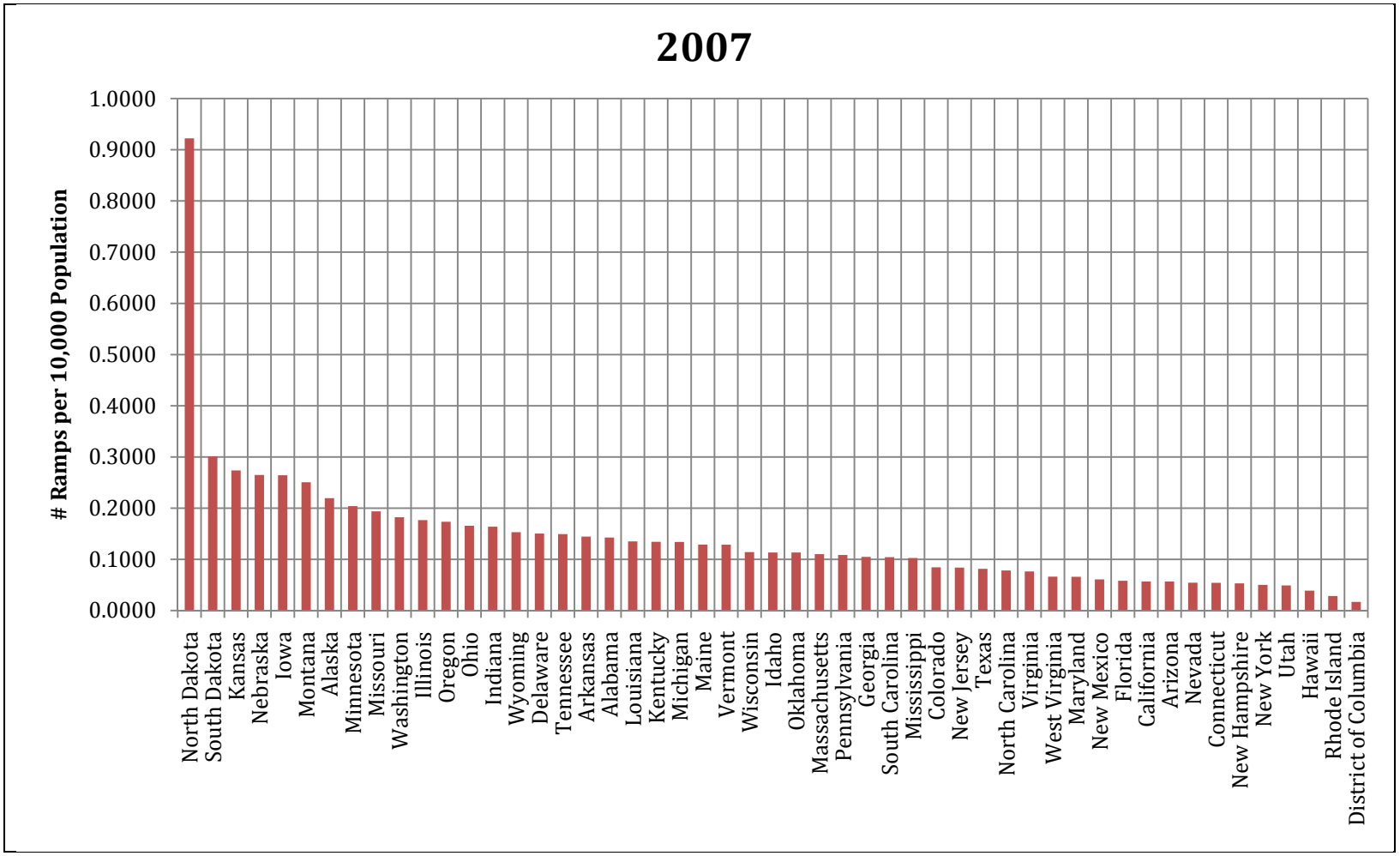

2007
Distance from the center of state to the closest international port
1400.000
1200.000
1000.000
800.000
600.000
400.000
200.000
0.000
Minnesota
South Dakota
North Dakota
Colorado
Wyoming
Nebraska
Iowa
Wisconsin
New Mexico
Illinois
Michigan
Kansas
Montana
Missouri
Utah
Idaho
Indiana
Kentucky
Maine
Oklahoma
Ohio
Arkansas
Arizona
Tennessee
Nevada
West Virginia
Oregon
Texas
New Hampshire
Vermont
Florida
Georgia
New York
North Carolina
Mississippi
Alabama
Pennsylvania
California
Massachusetts
Rhode Island
Virginia
Louisiana
Washington
District of Columbia
South Carolina
Maryland
Connecticut
Delaware
New Jersey
Alaska
Hawaii

Indicator #7	**Intermodal Connectivity**
Definition:	# Ramps per 10, 000 Population
Why it's important:	Intermodal transport refers to the shipment of goods that involves two or more modes of transport in a single journey. The best attributes of each mode of transport are combined in a system that yields the lowest cost of transportation for the supply chain. Efficiency is the prime rationale for intermodal transport, but accessibility is a further reason for using two or more modes of transport.
Criteria metric:	Supply
Contribution to Index: *State-by-State – 0.049* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transportation Atlas Database (NTAD) (http://www.bts.gov/publications/national_transportation_atlas_database/) and U.S. Census Bureau (http://www.census.gov/population/www/metroareas/metroarea.html)
Data issues & opportunities	(1) The NTAD data are available only in 2000 and 2007 from Bureau of Transportation Statistics (BTS). (2) The data in 1995 are assumed to be the same as those in 2000.
Observations: • Data show some unexpected fluctuations that must be explored.	

Historical Values:

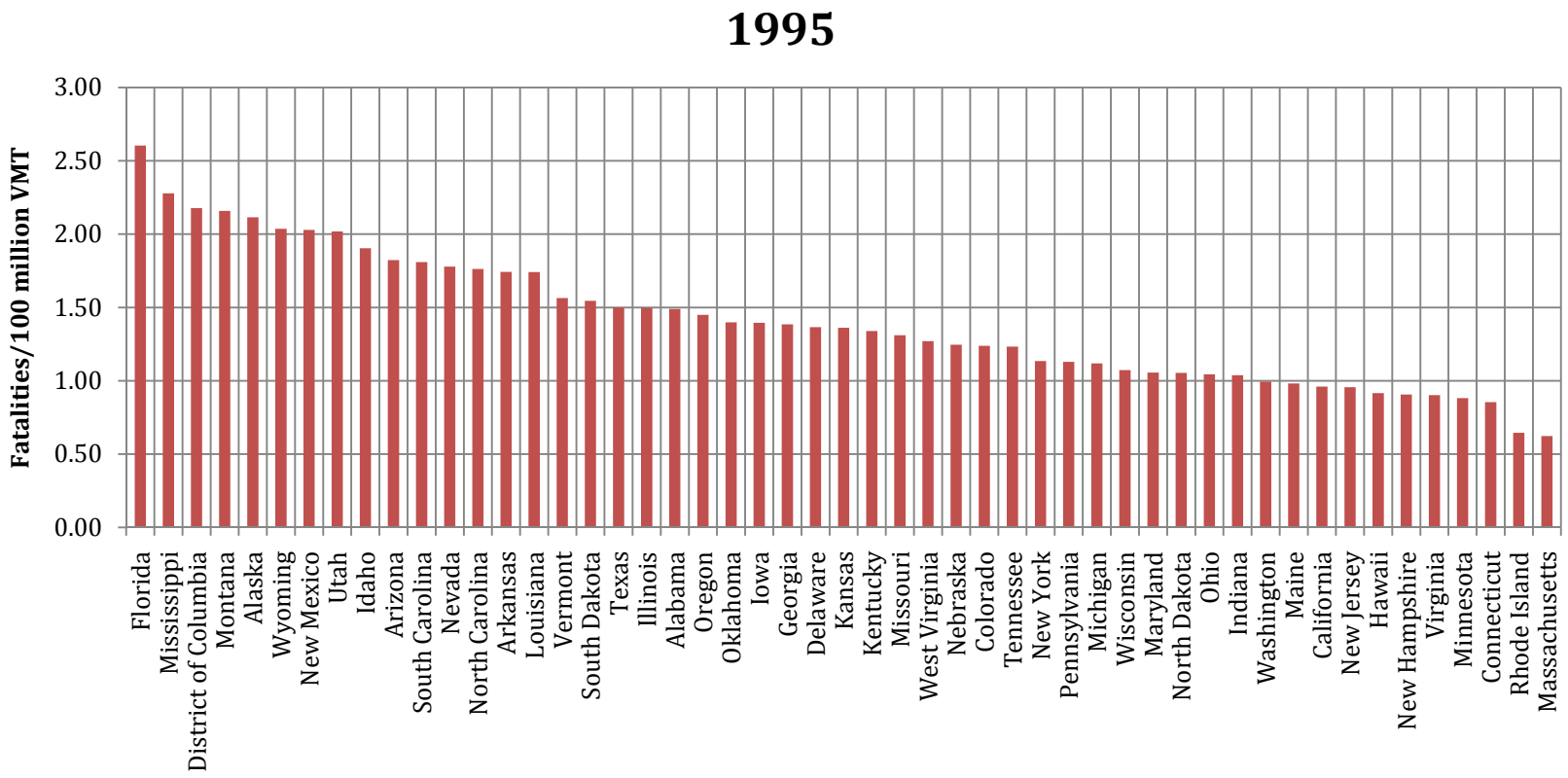


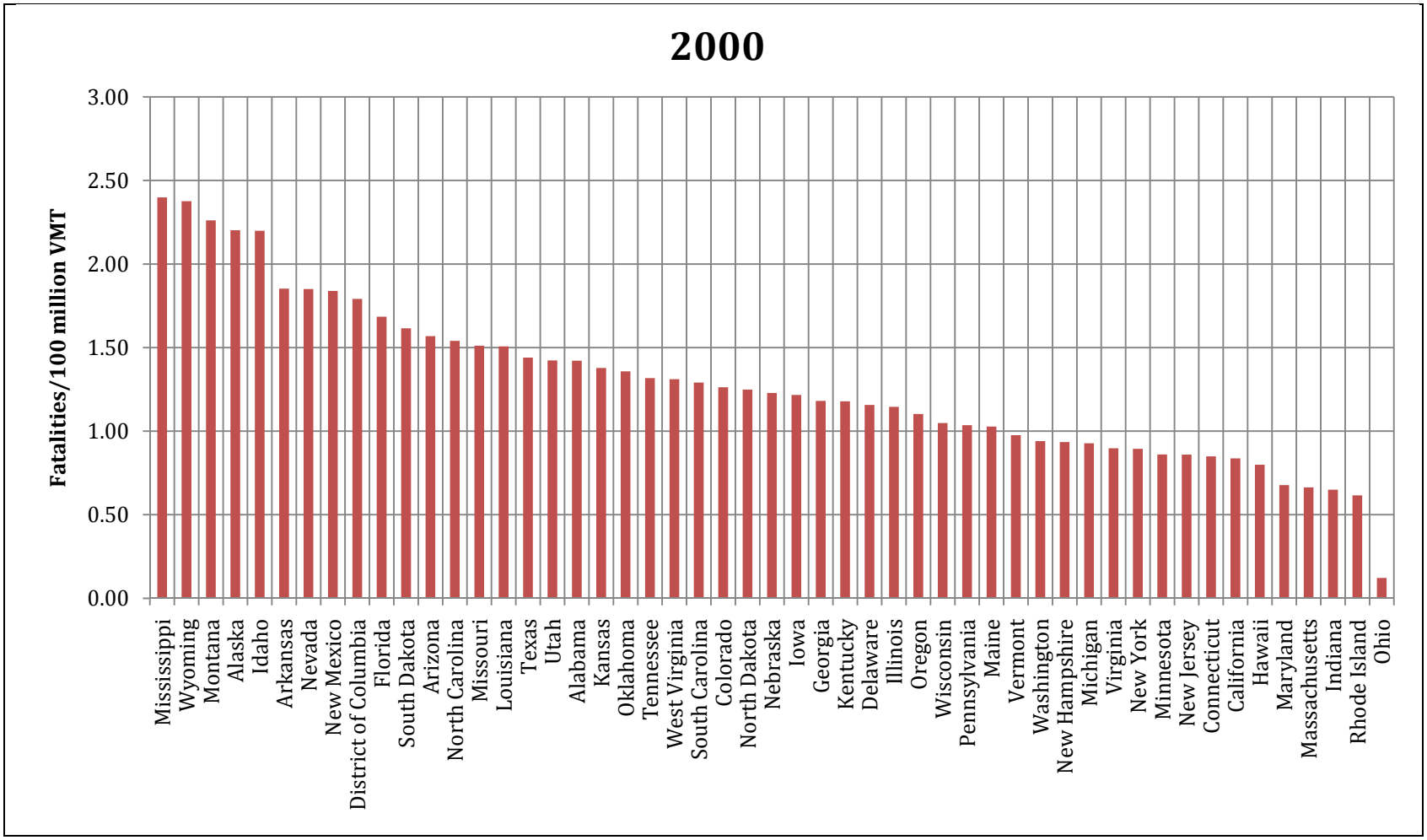

2000
Ramps per 10,000 Population
0.90000
0.80000
0.70000
0.60000
0.50000
0.40000
0.30000
0.20000
0.10000
0.00000
Alaska
West Virginia
Kentucky
Louisiana
Arkansas
Alabama
Tennessee
Oregon
Illinois
Missouri
Iowa
Mississippi
Maine
Washington
Ohio
Minnesota
Wisconsin
Rhode Island
Indiana
Vermont
New Jersey
Michigan
Delaware
Hawaii
Florida
Nebraska
Maryland
Massachusetts
Oklahoma
Texas
Pennsylvania
Virginia
South Carolina
Connecticut
New Hampshire
Georgia
Kansas
New York
North Carolina
California
Utah
Montana
Idaho
Nevada
Colorado
New Mexico
Wyoming
Arizona
District of Columbia
North Dakota
South Dakota

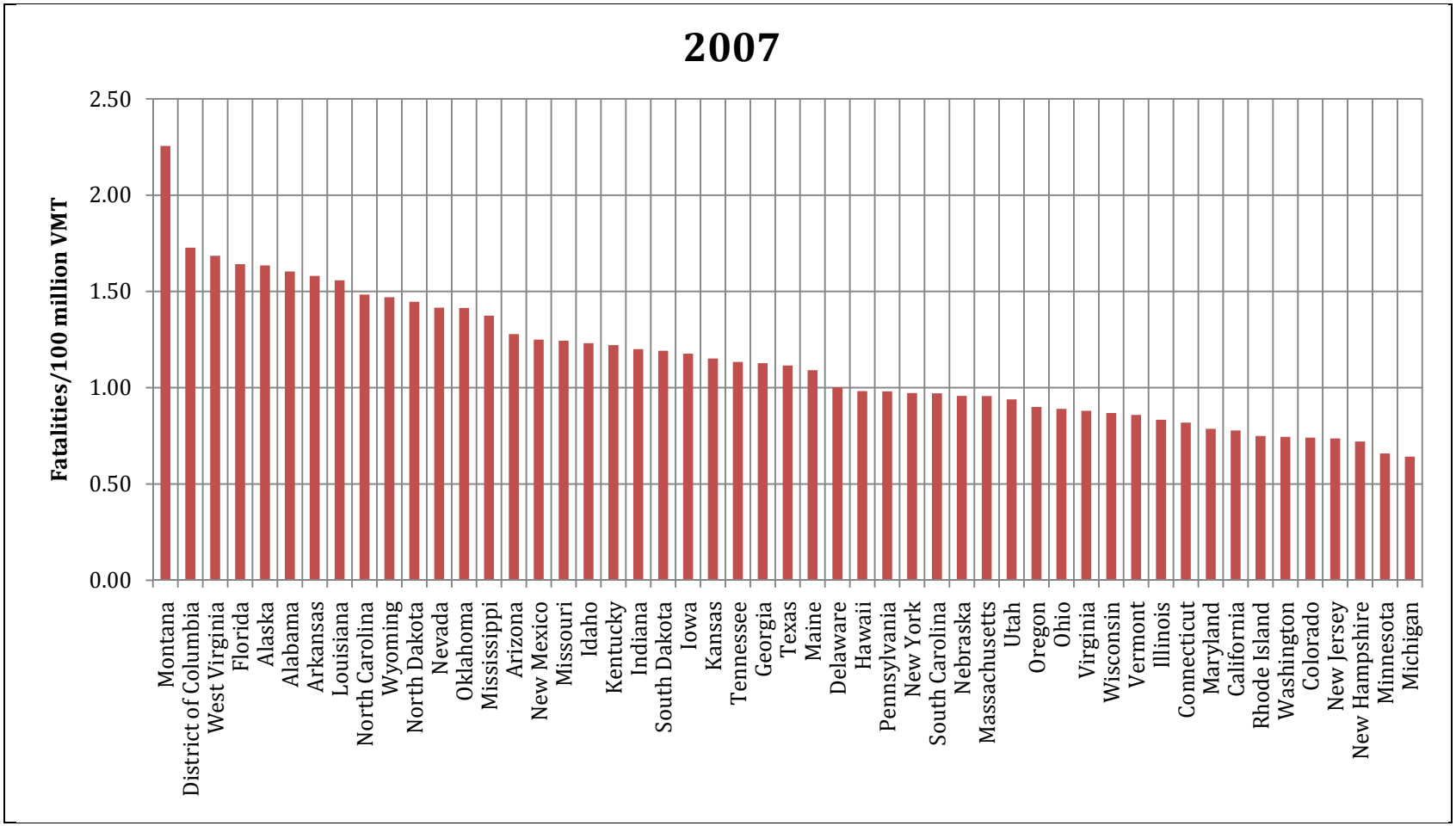

2007
Ramps per 10,000 Population
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
North Dakota
South Dakota
Kansas
Nebraska
Iowa
Montana
Alaska
Minnesota
Missouri
Washington
Illinois
Oregon
Ohio
Indiana
Wyoming
Delaware
Tennessee
Arkansas
Alabama
Louisiana
Kentucky
Michigan
Maine
Vermont
Wisconsin
Idaho
Oklahoma
Massachusetts
Pennsylvania
Georgia
South Carolina
Mississippi
Colorado
New Jersey
Texas
North Carolina
Virginia
West Virginia
Maryland
New Mexico
Florida
California
Arizona
Nevada
Connecticut
New Hampshire
New York
Utah
Hawaii
Rhode Island
District of Columbia

Indicator #8	**Highway Safety**
Definition:	Safety is measured by the total number of fatalities on a traffic way customarily open to the public in a state for a specific year divided by the total Vehicle Miles Traveled (VMT) (in 100 million) in this state during the same period.
Why it's important:	It provides an overall measure of highway safety.
Criteria metric:	Quality of Service
Contribution to Index: *State-by-State – 0.095* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	The number of fatalities data are from the Fatality Analysis Reporting System (FARS) (http://www-fars.nhtsa.dot.gov/Main/index.aspx). VMT data are obtained from the Highway Performance Monitoring System (HPMS) data.
Data issues & opportunities	
Observations: • While the ranking of anyone state changes from year to year, the overall trend among states is fairly consistent.	

Historical Values:

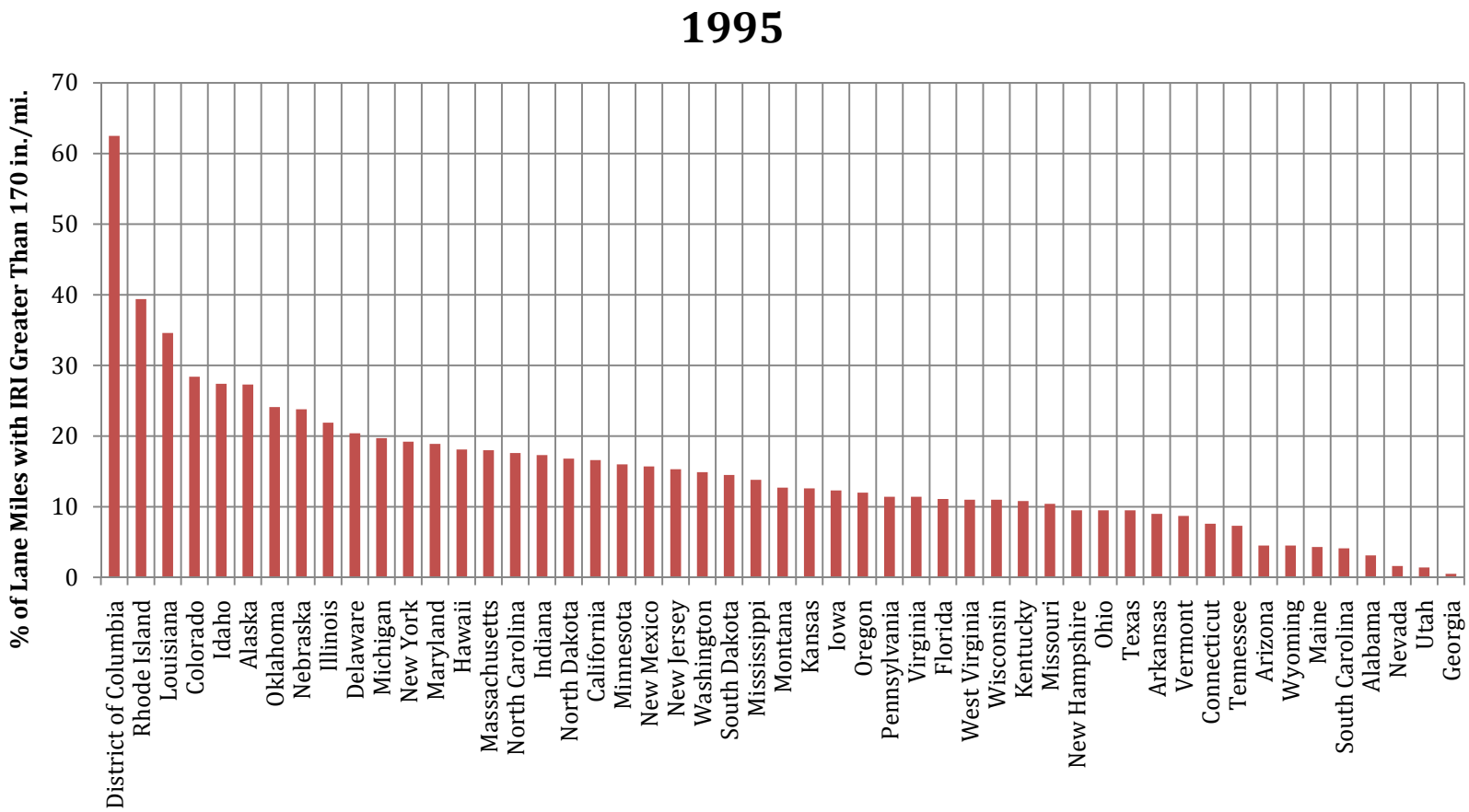


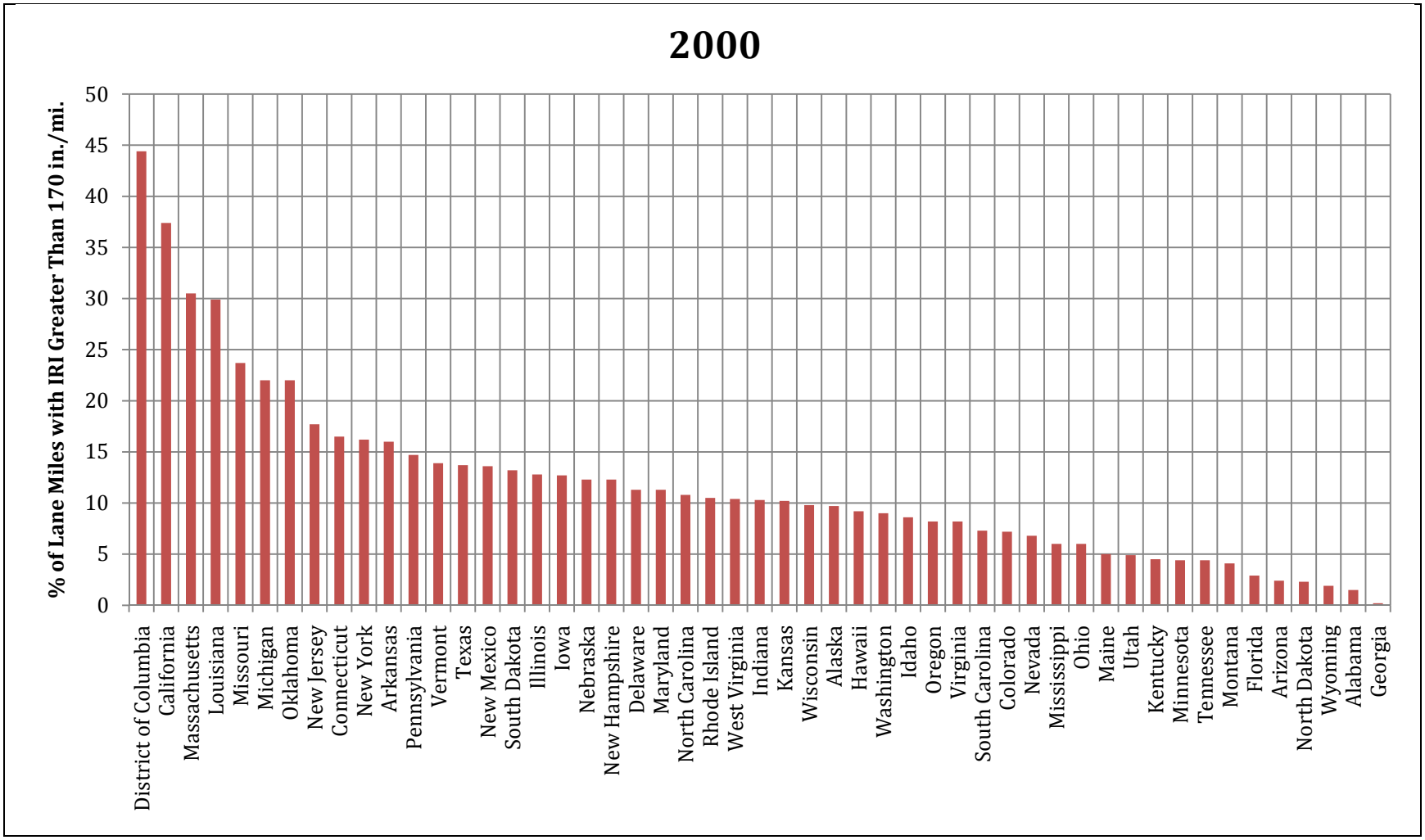

2000
Fatalities/100 million VMT
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Mississippi
Wyoming
Montana
Alaska
Idaho
Arkansas
Nevada
New Mexico
District of Columbia
Florida
South Dakota
Arizona
North Carolina
Missouri
Louisiana
Texas
Utah
Alabama
Kansas
Oklahoma
Tennessee
West Virginia
South Carolina
Colorado
North Dakota
Nebraska
Iowa
Georgia
Kentucky
Delaware
Illinois
Oregon
Wisconsin
Pennsylvania
Maine
Vermont
Washington
New Hampshire
Michigan
Virginia
New York
Minnesota
New Jersey
Connecticut
California
Hawaii
Maryland
Massachusetts
Indiana
Rhode Island
Ohio

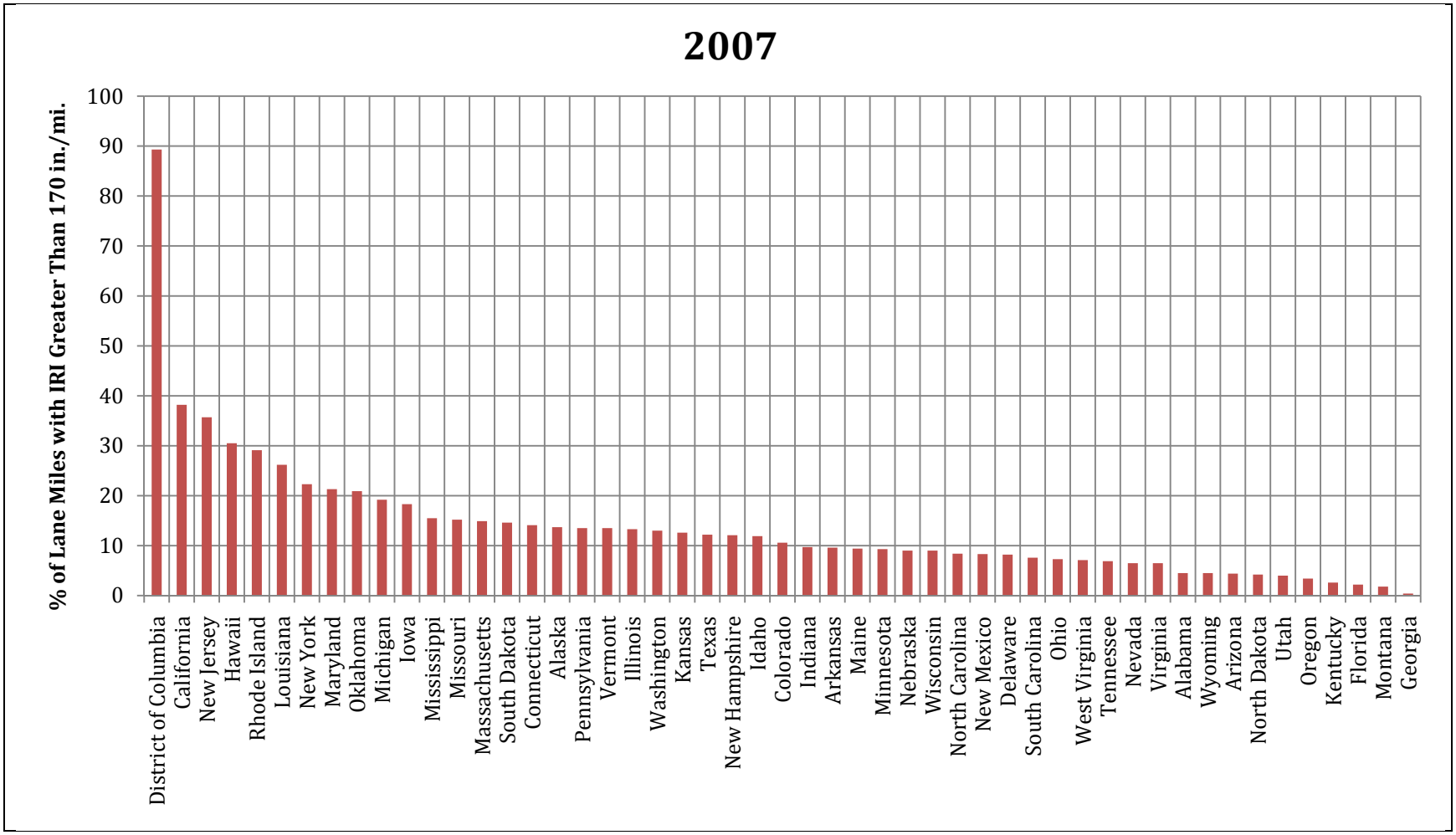

2007
Fatalities/100 million VMT
2.50
2.00
1.50
1.00
0.50
0.00
Montana
District of Columbia
West Virginia
Florida
Alaska
Alabama
Arkansas
Louisiana
North Carolina
Wyoming
North Dakota
Nevada
Oklahoma
Mississippi
Arizona
New Mexico
Missouri
Idaho
Kentucky
Indiana
South Dakota
Iowa
Kansas
Tennessee
Georgia
Texas
Maine
Delaware
Hawaii
Pennsylvania
New York
South Carolina
Nebraska
Massachusetts
Utah
Oregon
Ohio
Virginia
Wisconsin
Vermont
Illinois
Connecticut
Maryland
California
Rhode Island
Washington
Colorado
New Jersey
New Hampshire
Minnesota
Michigan

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
Contribution to Index: *State-by-State – 0.036* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	The IRI data are obtained from the Highway Performance Monitoring System (HPMS) data. The threshold for "Acceptable" ride quality used is set as 170 in./mi.
Data issues & opportunities	FHWA needs either an IRI or a PSR value coded for every sample section. On sample sections where IRI is not available, a PSR value smaller than 2.5 is used for the indicator.
Observations: • Most states are reducing their lane miles of rough roads.	

Historical Values:

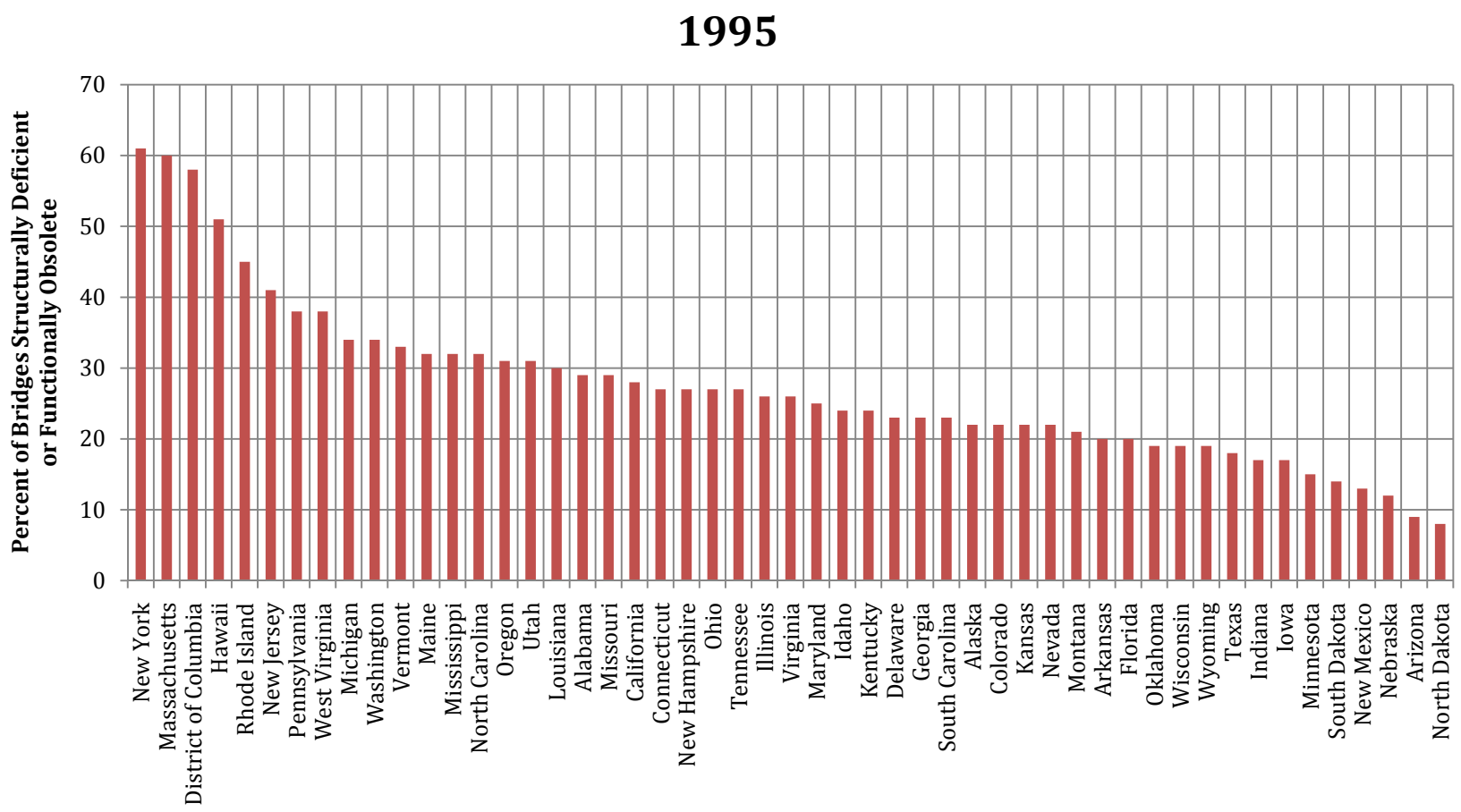


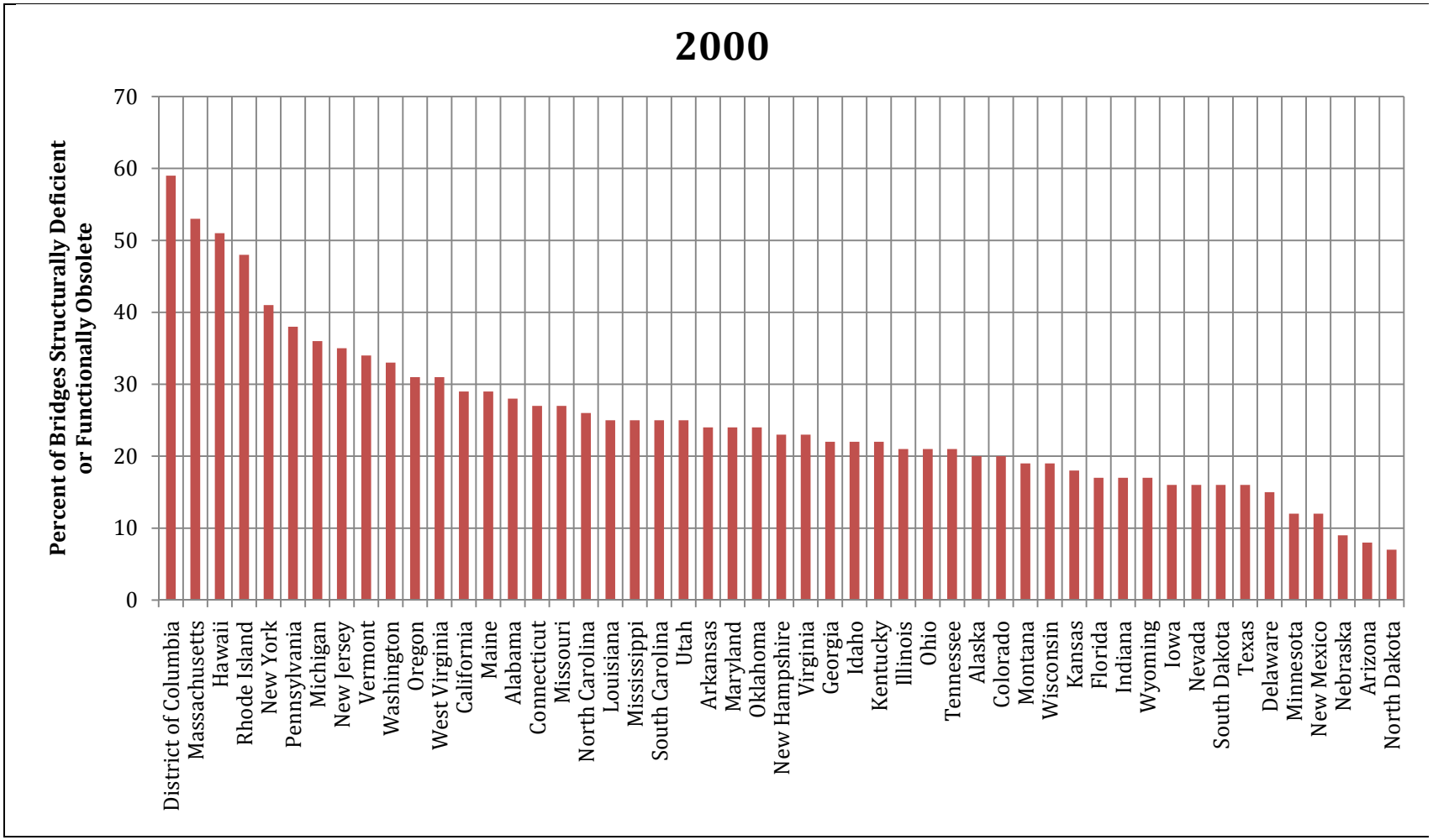

2000
% of Lane Miles with IRI Greater Than 170 in./mi.
50
45
40
35
30
25
20
15
10
5
0
District of Columbia
California
Massachusetts
Louisiana
Missouri
Michigan
Oklahoma
New Jersey
Connecticut
New York
Arkansas
Pennsylvania
Vermont
Texas
New Mexico
South Dakota
Illinois
Iowa
Nebraska
New Hampshire
Delaware
Maryland
North Carolina
Rhode Island
West Virginia
Indiana
Kansas
Wisconsin
Alaska
Hawaii
Washington
Idaho
Oregon
Virginia
South Carolina
Colorado
Nevada
Mississippi
Ohio
Maine
Utah
Kentucky
Minnesota
Tennessee
Montana
Florida
Arizona
North Dakota
Wyoming
Alabama
Georgia

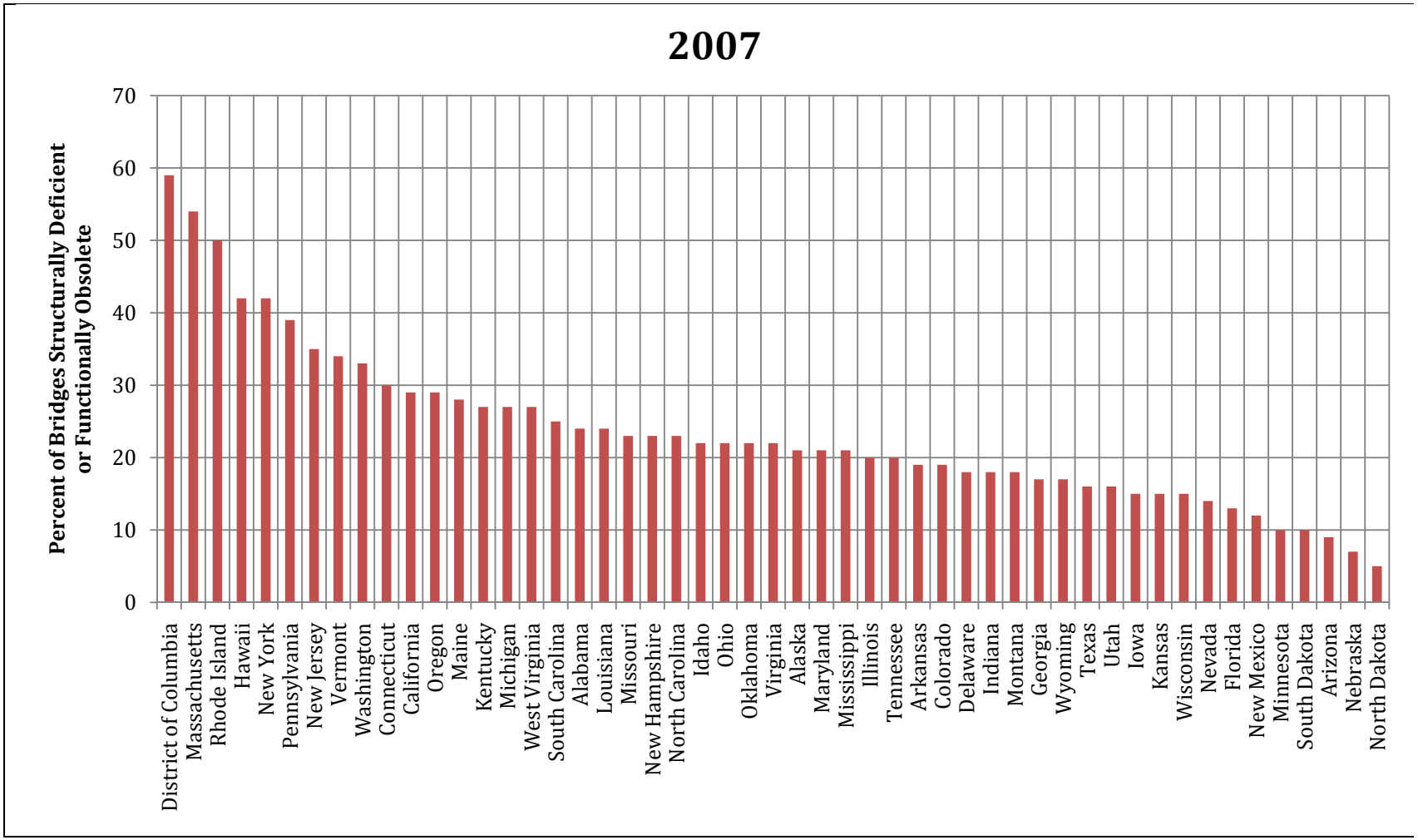

2007
% of Lane Miles with IRI Greater Than 170 in./mi.
100
90
80
70
60
50
40
30
20
10
0
District of Columbia
California
New Jersey
Hawaii
Rhode Island
Louisiana
New York
Maryland
Oklahoma
Michigan
Iowa
Mississippi
Missouri
Massachusetts
South Dakota
Connecticut
Alaska
Pennsylvania
Vermont
Illinois
Washington
Kansas
Texas
New Hampshire
Idaho
Colorado
Indiana
Arkansas
Maine
Minnesota
Nebraska
Wisconsin
North Carolina
New Mexico
Delaware
South Carolina
Ohio
West Virginia
Tennessee
Nevada
Virginia
Alabama
Wyoming
Arizona
North Dakota
Utah
Oregon
Kentucky
Florida
Montana
Georgia

Indicator #10	**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
Contribution to Index: *State-by-State – 0.102* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Bridge Inventory (NBI) from Federal Highway Administration (FHWA).
Data issues & opportunities	
Observations: • The general trend for any state shows an improvement from 1995 to 2000 and then steady state conditions from 2000 to 2007.	

Historical Values:

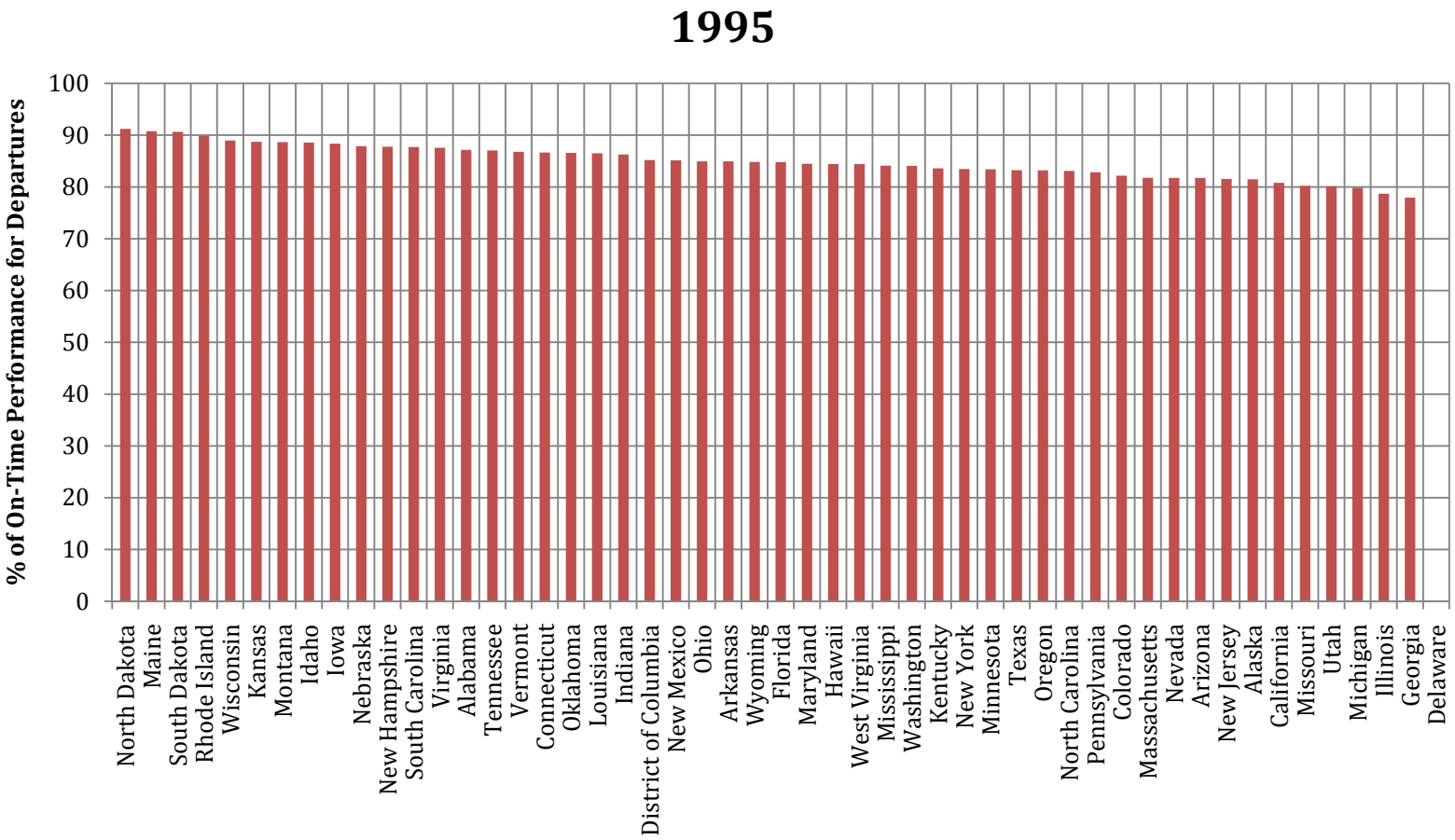


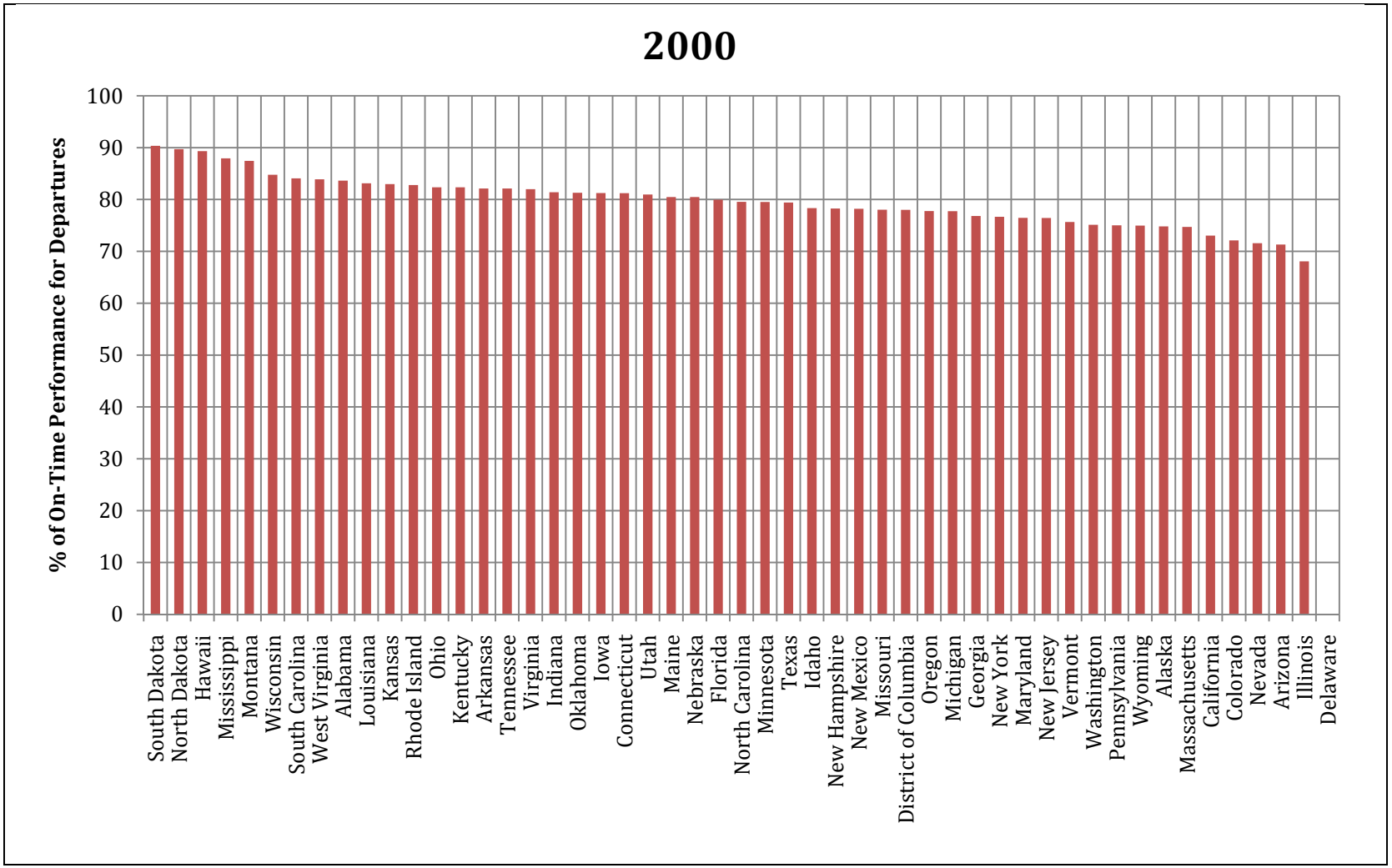

2000
Percent of Bridges Structurally Deficient or Functionally Obsolete
70
60
50
40
30
20
10
0
District of Columbia
Massachusetts
Hawaii
Rhode Island
New York
Pennsylvania
Michigan
New Jersey
Vermont
Washington
Oregon
West Virginia
California
Maine
Alabama
Connecticut
Missouri
North Carolina
Louisiana
Mississippi
South Carolina
Utah
Arkansas
Maryland
Oklahoma
New Hampshire
Virginia
Georgia
Idaho
Kentucky
Illinois
Ohio
Tennessee
Alaska
Colorado
Montana
Wisconsin
Kansas
Florida
Indiana
Wyoming
Iowa
Nevada
South Dakota
Texas
Delaware
Minnesota
New Mexico
Nebraska
Arizona
North Dakota

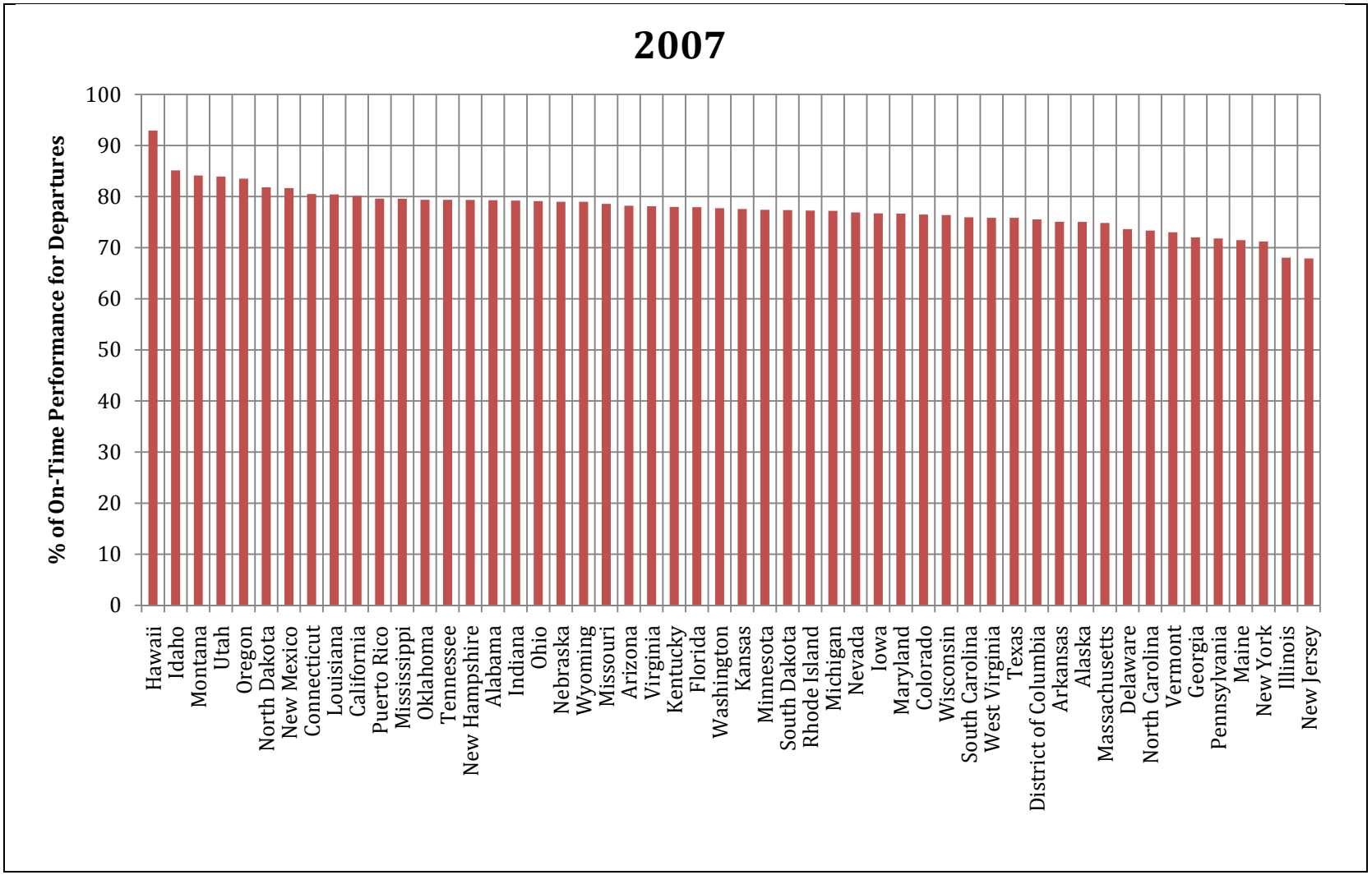

2007
Percent of Bridges Structurally Deficient or Functionally Obsolete
70
60
50
40
30
20
10
0
District of Columbia
Massachusetts
Rhode Island
Hawaii
New York
Pennsylvania
New Jersey
Vermont
Washington
Connecticut
California
Oregon
Maine
Kentucky
Michigan
West Virginia
South Carolina
Alabama
Louisiana
Missouri
New Hampshire
North Carolina
Idaho
Ohio
Oklahoma
Virginia
Alaska
Maryland
Mississippi
Illinois
Tennessee
Arkansas
Colorado
Delaware
Indiana
Montana
Georgia
Wyoming
Texas
Utah
Iowa
Kansas
Wisconsin
Nevada
Florida
New Mexico
Minnesota
South Dakota
Arizona
Nebraska
North Dakota

Indicator #11	**Air Congestion**
Definition:	Percent of On-Time performance for Departures
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:	Quality of Service
Contribution to Index: *State-by-State – 0.031* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	The data are obtained from the Office of Airline Information, Bureau of Transportation Statistics (BTS) (http://www.transtats.bts.gov/OT_Delay/OT_DelayCause1.asp) and Terminal Area Forecast (http://aspm.faa.gov/main/taf.asp).
Data issues & opportunities	If multiple airports exist, the on-time performance data are weighted based on the number of enplanements at each airport.
Observations: • The indicator reflect the focused effort by airlines to improve on-time performance.	

Historical Values:

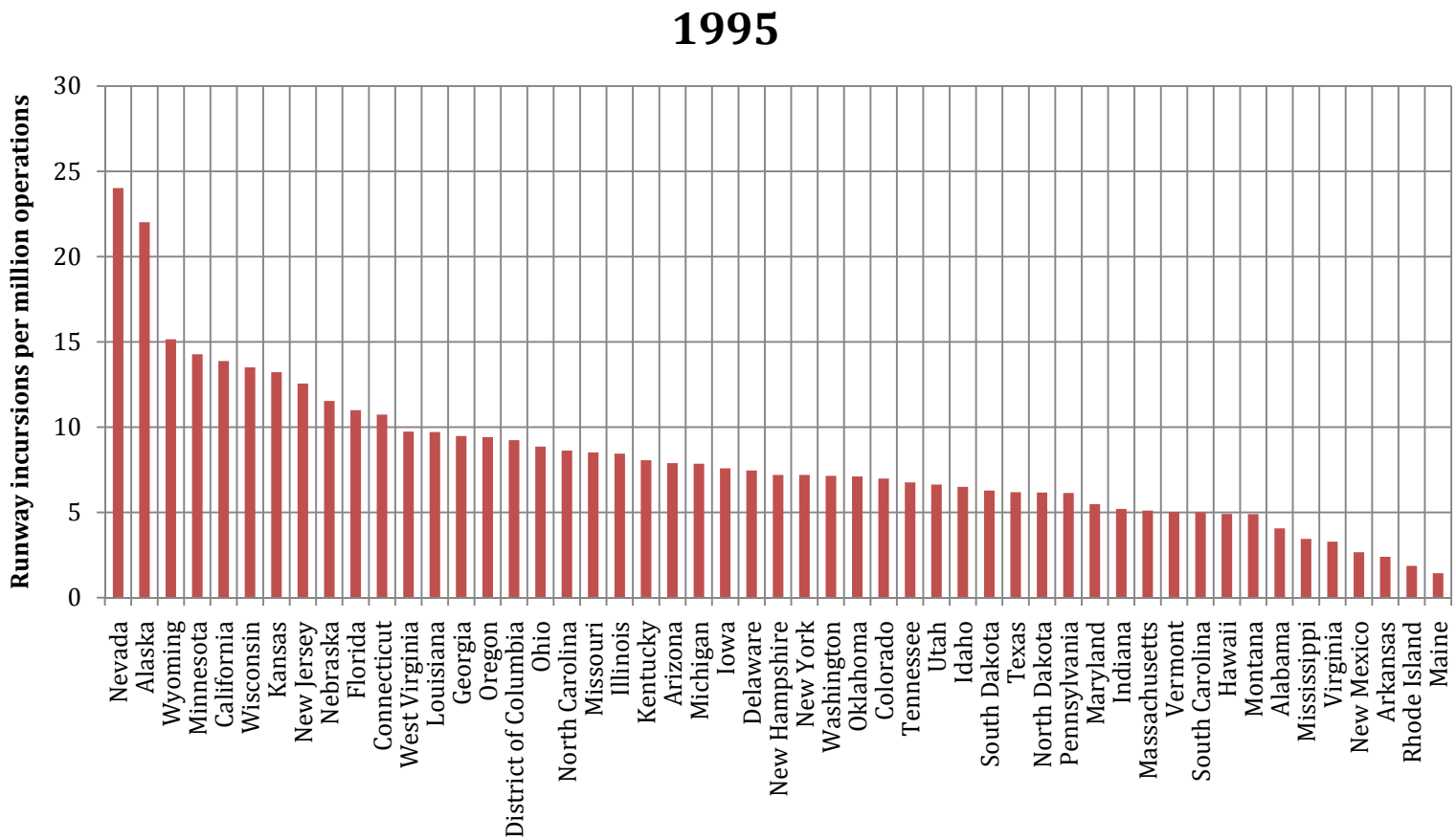


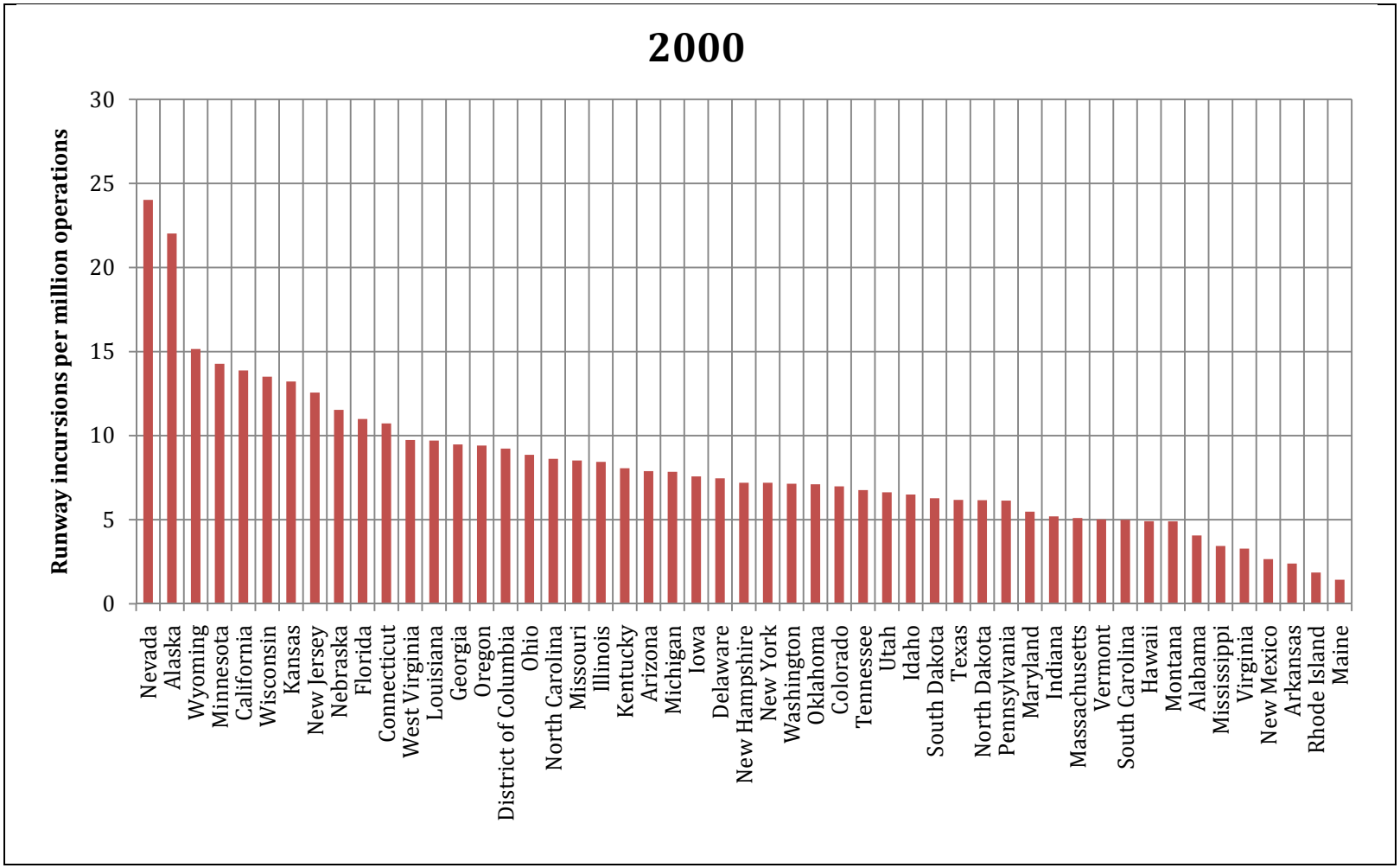

2000
% of On-Time Performance for Departures
100
90
80
70
60
50
40
30
20
10
0
South Dakota
North Dakota
Hawaii
Mississippi
Montana
Wisconsin
South Carolina
West Virginia
Alabama
Louisiana
Kansas
Rhode Island
Ohio
Kentucky
Arkansas
Tennessee
Virginia
Indiana
Oklahoma
Iowa
Connecticut
Utah
Maine
Nebraska
Florida
North Carolina
Minnesota
Texas
Idaho
New Hampshire
New Mexico
Missouri
District of Columbia
Oregon
Michigan
Georgia
New York
Maryland
New Jersey
Vermont
Washington
Pennsylvania
Wyoming
Alaska
Massachusetts
California
Colorado
Nevada
Arizona
Illinois
Delaware

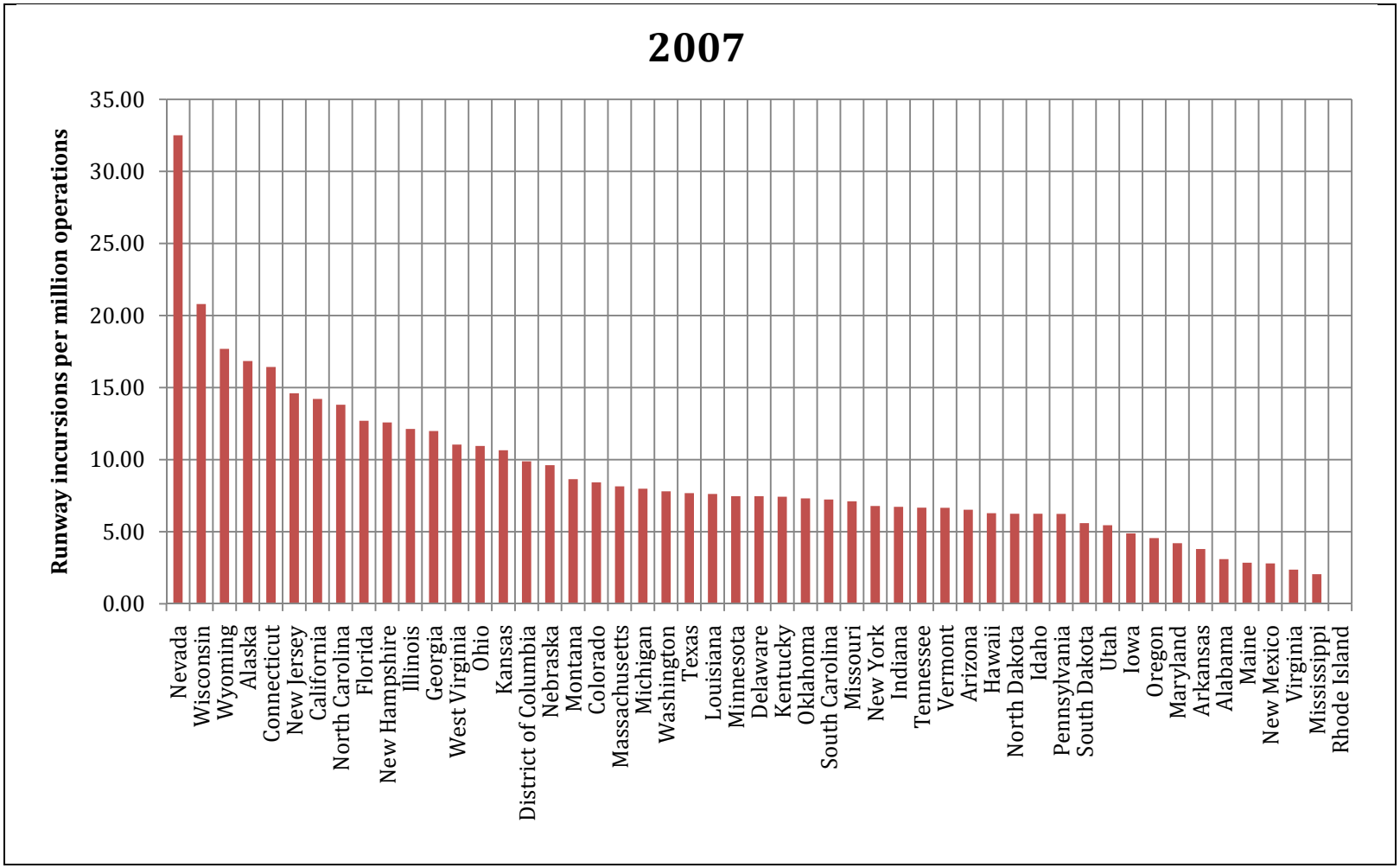

2007
% of On-Time Performance for Departures
100
90
80
70
60
50
40
30
20
10
0
Hawaii
Idaho
Montana
Utah
Oregon
North Dakota
New Mexico
Connecticut
Louisiana
California
Puerto Rico
Mississippi
Oklahoma
Tennessee
New Hampshire
Alabama
Indiana
Ohio
Nebraska
Wyoming
Missouri
Arizona
Virginia
Kentucky
Florida
Washington
Kansas
Minnesota
South Dakota
Rhode Island
Michigan
Nevada
Iowa
Maryland
Colorado
Wisconsin
South Carolina
West Virginia
Texas
District of Columbia
Arkansas
Alaska
Massachusetts
Delaware
North Carolina
Vermont
Georgia
Pennsylvania
Maine
New York
Illinois
New Jersey

Indicator #12	**Air Safety**
Definition:	Runway Incursions per Million Operations
Why it's important:	A runway incursion occurs any time an airplane, vehicle, person or object on the ground creates a collision hazard with an airplane that is taking off or landing at an airport under the supervision of Air Traffic Control (ATC).
Criteria metric:	Quality of Service
Contribution to Index: *State-by-State – 0.071* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	Runway Safety Office Runway Incursion Database (http://www.asias.faa.gov/portal/page/portal/ASIAS_PAGES/ASIAS_HOME/WELCOME_TAB) maintained by the FAA Office of Runway Safety; # of operations are obtained from the Terminal Area Forecast (TAF) (http://aspm.faa.gov/main/taf.asp) system from FAA.
Data issues & opportunities	The runway incursion data are available after 2001. 2000 takes the data in 2002, and 1995 the average of 2002 and 2007.
Observations: • While this indicator is highly variable for any state the overall distribution for all states is fairly consistent.	

Historical Values:

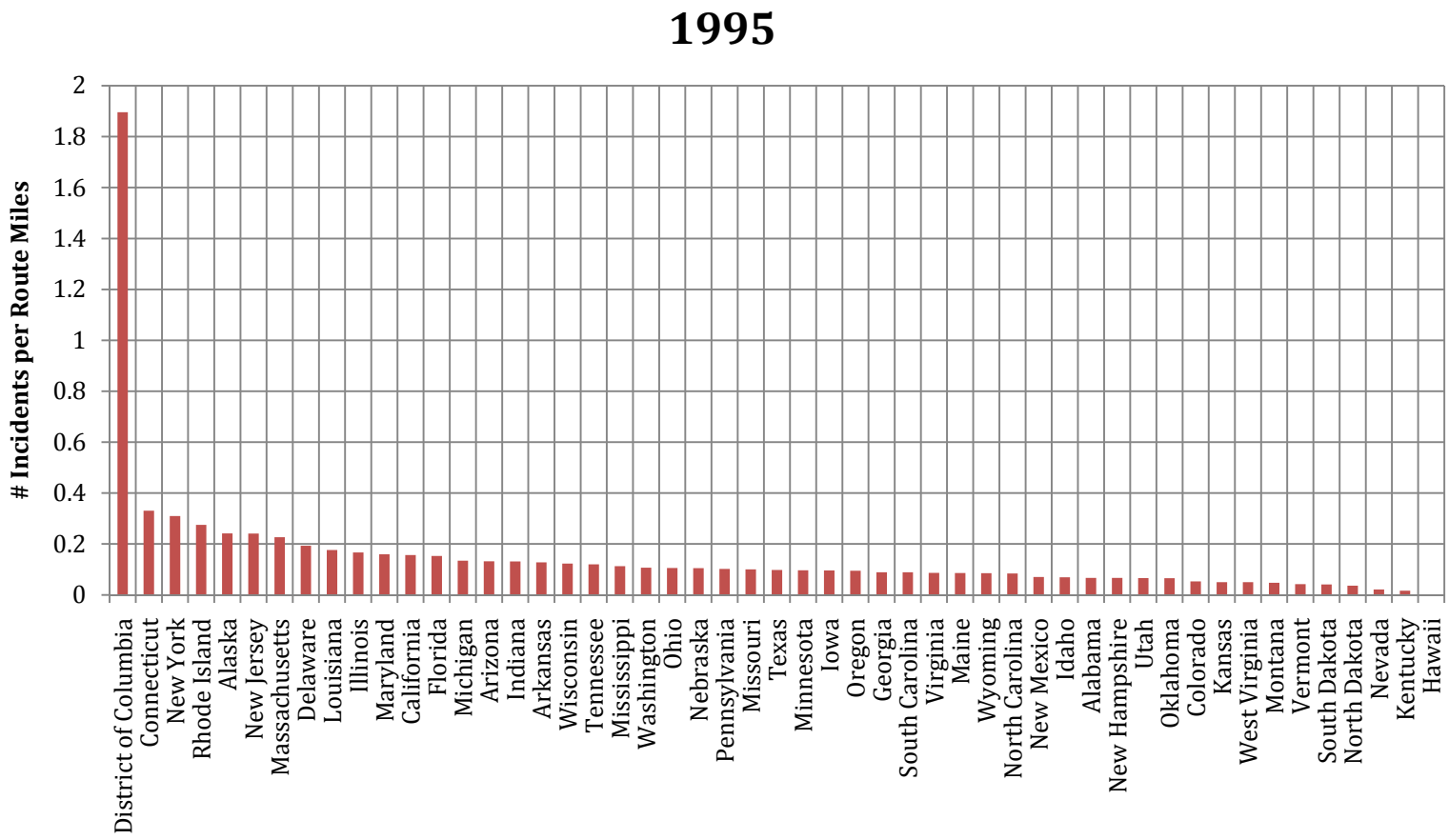


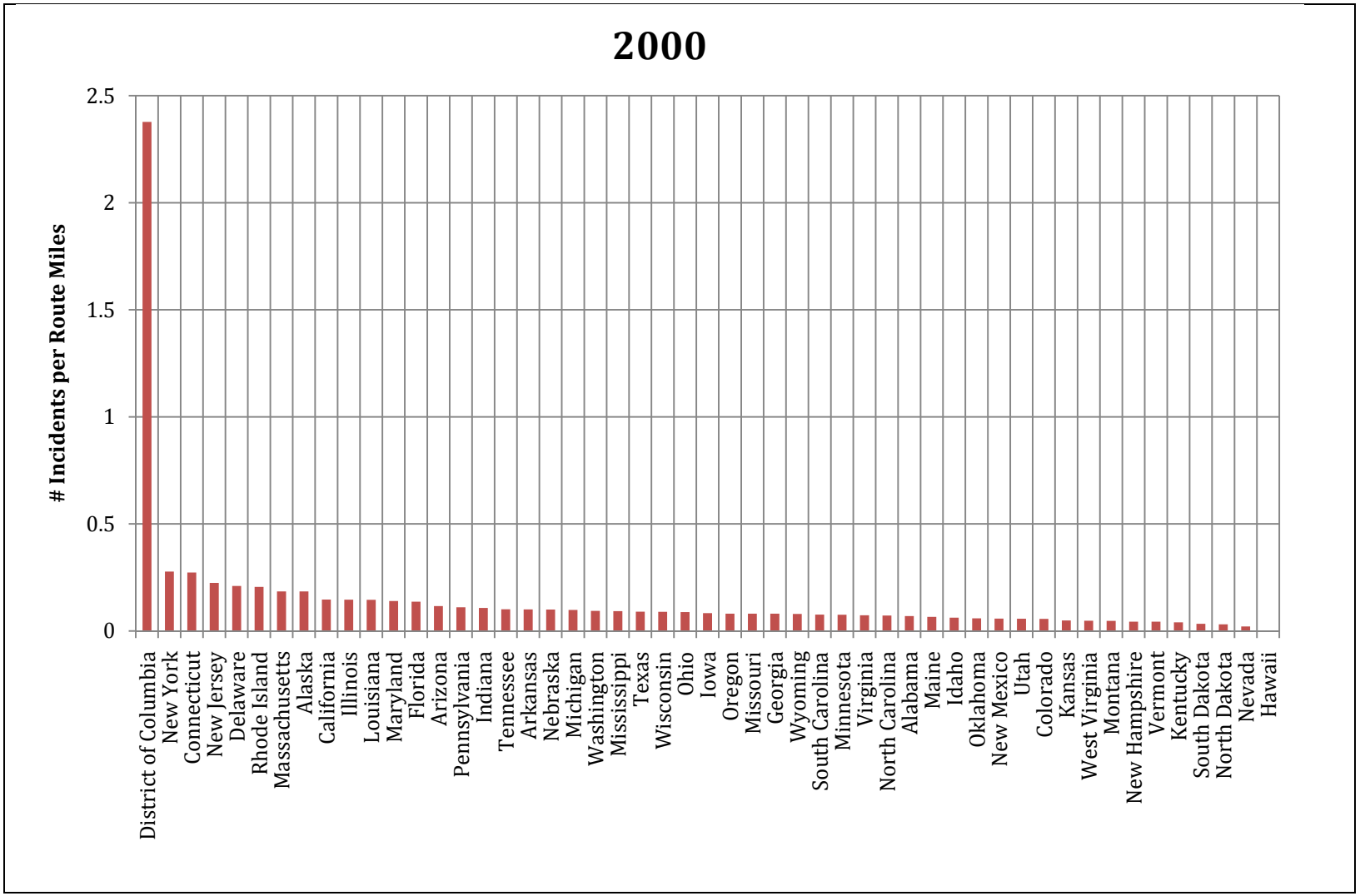

2000
Runway incursions per million operations
30
25
20
15
10
5
0
Nevada
Alaska
Wyoming
Minnesota
California
Wisconsin
Kansas
New Jersey
Nebraska
Florida
Connecticut
West Virginia
Louisiana
Georgia
Oregon
District of Columbia
Ohio
North Carolina
Missouri
Illinois
Kentucky
Arizona
Michigan
Iowa
Delaware
New Hampshire
New York
Washington
Oklahoma
Colorado
Tennessee
Utah
Idaho
South Dakota
Texas
North Dakota
Pennsylvania
Maryland
Indiana
Massachusetts
Vermont
South Carolina
Hawaii
Montana
Alabama
Mississippi
Virginia
New Mexico
Arkansas
Rhode Island
Maine

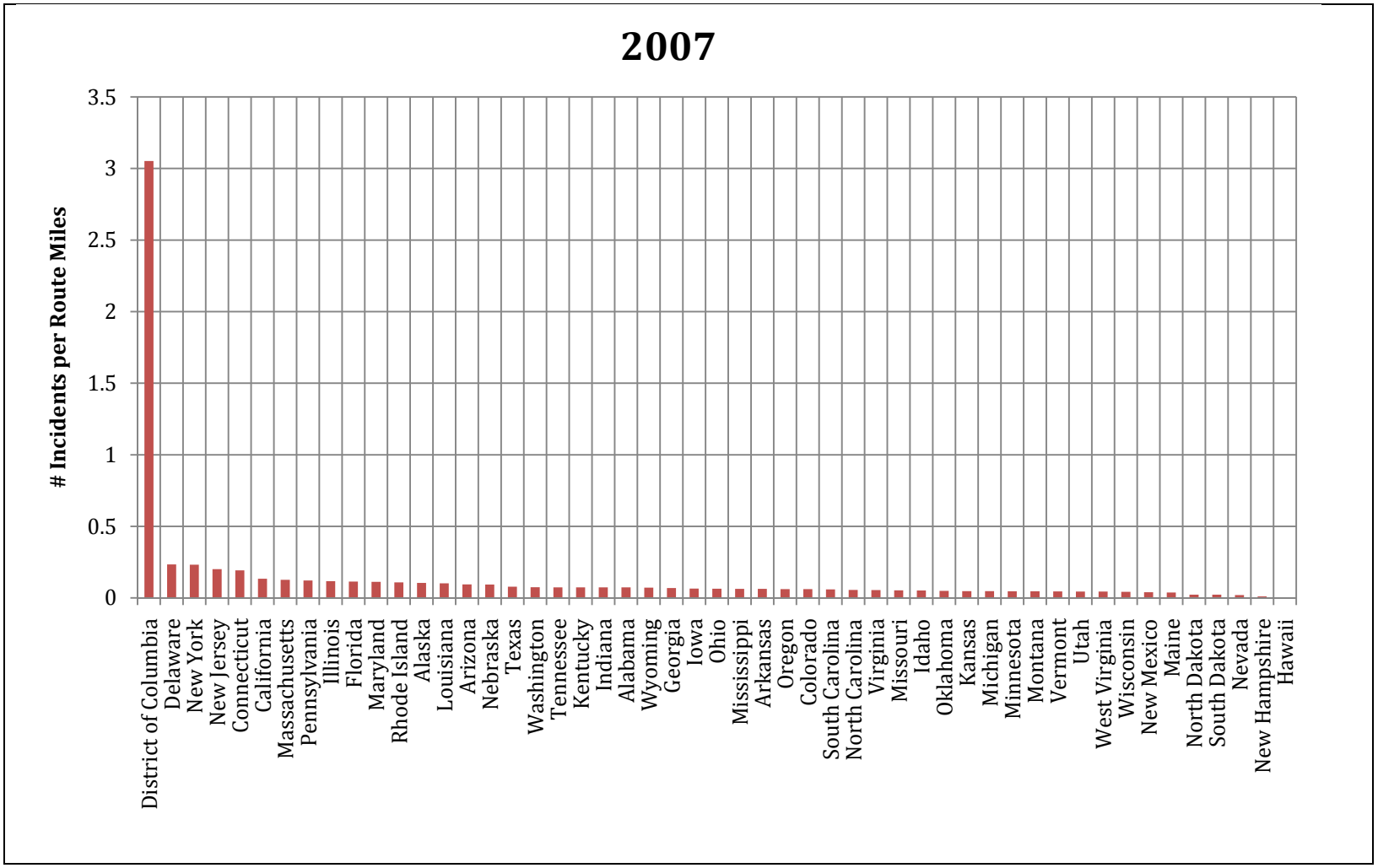

2007
Runway incursions per million operations
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Nevada
Wisconsin
Wyoming
Alaska
Connecticut
New Jersey
California
North Carolina
Florida
New Hampshire
Illinois
Georgia
West Virginia
Ohio
Kansas
District of Columbia
Nebraska
Montana
Colorado
Massachusetts
Michigan
Washington
Texas
Louisiana
Minnesota
Delaware
Kentucky
Oklahoma
South Carolina
Missouri
New York
Indiana
Tennessee
Vermont
Arizona
Hawaii
North Dakota
Idaho
Pennsylvania
South Dakota
Utah
Iowa
Oregon
Maryland
Arkansas
Alabama
Maine
New Mexico
Virginia
Mississippi
Rhode Island

Indicator #13	**Rail Safety**
Definition:	Number of Incidents per Million Train Miles
Why it's important:	The "Highest Priority of the Federal Railroad Administration is the Safety of the U.S. railroad system".
Criteria metric:	Quality of Service
Contribution to Index: *State-by-State – 0.050* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	State Transportation Statistics (http://www.bts.gov/publications/state_transportation_statistics/).
Data issues & opportunities	The data are available only in 2000 and 2007. The data in 1995 are extrapolated based on those in 2000 and 2007.
Observations: • Similar patterns are observed for all states for all years.	

Historical Values:

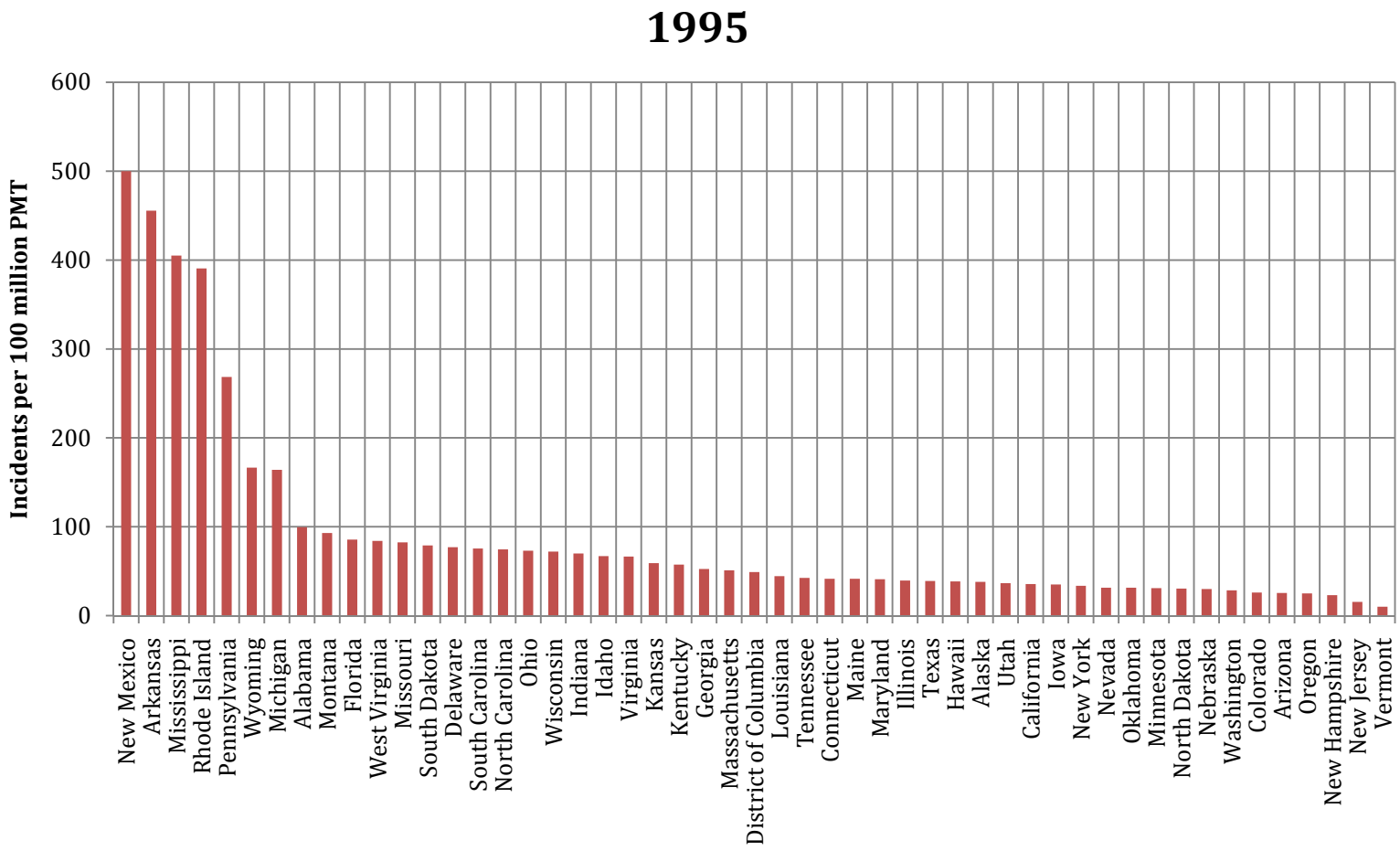


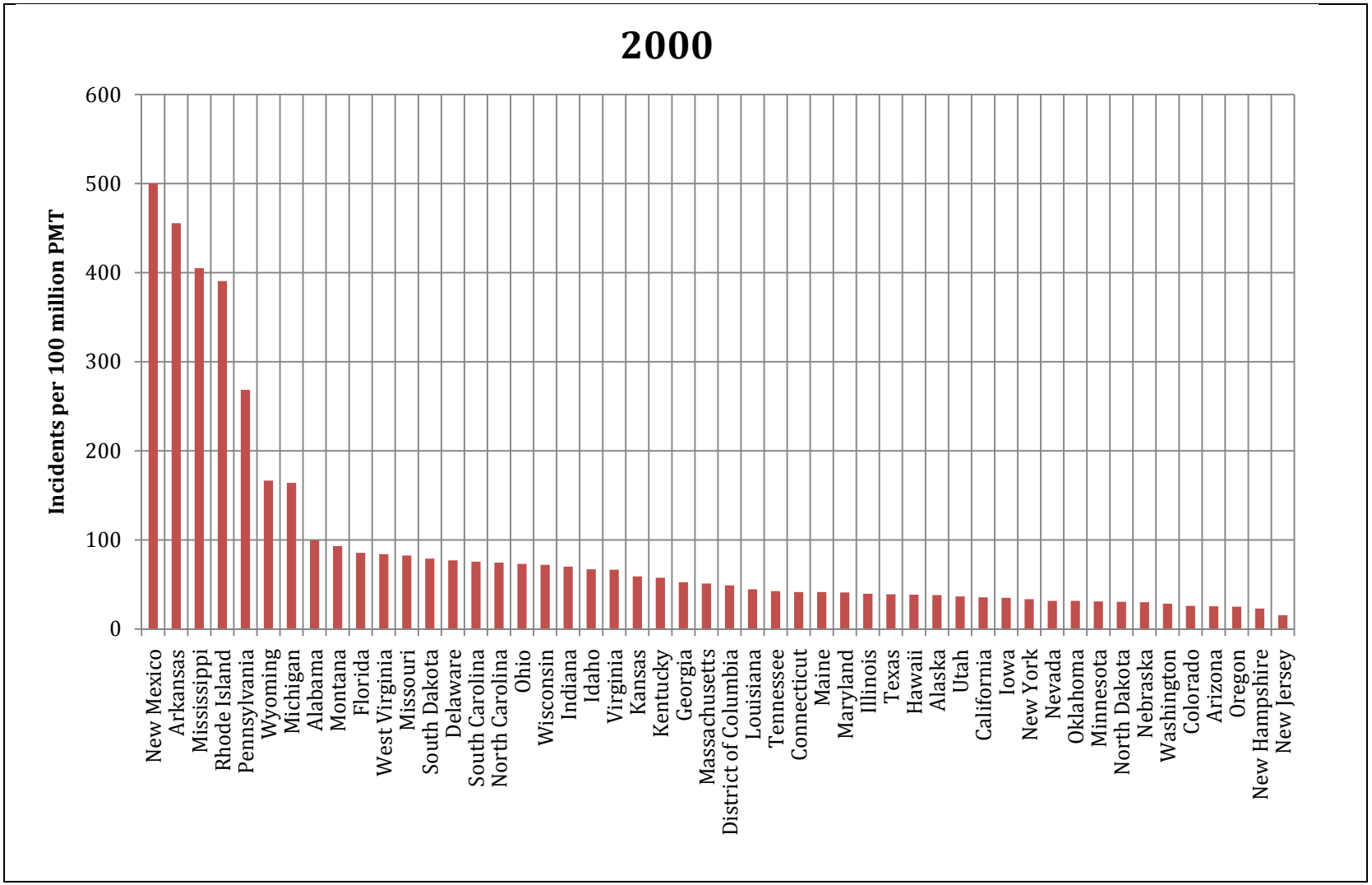

2000
Incidents per Route Miles
2.5
2
1.5
1
0.5
0
District of Columbia
New York
Connecticut
New Jersey
Delaware
Rhode Island
Massachusetts
Alaska
California
Illinois
Louisiana
Maryland
Florida
Arizona
Pennsylvania
Indiana
Tennessee
Arkansas
Nebraska
Michigan
Washington
Mississippi
Texas
Wisconsin
Ohio
Iowa
Oregon
Missouri
Georgia
Wyoming
South Carolina
Minnesota
Virginia
North Carolina
Alabama
Maine
Idaho
Oklahoma
New Mexico
Utah
Colorado
Kansas
West Virginia
Montana
New Hampshire
Vermont
Kentucky
South Dakota
North Dakota
Nevada
Hawaii

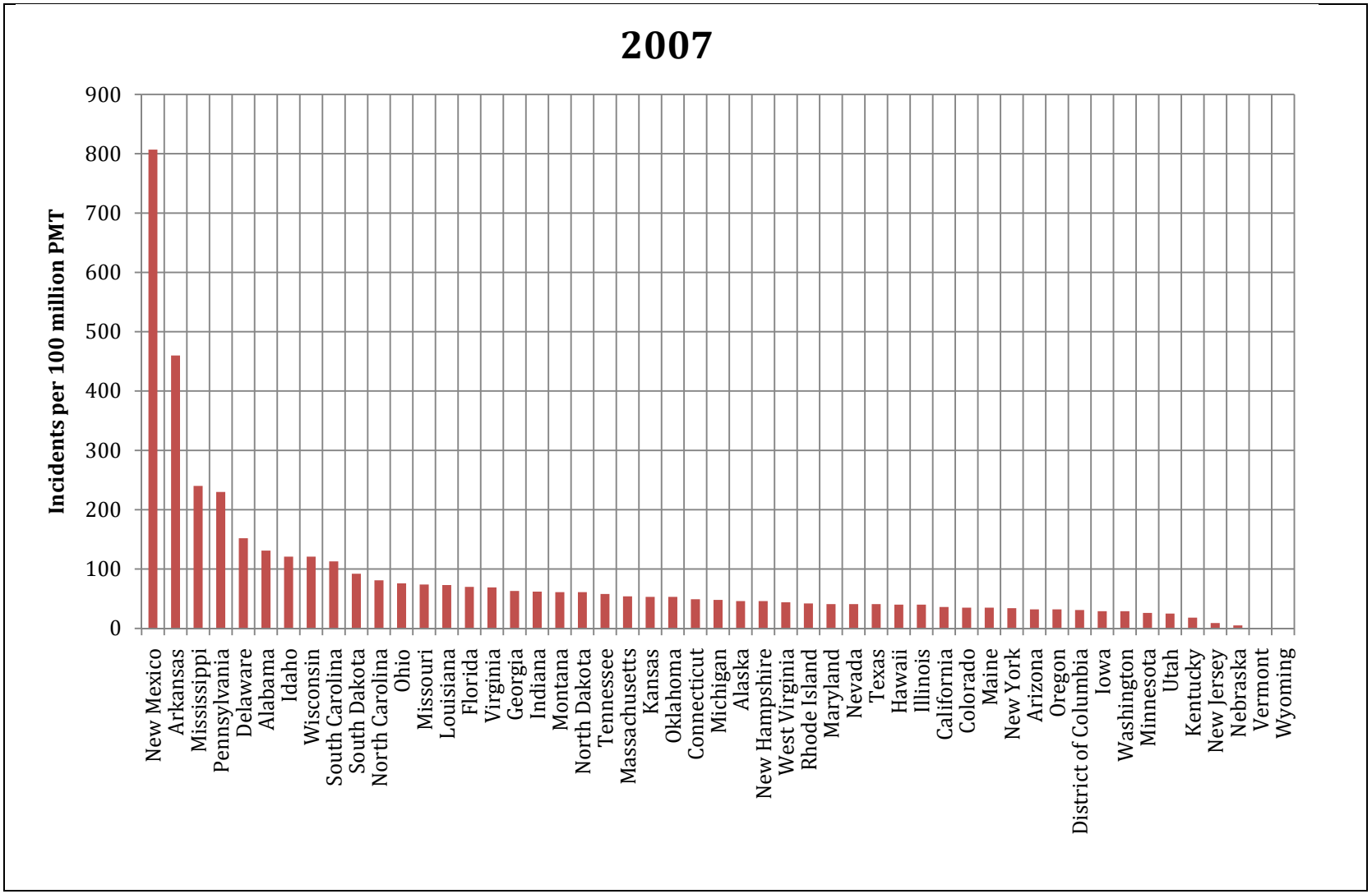

2007
Incidents per Route Miles
3.5
3
2.5
2
1.5
1
0.5
0
District of Columbia
Delaware
New York
New Jersey
Connecticut
California
Massachusetts
Pennsylvania
Illinois
Florida
Maryland
Rhode Island
Alaska
Louisiana
Arizona
Nebraska
Texas
Washington
Tennessee
Kentucky
Indiana
Alabama
Wyoming
Georgia
Iowa
Ohio
Mississippi
Arkansas
Oregon
Colorado
South Carolina
North Carolina
Virginia
Missouri
Idaho
Oklahoma
Kansas
Michigan
Minnesota
Montana
Vermont
Utah
West Virginia
Wisconsin
New Mexico
Maine
North Dakota
South Dakota
Nevada
New Hampshire
Hawaii

Indicator #14	**Transit Safety**
Definition:	Number of Incidents per 100 Million PMT
Why it's important:	A situation, such as a fire, the presence of smoke, fuel leak, electrical or other hazard, crashes, that constitutes an imminent danger to passengers, employees, contractors, or other persons.
Criteria metric:	Quality of Service
Contribution to Index: *State-by-State – 0.086* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transit Database (NTD) (http://www.ntdprogram.gov/ntdprogram/).
Data issues & opportunities	The NTD data are available until 2002 from Federal Transit Administration. The data for 2000 and 1995 take the average values of those in 2002 and 2007.
Observations: • Data exhibits significant variability.	

Historical Values:

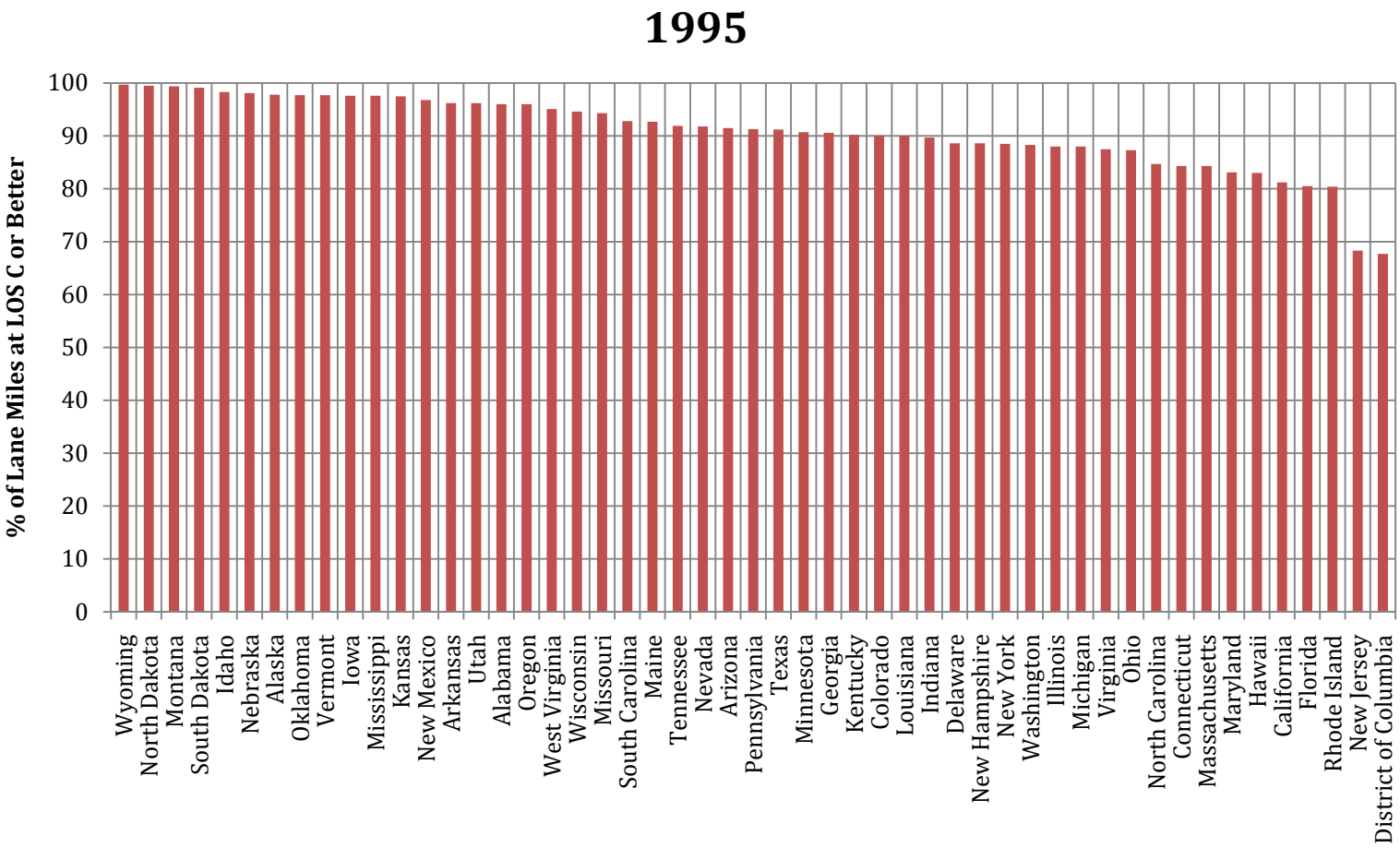


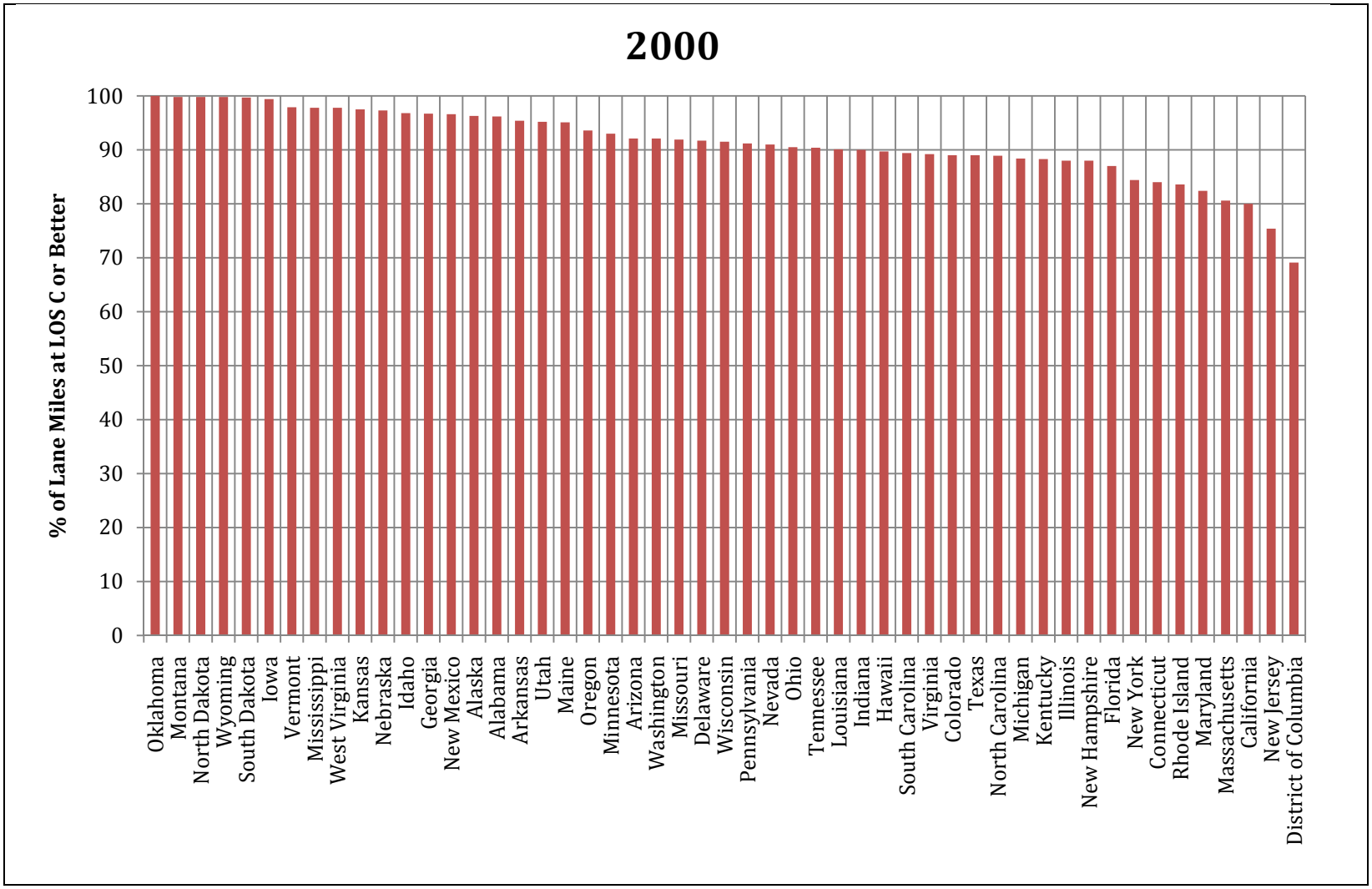

2000
Incidents per 100 million PMT
600
500
400
300
200
100
0
New Mexico
Arkansas
Mississippi
Rhode Island
Pennsylvania
Wyoming
Michigan
Alabama
Montana
Florida
West Virginia
Missouri
South Dakota
Delaware
South Carolina
North Carolina
Ohio
Wisconsin
Indiana
Idaho
Virginia
Kansas
Kentucky
Georgia
Massachusetts
District of Columbia
Louisiana
Tennessee
Connecticut
Maine
Maryland
Illinois
Texas
Hawaii
Alaska
Utah
California
Iowa
New York
Nevada
Oklahoma
Minnesota
North Dakota
Nebraska
Washington
Colorado
Arizona
Oregon
New Hampshire
New Jersey

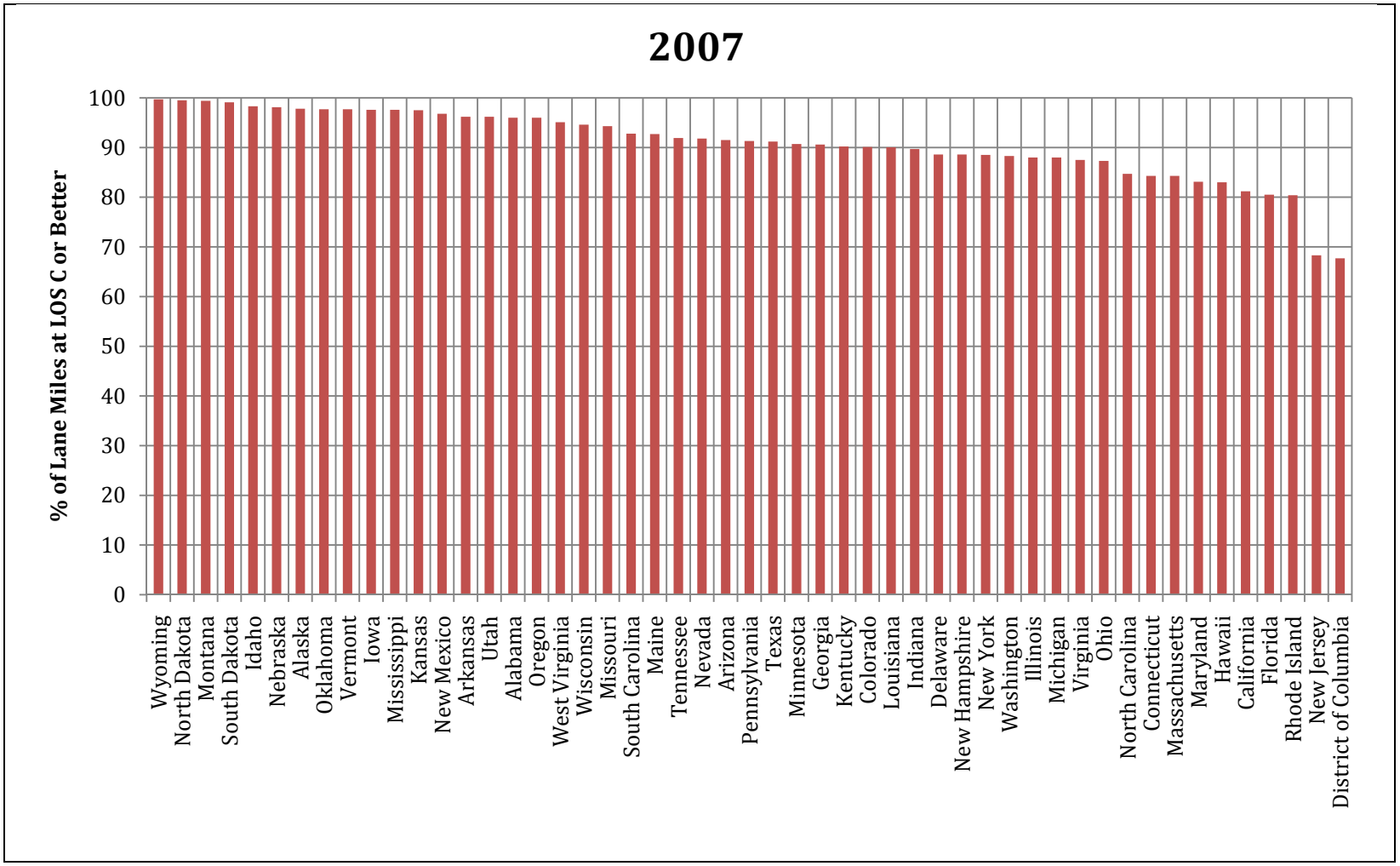

2007
Incidents per 100 million PMT
900
800
700
600
500
400
300
200
100
0
New Mexico
Arkansas
Mississippi
Pennsylvania
Delaware
Alabama
Idaho
Wisconsin
South Carolina
South Dakota
North Carolina
Ohio
Missouri
Louisiana
Florida
Virginia
Georgia
Indiana
Montana
North Dakota
Tennessee
Massachusetts
Kansas
Oklahoma
Connecticut
Michigan
Alaska
New Hampshire
West Virginia
Rhode Island
Maryland
Nevada
Texas
Hawaii
Illinois
California
Colorado
Maine
New York
Arizona
Oregon
District of Columbia
Iowa
Washington
Minnesota
Utah
Kentucky
New Jersey
Nebraska
Vermont
Wyoming

Indicator #15	**Uncongested Roads**
Definition:	Road congestion is measured by the percentage of lane miles with Level of Service (LOS) at C or better.
Why it's important:	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.
Criteria metric:	Utilization
Contribution to Index: *State-by-State – 0.132* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	Highway Performance Monitoring System (HPMS) data.
Data issues & opportunities	A level of 0.80 of Volume-to-service flow (V/SF) ratio 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).
Observations: • Best performing states are the Plains states where the worst performing are highly urbanized states.	

Historical Values:

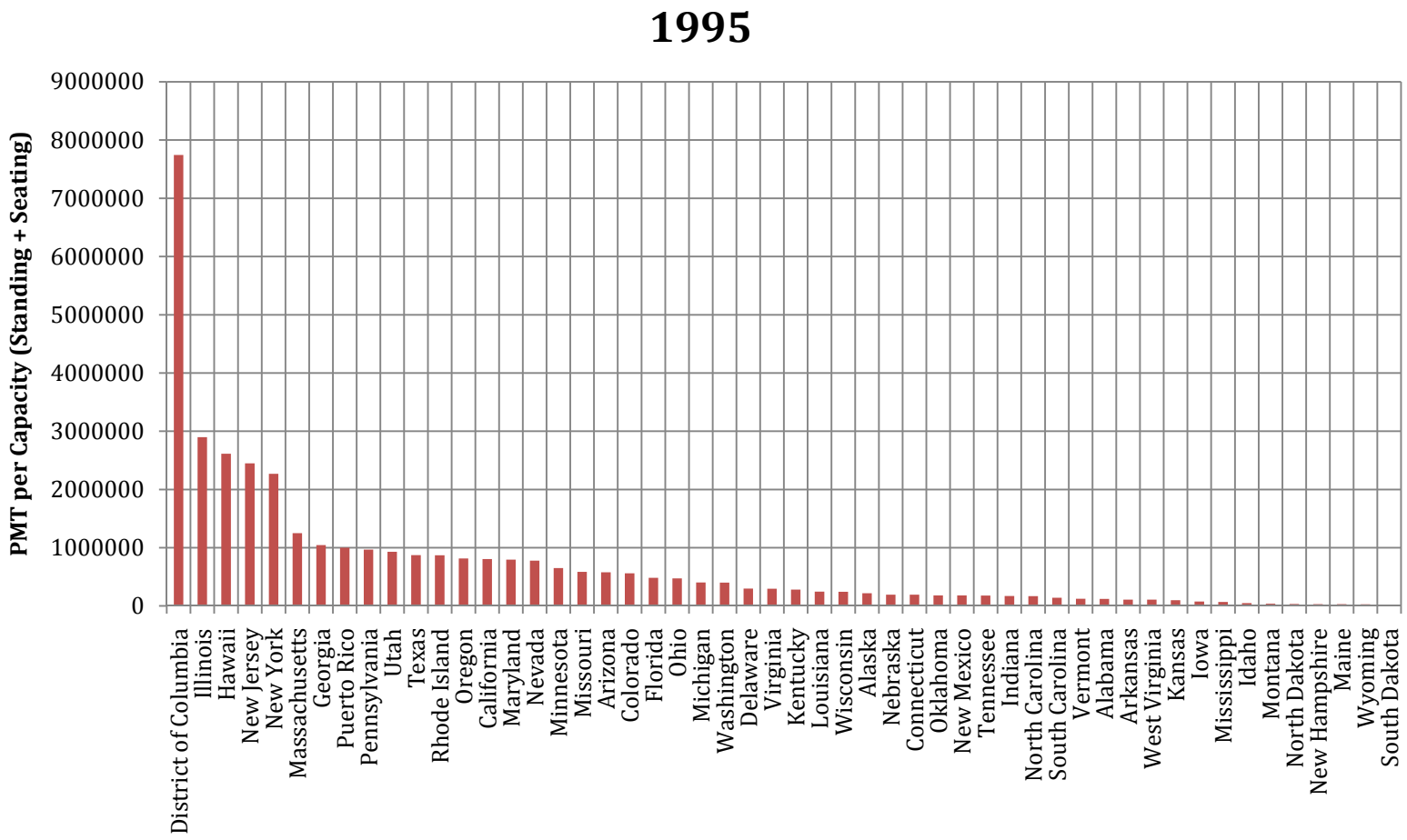


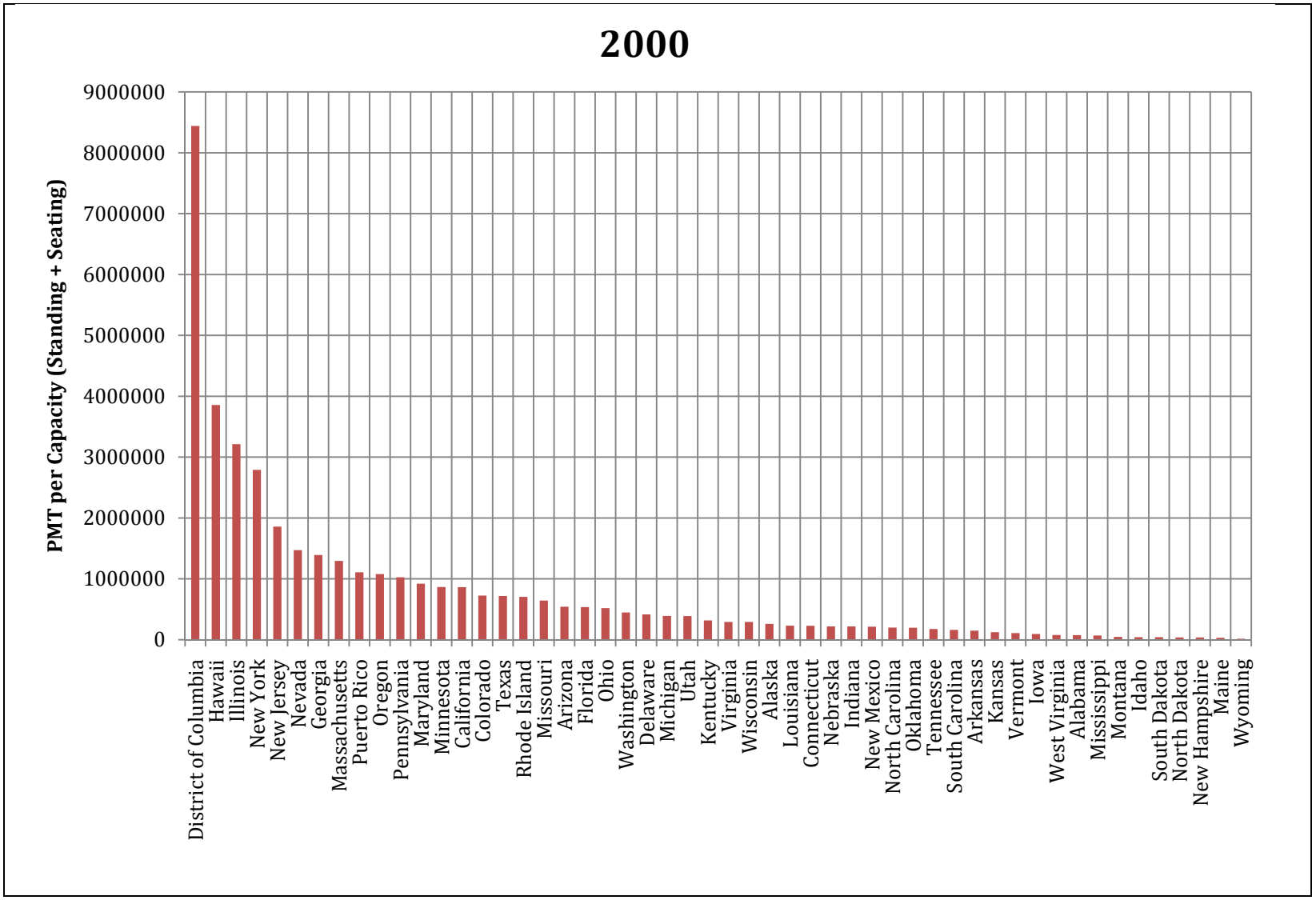

2000
% of Lane Miles at LOS C or Better
100
90
80
70
60
50
40
30
20
10
0
Oklahoma
Montana
North Dakota
Wyoming
South Dakota
Iowa
Vermont
Mississippi
West Virginia
Kansas
Nebraska
Idaho
Georgia
New Mexico
Alaska
Alabama
Arkansas
Utah
Maine
Oregon
Minnesota
Arizona
Washington
Missouri
Delaware
Wisconsin
Pennsylvania
Nevada
Ohio
Tennessee
Louisiana
Indiana
Hawaii
South Carolina
Virginia
Colorado
Texas
North Carolina
Michigan
Kentucky
Illinois
New Hampshire
Florida
New York
Connecticut
Rhode Island
Maryland
Massachusetts
California
New Jersey
District of Columbia

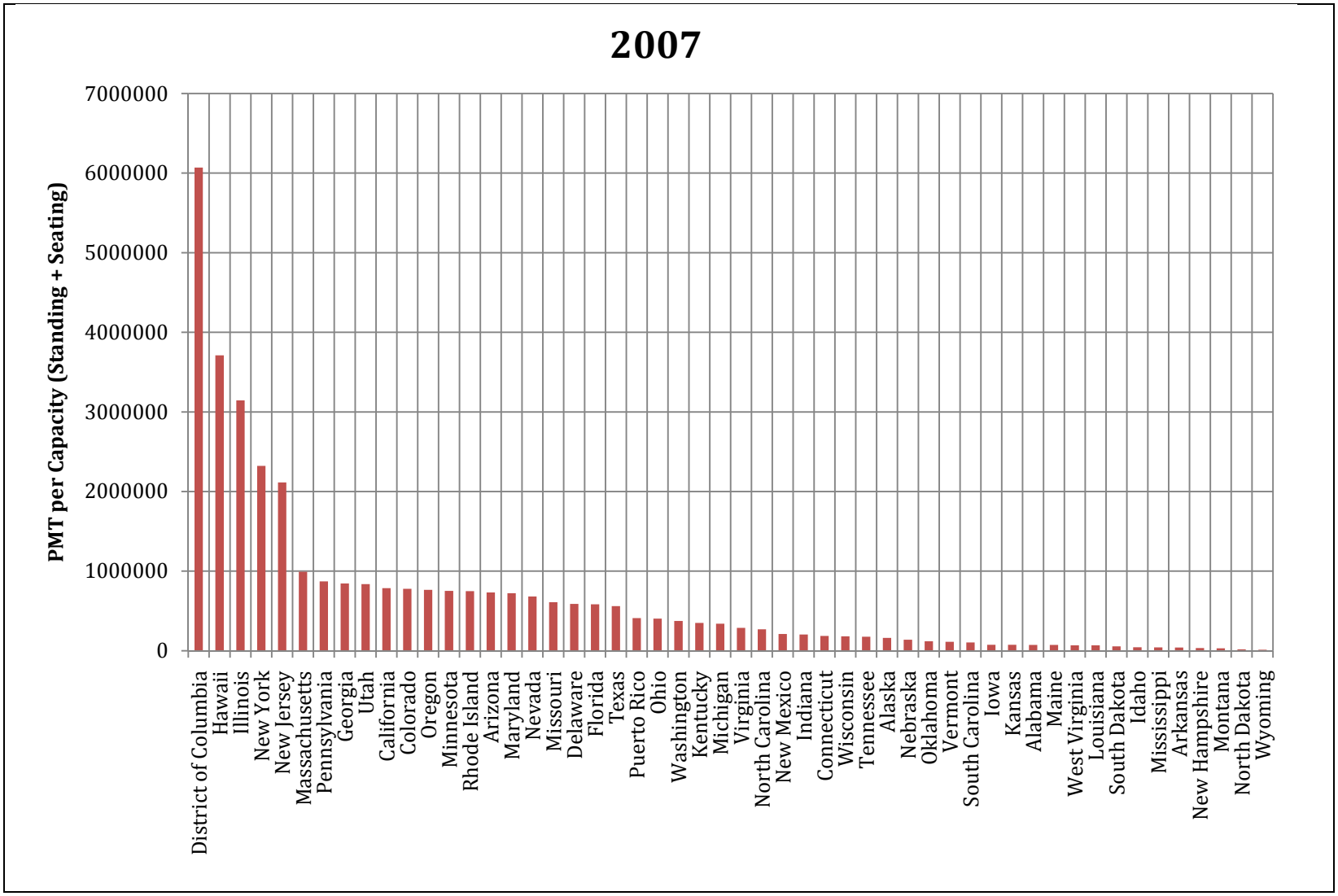

2007
% of Lane Miles at LOS C or Better
100
90
80
70
60
50
40
30
20
10
0
Wyoming
North Dakota
Montana
South Dakota
Idaho
Nebraska
Alaska
Oklahoma
Vermont
Iowa
Mississippi
Kansas
New Mexico
Arkansas
Utah
Alabama
Oregon
West Virginia
Wisconsin
Missouri
South Carolina
Maine
Tennessee
Nevada
Arizona
Pennsylvania
Texas
Minnesota
Georgia
Kentucky
Colorado
Louisiana
Indiana
Delaware
New Hampshire
New York
Washington
Illinois
Michigan
Virginia
Ohio
North Carolina
Connecticut
Massachusetts
Maryland
Hawaii
California
Florida
Rhode Island
New Jersey
District of Columbia

Indicator #16	**Transit Utilization**
Definition:	Passenger Miles Traveled (PMT) per Capacity (Standing + Seating)
Why it's important:	The indicator captures the utilization of public transit, cumulative sum of the distances ridden by each passenger, comparing the capacity provided.
Criteria metric:	Utilization
Contribution to Index: *State-by-State – 0.044* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	National Transit Database (NTD) (http://www.ntdprogram.gov/ntdprogram/).
Data issues & opportunities	
Observations: • Most transit systems do not have much "reserve" capacity.	

Historical Values:

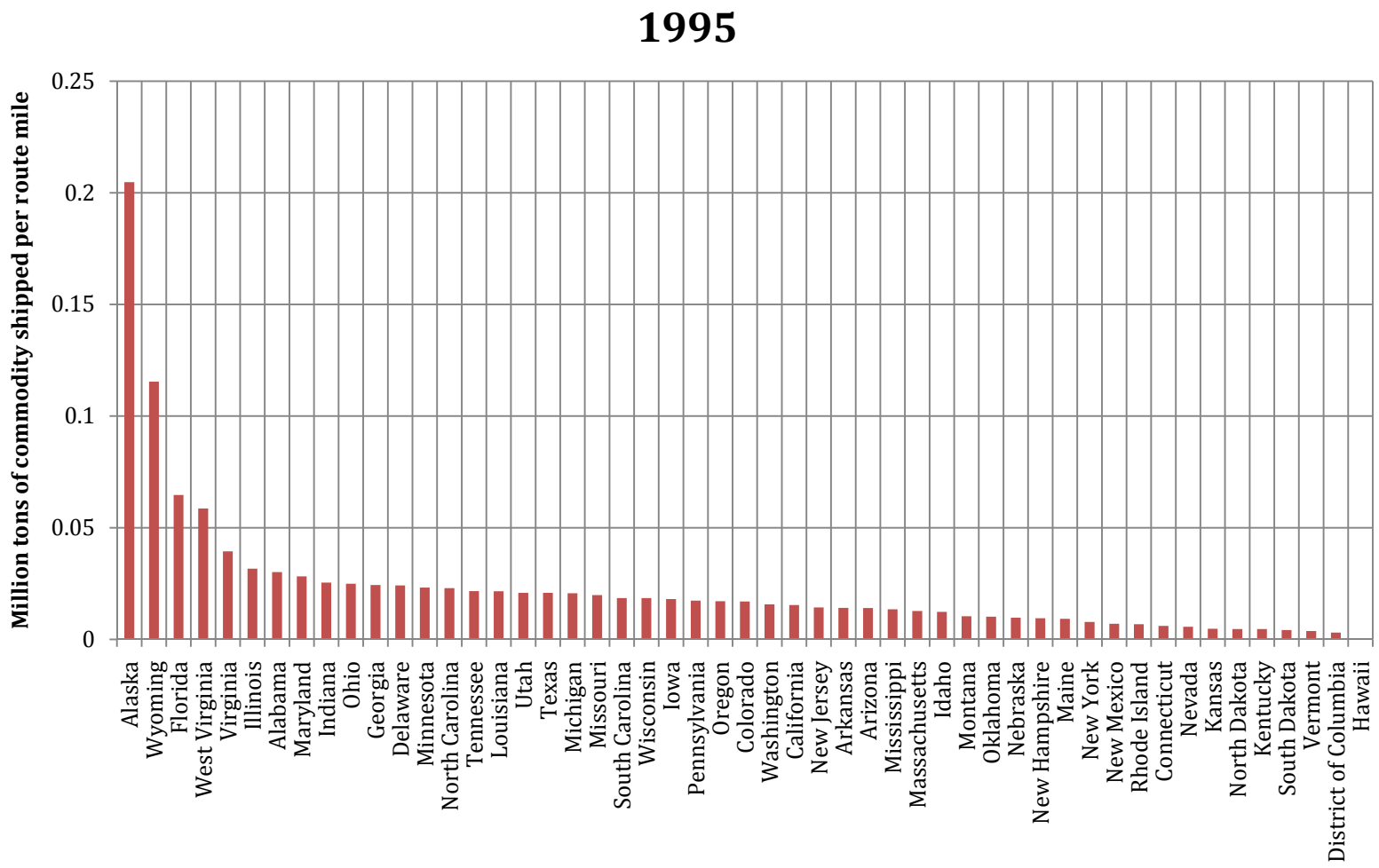


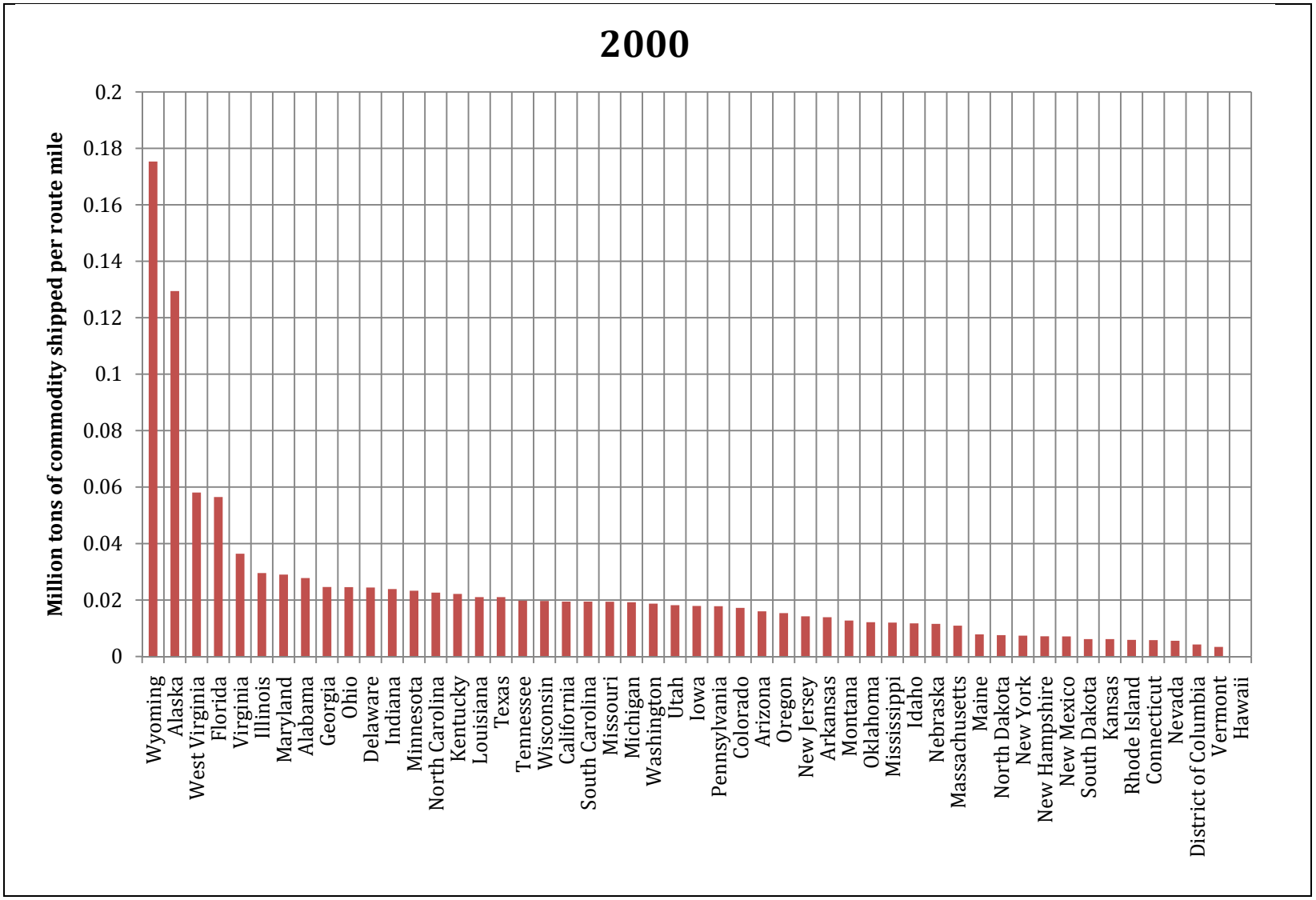

2000
PMT per Capacity (Standing + Seating)
9000000
8000000
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
District of Columbia
Hawaii
Illinois
New York
New Jersey
Nevada
Georgia
Massachusetts
Puerto Rico
Oregon
Pennsylvania
Maryland
Minnesota
California
Colorado
Texas
Rhode Island
Missouri
Arizona
Florida
Ohio
Washington
Delaware
Michigan
Utah
Kentucky
Virginia
Wisconsin
Alaska
Louisiana
Connecticut
Nebraska
Indiana
New Mexico
North Carolina
Oklahoma
Tennessee
South Carolina
Arkansas
Kansas
Vermont
Iowa
West Virginia
Alabama
Mississippi
Montana
Idaho
South Dakota
North Dakota
New Hampshire
Maine
Wyoming

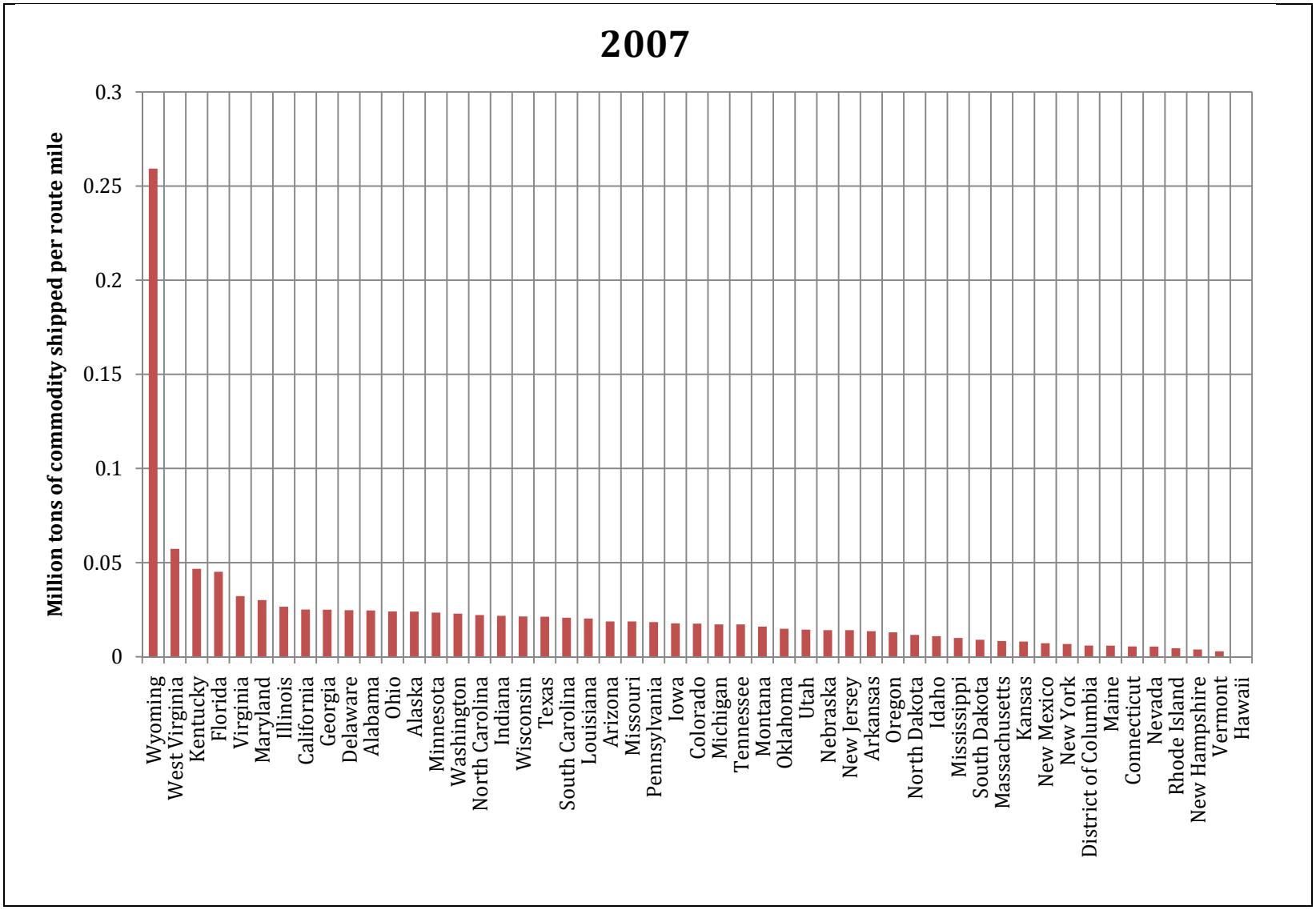

2007
PMT per Capacity (Standing + Seating)
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
District of Columbia
Hawaii
Illinois
New York
New Jersey
Massachusetts
Pennsylvania
Georgia
Utah
California
Colorado
Oregon
Minnesota
Rhode Island
Arizona
Maryland
Nevada
Missouri
Delaware
Florida
Texas
Puerto Rico
Ohio
Washington
Kentucky
Michigan
Virginia
North Carolina
New Mexico
Indiana
Connecticut
Wisconsin
Tennessee
Alaska
Nebraska
Oklahoma
Vermont
South Carolina
Iowa
Kansas
Alabama
Maine
West Virginia
Louisiana
South Dakota
Idaho
Mississippi
Arkansas
New Hampshire
Montana
North Dakota
Wyoming

Indicator #17	**Rail Usage for Freight**
Definition:	Million tons of commodity shipped per route mile
Why it's important:	Freight railroads play an important role in the United States' economy. They connect businesses with each other across the country and with markets overseas.
Criteria metric:	Utilization
Contribution to Index: *State-by-State – 0.042* The weight factors are determined and calculated from Analytical Hierarchical Process based on a survey of U.S. Chamber members.	
Primary data sources:	State Transportation Statistics (http://www.bts.gov/publications/state_transportation_statistics/).
Data issues & opportunities	The data are available only in 2000 and 2007. The data in 1995 are extrapolated based on those in 2000 and 2007.
Observations: • This simple measure captures the pressures on rail in Wyoming due to the transport of coal out of the Powder River Basin.	

Historical Values:




2000
Million tons of commodity shipped per route mile
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Wyoming
Alaska
West Virginia
Florida
Virginia
Illinois
Maryland
Alabama
Georgia
Ohio
Delaware
Indiana
Minnesota
North Carolina
Kentucky
Louisiana
Texas
Tennessee
Wisconsin
California
South Carolina
Missouri
Michigan
Washington
Utah
Iowa
Pennsylvania
Colorado
Arizona
Oregon
New Jersey
Arkansas
Montana
Oklahoma
Mississippi
Idaho
Nebraska
Massachusetts
Maine
North Dakota
New York
New Hampshire
New Mexico
South Dakota
Kansas
Rhode Island
Connecticut
Nevada
District of Columbia
Vermont
Hawaii


2007
Million tons of commodity shipped per route mile
0.3
0.25
0.2
0.15
0.1
0.05
0
Wyoming
West Virginia
Kentucky
Florida
Virginia
Maryland
Illinois
California
Georgia
Delaware
Alabama
Ohio
Alaska
Minnesota
Washington
North Carolina
Indiana
Wisconsin
Texas
South Carolina
Louisiana
Arizona
Missouri
Pennsylvania
Iowa
Colorado
Michigan
Tennessee
Montana
Oklahoma
Utah
Nebraska
New Jersey
Arkansas
Oregon
North Dakota
Idaho
Mississippi
South Dakota
Massachusetts
Kansas
New Mexico
New York
District of Columbia
Maine
Connecticut
Nevada
Rhode Island
New Hampshire
Vermont
Hawaii

APPENDIX E- SURVEY

This appendix summarizes the survey process used to collect pairwise comparison results from the business community to obtain the indicator weights. The pairwise comparison results were used to calculate weights that represent the importance of the transportation indicators to transportation infrastructure performance.

Email to Participants

A web-based software, Comparion Suite, was used to conduct the survey and calculate the results. The first step was sending an email to the survey participants shown below:

Email to Survey Participants

Subject: Please Participate in the U.S. Chamber's Survey that Evaluates the U.S. Transportation Infrastructure

Dear [Name of Survey Participant],

The University of Delaware is working with the U.S. Chamber of Commerce to develop a Transportation Index. The goal of this project is to capture the relationship between transportation infrastructure performance and the U.S. economy. The following indicators or "building blocks" for creating the index have been identified based on stakeholder input and currently available data.

We need your input to help us understand the relative importance of these indicators with respect to transportation infrastructure performance for the transportation index. Included below is a link to an online survey. It will take about 20 minutes to complete the survey. The survey is completed by sliding the bars or clicking on the bars representing the degree you favor one measure over another. There are 42 questions; you proceed to the next question by clicking "Next" in the bottom right.

Please complete the survey from the perspective of your business by clicking on the following link. This link will take you directly to the survey. If there is someone else in your organization that wishes to take the survey in your place please forward their contact information to Michelle Oswald at moswald@udel.edu.

[Personal Link to Comparion Suite Survey]

A second email should have been sent from Comparion Suite that provides a password if in the future you wish to have an account. Otherwise please disregard the second email.

Your participation in this study is entirely voluntary and your survey responses will remain confidential. In terms of the results, only summary data will be reported. By completing the survey, you are consenting to give the team permission to present the summary data in written and oral form, without further permission.

You may also find the following indicator descriptions useful when completing the survey.

Your time and cooperation are greatly appreciated. We would like your responses by close of business on Tuesday June 29, 2010. If you have any questions, please contact Michelle Oswald (email: moswald@udel.edu, phone: 410-207-5267) or Sue McNeil (email: smcneil@udel.edu, phone: 302-831-6578).

Thank you for your time.

Sincerely,
Sue McNeil and Michelle Oswald

Supply Category

Highway Density (Availability of highways) - Lane-miles per 10,000 population
Transit Density (Availability of transit) - Miles of transit per 10,000 population
Airport Access (Proximity of airports) - % population within 50 miles of major airport
Airport Capacity (Availability of airport service) - Airport arrival rate and departure rate per hour
Rail Density (Availability of railroads) - Track miles per 10,000 population
Inland Waterway Density (Availability of waterways) - Miles of waterways per 10,000 population
Port Access (Proximity of ports) - Distance from the center of MSA to the closest international container port
Intermodal Freight Access (Proximity of intermodal facilities) – Number of facilities per 10,000 population

Quality of Service Category

Travel Time Reliability (Variability in travel time due to congestion) - Travel Time Index
Highway Safety (Fatal highway crashes) - Facilities per 100 million Vehicle Miles Traveled
Road Roughness (Highway ride comfort) - % of lane miles with IRI greater than 170 in/mi
Bridge Integrity (Ability of bridges to meet the needs of the users) - % of bridges structurally deficient or functionally obsolete
Air Congestion (Airport congestion) - % of on-time for departures
Air Safety (Chances of crashes) - Runway incursions per million operations
Rail Safety (Railroad incidents) - # of incidents per million train miles

Waterway Congestion (Delays on inland waterway) – Average lock delay per tow
Transit Safety (Transit incidents) - # of incidents per million PMT

Utilization Category
Highway Utilization (Highway reserve capacity) - % of lane miles at LOS C or better
Air Utilization (Airport reserve capacity) - % of capacity used between 7 am to 9 pm
Transit Utilization (Transit reserve capacity) - passenger miles traveled per capacity (standing and seating)
Rail Utilization (Rail reserve capacity) - Ton-miles per track mile of owned

Survey

Once the email was sent, the participants received a link that allowed them to open a personalized survey form. The survey included pairwise comparisons of each of the indicators as well as the criteria. Figure 49 shows an example pairwise comparison between two criteria categories: supply and quality of service. Figure 50 shows an example pairwise comparison between two indicators: highway density and transit density. The same format is used to compare all indicators and criteria.

The results for each of the pairwise comparisons for each of the participants was collected and saved in Comparion Suite. The results were then analyzed using the ideal synthesis mode where the criteria weights were distributed without regard to the number of indicators under the criteria.

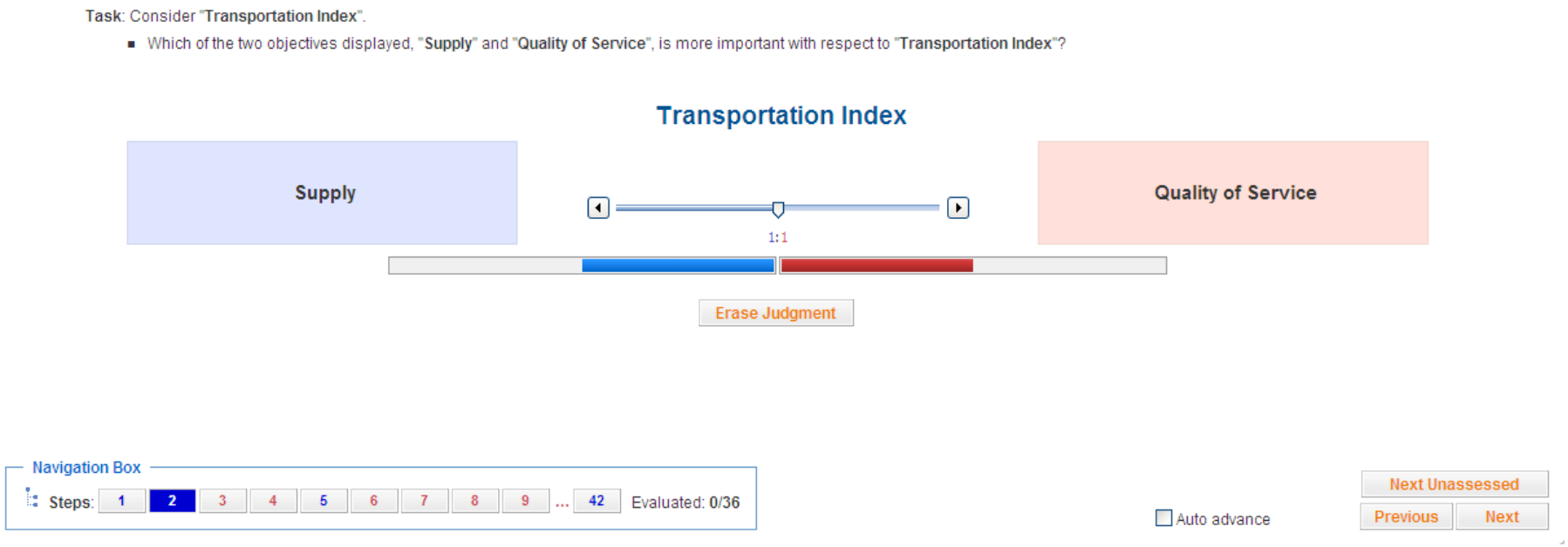


Figure 49. Sample Pairwise Comparison of the Criteria in Comparion Suite

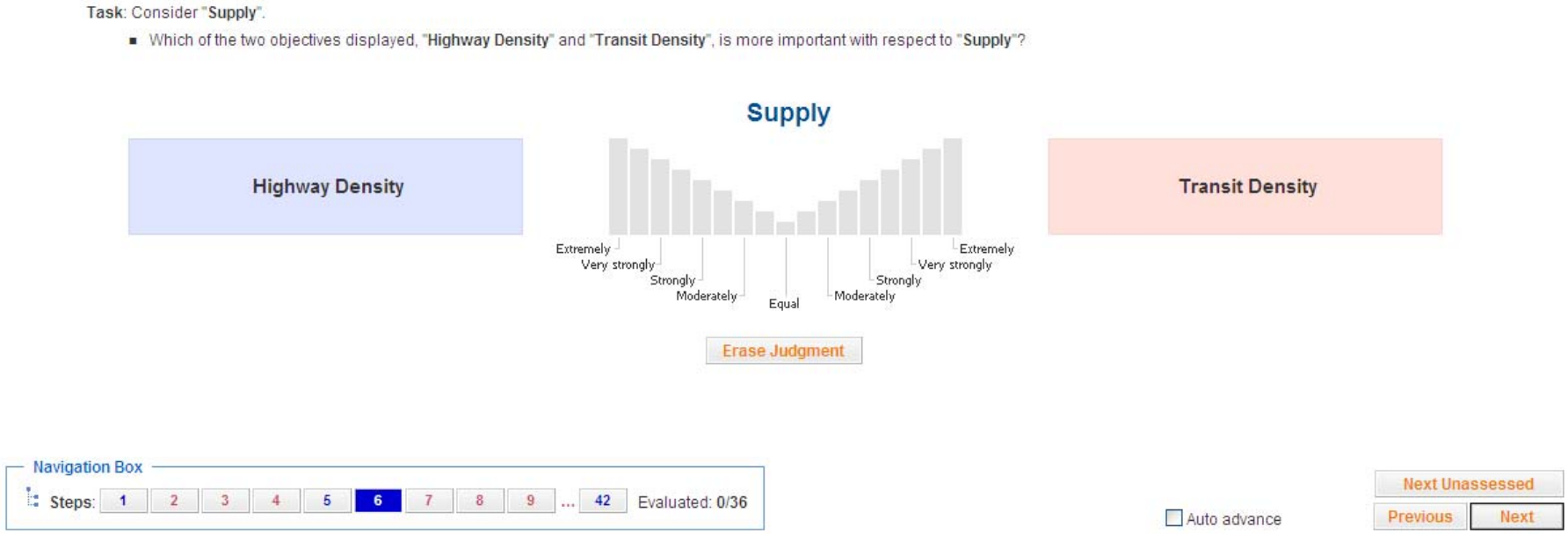


Figure 50. Sample Pairwise Comparison of Indicators in Comparion Suite

APPENDIX F: BASIC TRANSPORTATION INFRASTRUCTURE RATINGS

The United States ranks only #14 for Basic Infrastructure (World Economic Forum, Global Competitiveness Report 2009-2010). How the United States stacks up against our competitors who rank among the top 20 for Basic Infrastructure is shown in Table 35.

Table 35 World Economies by Global Rank

Basic Infrastructure Rank			Score for Quality of:				Global Rank:	
	Country	Overall Score	Roads	Railroads	Ports	Air Transport	GDP	per capita
1	Switzerland	6.8	6.7	6.8	5.4	6.5	38	19
2	Singapore	6.7	6.7	5.7	6.8	6.9	49	8
3	Hong Kong SAR	6.7	6.6	6.5	6.8	6.9	39	15
4	Austria	6.6	6.4	5.5	5.0	6.2	37	21
5	France	6.6	6.6	6.5	5.9	6.3	9	40
6	Germany	6.5	6.5	6.3	6.4	6.6	6	37
7	Finland	6.5	5.9	5.9	6.5	6.3	55	36
8	Iceland	6.3	5.1	n/a	6.2	6.3	142	20
9	Denmark	6.3	6.1	5.4	6.2	6.4	53	31
10	Sweden	6.2	5.7	5.4	5.9	6.0	35	28
11	United Arab Emirates	6.1	6.2	n/a	6.2	6.7	52	17
12	Luxembourg	6.1	5.8	5.1	5.5	5.4	98	3
13	Canada	5.9	5.7	5.2	5.6	5.9	15	27
14	United States	5.9	5.9	4.8	5.7	6.0	2*	11
15	Belgium	5.8	5.8	5.6	6.3	6.2	31	29
16	Barbados	5.8	5.1	n/a	5.5	6.1	157	64
17	Japan	5.8	5.6	6.6	5.2	5.1	4	41
18	Netherlands	5.8	5.4	5.6	6.6	6.4	22	22
19	Taiwan	5.8	5.8	5.8	5.6	5.5	20	47
20	Korea (Rep.)	5.8	5.8	5.7	5.1	6.0	14	49

* The European Union economy is the largest in the world (CIA Factbook). Scores are the result of responses to questions in the format: "How would you assess the quality of [X] in your country? (1 = extremely underdeveloped; 7 = extensive and efficient by international standards)," where [X] is "Basic Infrastructure", "Roads", Railroads", etc. Details available at http://www.weforum.org/documents/GCR09/index.html