Measuring Transportation Infrastructure Performance: Insights and Challenges

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Transportation

Moving people and goods by air, water, road and rail.

Performance

The degree to which transportation infrastructure systems serve the US economic and business community objectives.

Background

- In 2000, The World Bank projected the world economy to grow **33%** between years 2000 and 2010, increasing from $31.8 trillion to $40 trillion.
- It reached $60.5 trillion in 2008 ($78.9 trillion in 2011 est).
- By the year 2050, the world economy is projected to increase to between $135 trillion to $216 trillion.

Are our infrastructure systems ready for the growth?

Are the investments in US infrastructure adequate?

Motivation

- Transparency
- Accountability
- Gaps
  - Currently no “rigorous” index for measuring US infrastructure, specifically in relation to economic growth
  - Need a well-defined methodology for creating an index
  - Existing methods for creating indices should be applied

Objectives

- Develop methodology for constructing a US Transportation Performance Index (TPI)
  - Repeatable
  - Transparent
  - Use to evaluate trends in infrastructure performance
- Main goal of index: measure the effect of infrastructure performance on economic prosperity

Performance

- **Fragile Foundations (1988)**

  "the amount of infrastructure or its condition did not capture the ability or capability of the infrastructure to deliver the service expected or required"

- **NRC study (1997)**

  "the degree to which the system serves multilevel community objectives. Identifying these objectives and assessing and improving infrastructure performance occur through an essentially political process involving multiple stakeholders"

- **This study**

"the degree to which the infrastructure system serves U.S. economic and multi-level business community objectives"

Methodology

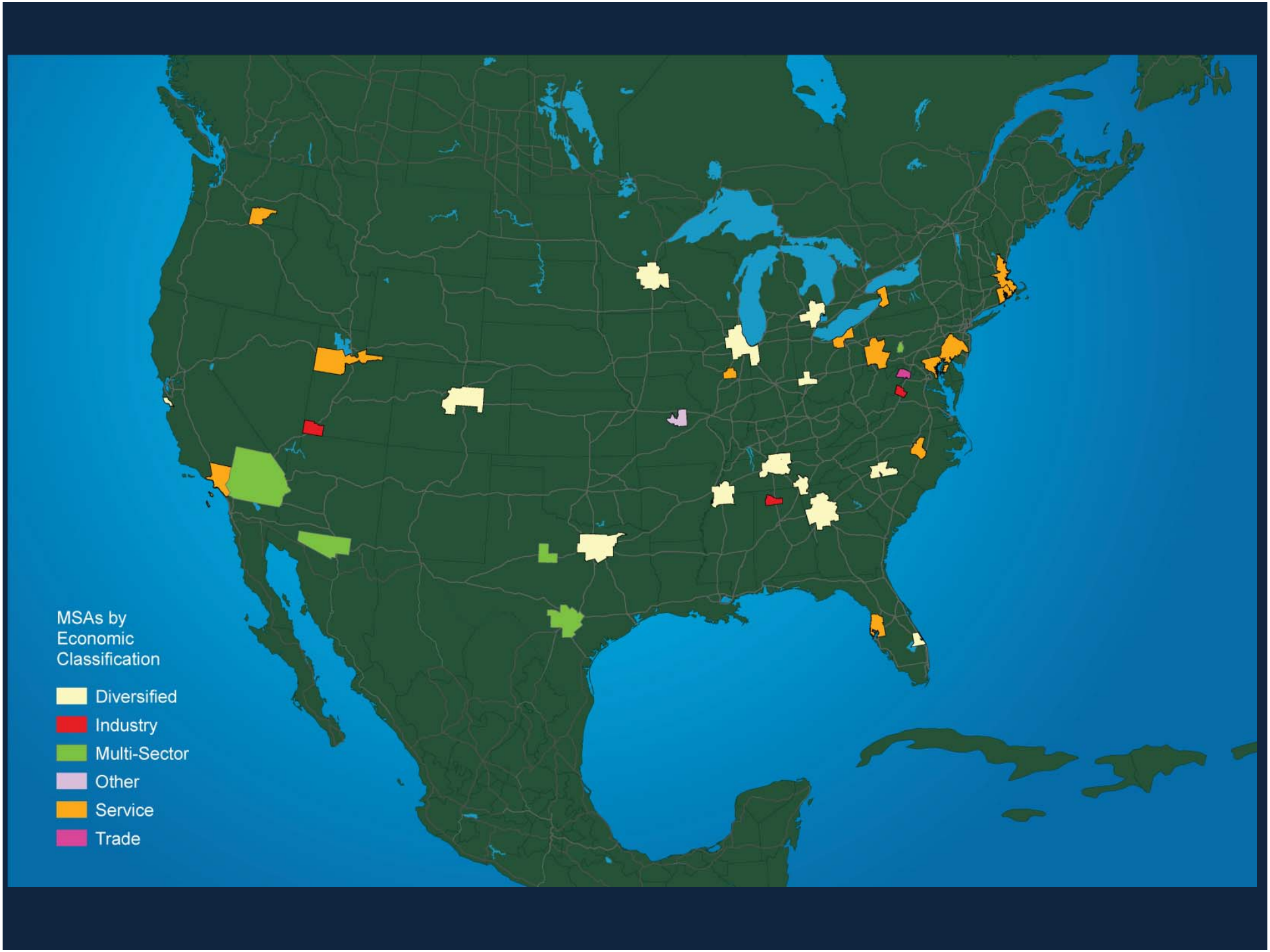
1. Definitions
2. Geographic Samples
3. Create Models of the Sectors and Criteria
4. Identify Indicators
5. Explore Data Sources & Assemble Data
6. Weight the Indicators
7. Compute the Index with Economic Correlation

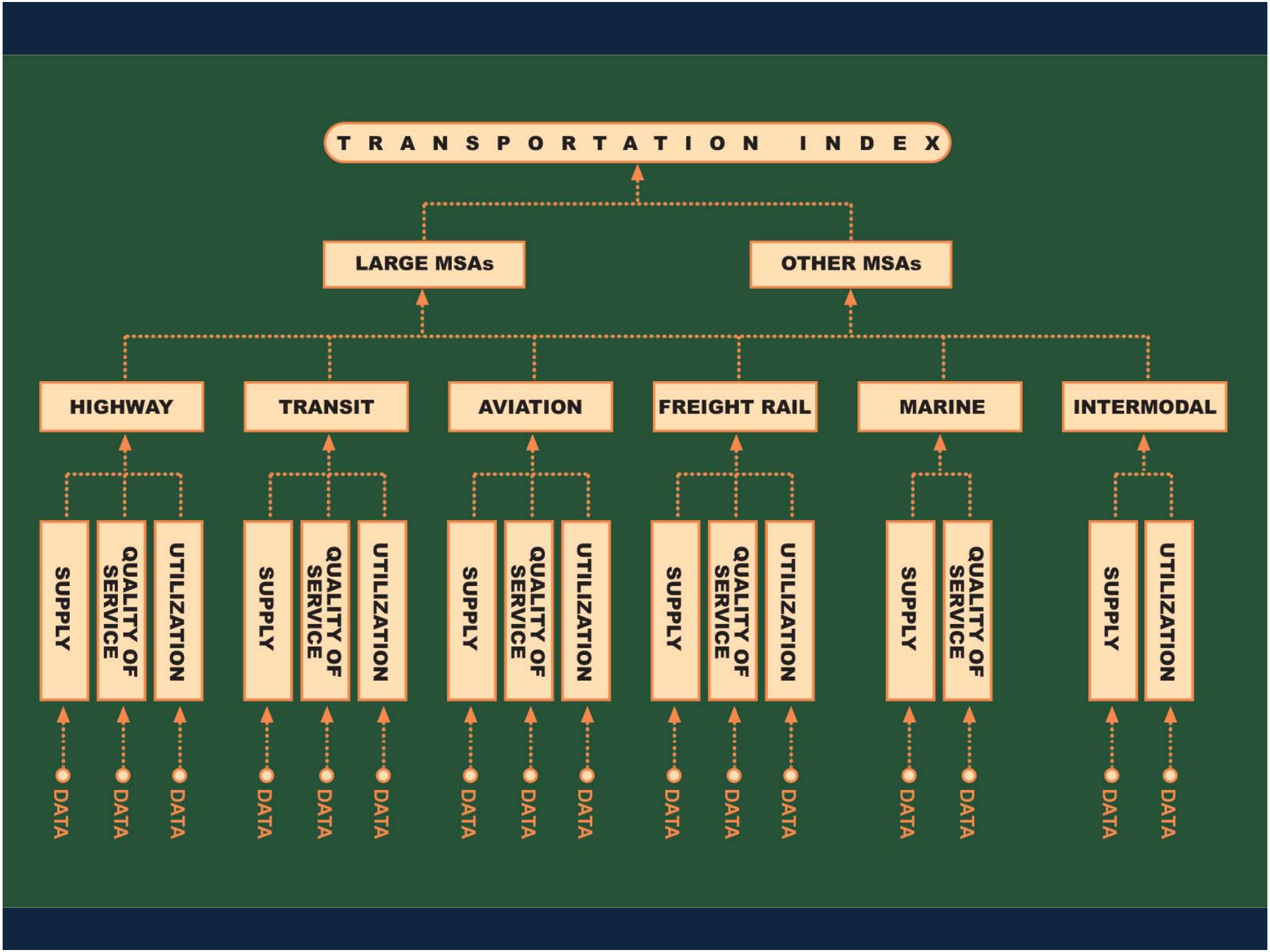
Phases

- **Initiation Phase – Prototype transportation index**
- **National Complete Transportation Performance Index (TPI) (1990-2008, 2015 projections)**
- **State by State Transportation Performance Index (1995, 2000, 2007, 2015 projections)**
- **Update TPI for 2009**

Geographic Sampling Strategy

- **Based on MSAs (366 in 2007)**
  - Organized based on sector
  - Stratified Random
  - Weighted based on economic contribution
- **MSA Sample for Transportation = 36 total**
  - Classifying MSA by Economic Sector
  - Classifying MSAs by Population
  - Combining Population and Economic Sector Classifications
  - Determining Sample Size by Economic Classification and Population Group
  - Selecting MSAs for the Sample


MSAs by
Economic
Classification
Diversified
Industry
Multi-Sector
Other
Service
Trade


TRANSPORTATION INDEX
LARGE MSAs
OTHER MSAs
HIGHWAY
TRANSIT
AVIATION
FREIGHT RAIL
MARINE
INTERMODAL
SUPPLY
QUALITY OF SERVICE
UTILIZATION
DATA

Selecting Indicators - Methodology

- Five-step process
  - Brainstorming (Literature review)
  - Exploring data (Initiation phase)
  - Expert meeting
  - Stakeholders workshops (Chicago, Atlanta, Houston, San Jose)
  - Revisions and data assembly

Ground Rule: Publically available data back to 1990

Indicator Criteria

- Supply- availability and coverage
  - What geographical area is covered?
- Quality of Service- inconvenience cost of disruption, and reliability
  - How well service is provided?
- Efficiency- the cost of service
  - Does the service provide full value for cost?
- Utilization- whether growth can be accommodated
  - How fully the existing facilities are used?

Transportation Performance Indicators

Supply	Quality of Service	Utilization
• Highway Density • Transit Density • Airport Access • Airport Capacity • Rail Density • Waterway Density • Port Access • Intermodal – Freight Access	• Travel Time Reliability • Highway Safety • Road Roughness • Bridge Integrity • Air Congestion • Air Safety • Rail Safety • Waterway Congestion • Transit Safety	• Highway Reserve Capacity • Air Reserve Capacity • Transit Reserve Capacity • Rail Reserve Capacity

Connections to MAP-21

Supply	Quality of Service	Utilization
• Highway Density • Transit Density • Airport Access • Airport Capacity • Rail Density • Waterway Density • Port Access • Intermodal – Freight Access	• Travel Time Reliability • Highway Safety • Road Roughness • Bridge Integrity • Air Congestion • Air Safety • Rail Safety • Waterway Congestion • Transit Safety	• Highway Reserve Capacity • Air Reserve Capacity • Transit Reserve Capacity • Rail Reserve Capacity

Safety
Infrastructure Condition
Congestion Reduction

System Reliability
Freight Movement and Economic Vitality

Indicator	Measure
Highway Density	Route miles per 10,000 population
Transit Density	Miles of transit per 10,000 population
Airport Access	% of population within 50 miles of major airport
Airport Capacity	AAR/ADR per hour
Rail Density	Route miles per 10,000 population
Waterway Density	Miles of inland waterways per sq mi
Port Access	Distance to closest international port
Freight Access	Number of facilities per 10,000 population
Travel time reliability	Travel time index
Safety	Fatalities per 100 million VMT
Road Roughness	% of road with IRI > 170 in./mi.
Bridge Integrity	% of bridges structurally deficient or obsolete
Air Congestion	% on time performance for departures
Air Safety	Runway incursions per million operations
Rail Safety	# incidents per million operations
Waterway Congestion	Average lock delay per tow
Transit Safety	# incident per million PMT
Highway Reserve Capacity	% of lane miles at level of service ‘C’ or better
Air Reserve Capacity	% capacity used between 7am to 9pm
Transit Reserve Capacity	PMT per capacity
Rail Reserve Capacity	Ton-miles per track mile

Transportation Performance Index Indicators

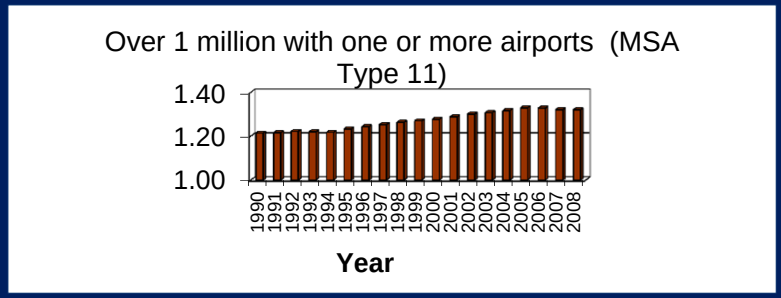
- Population over 1 million (all MSAs have airports) – 23 MSAs; 21 indicators
- Population under 1 million with a primary airport – 7 MSAs; 18 indicators
- Population under 1 million without a primary airport – 6 MSAs; 15 indicators.

Data Sources

- 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)
- FAA's Runway Safety Database
- Terminal Area Forecast (TAF)
- Fatal Accident Reporting System (FARS)
- Federal Railroad Administration (FRA)
- U.S. Army Corps of Engineers
- U.S. Bureau of Census

- 1990 to 2008
- 10,440 pieces of data
- >10GB

Data Presentation

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.

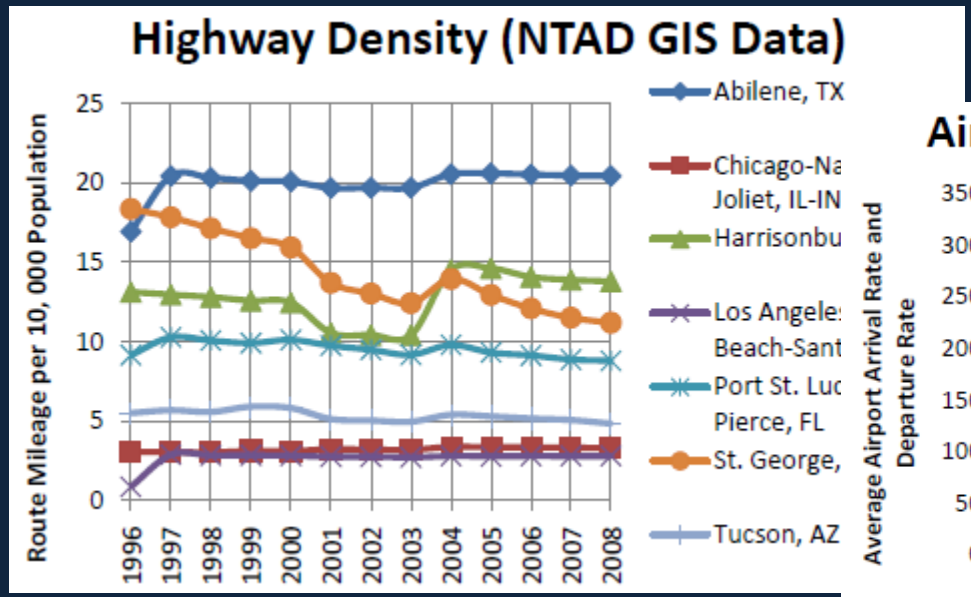
Contribution to Index:

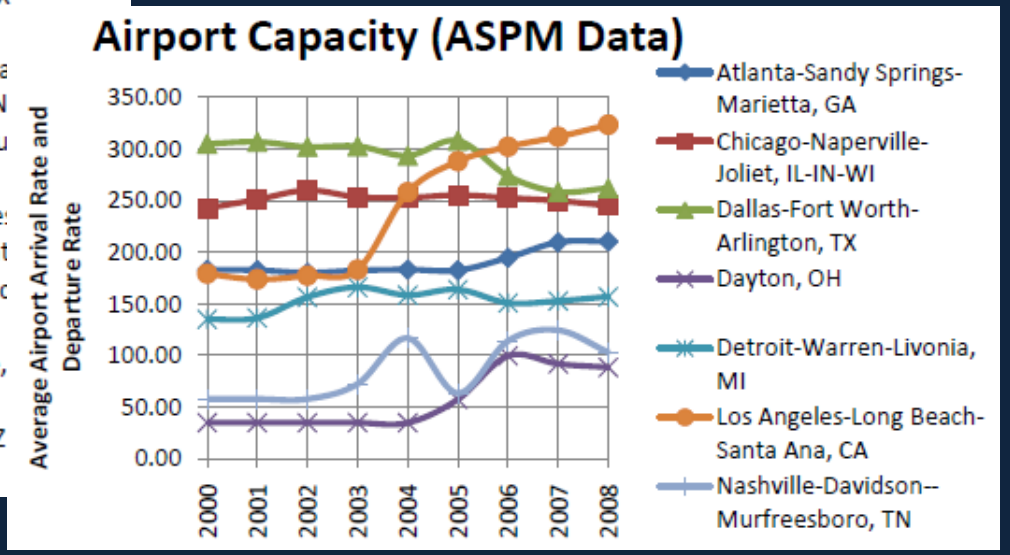
MSA type 00 (population under 1 million without primary airport) – 0.000
MSA type 01 (population under 1 million with primary airport(s)) – 0.000
MSA type 11 (population over 1 million with primary airport(s)) – 0.113
The weight factors are determined and calculated from Analytical Hierarchical Process 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.

Data Assessment & Evaluation

- Review of the type of data and the range of the data
- Graphs of indicators by MSA and over time to check for consistency.

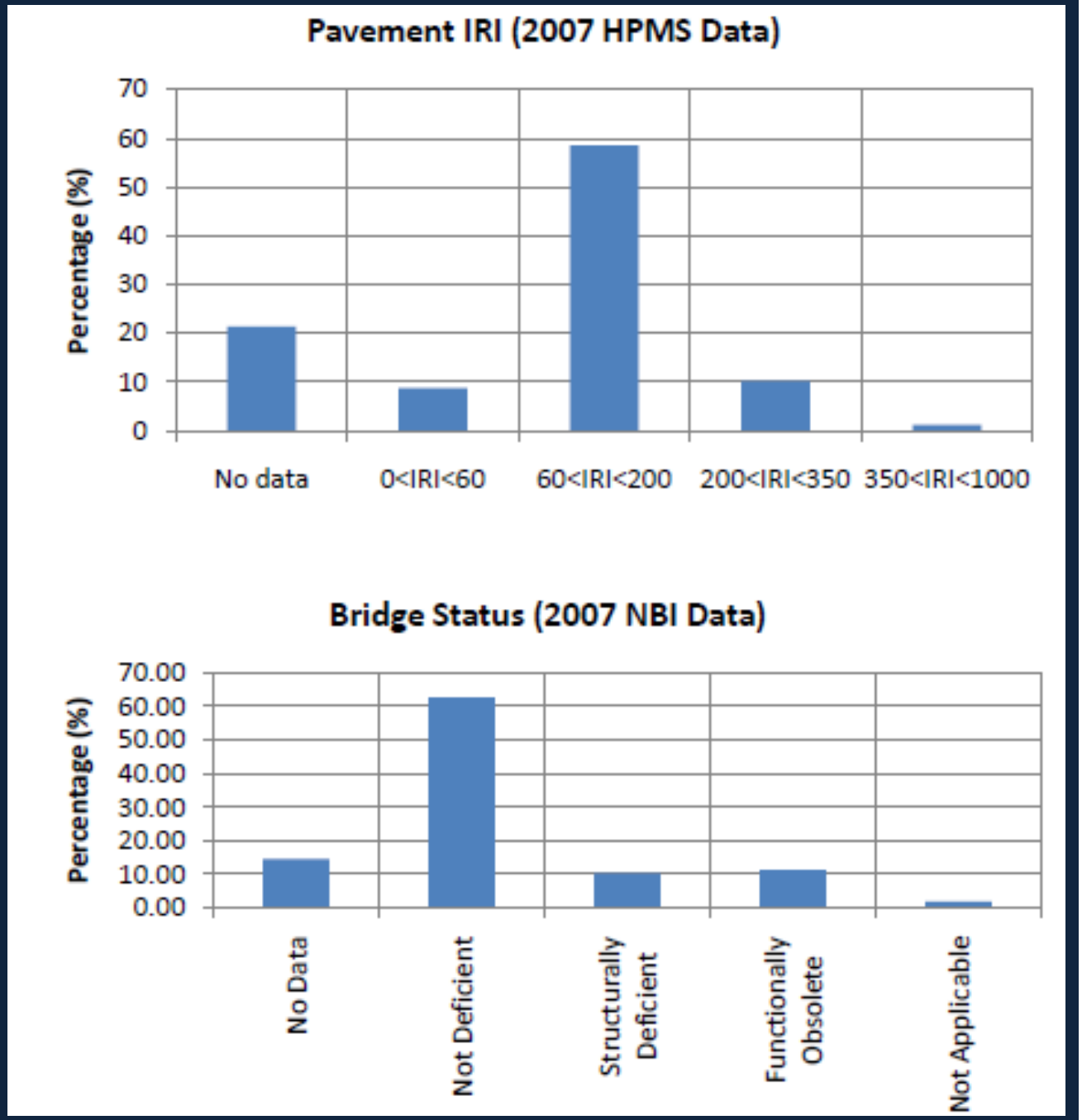




Data Challenges

- Scale and Level of Aggregation
- Missing and Erroneous Data
  - Data not reported or collected
  - Changes in format or inconsistent reporting
  - Errors in sources data
- Forecasting and Prediction
- Institutional Constraints

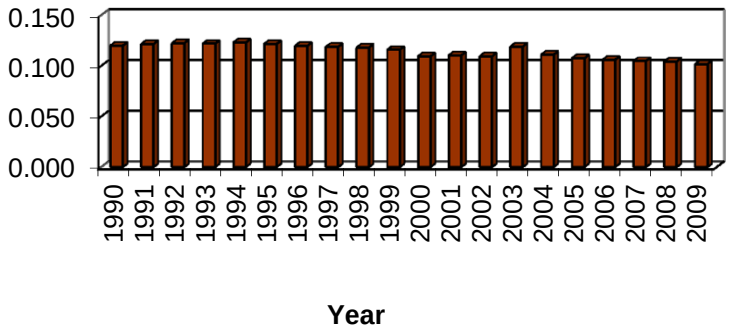
Data Examples



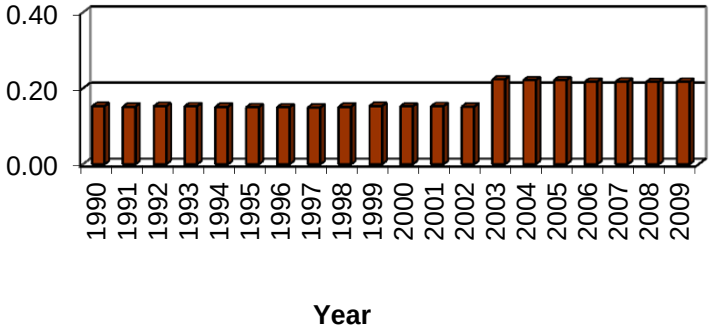
Data Examples

Intermodal connectivity (ramps/10,000 population)

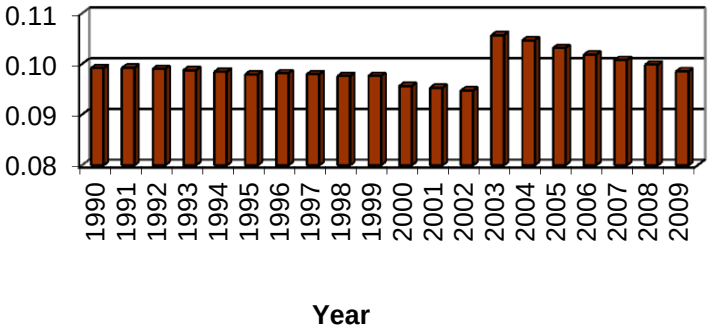
Under 1 million with no airports (MSA Type 00)



Under 1 million with one or more airports (MSA Type 01)



Over 1 million with one or more airports (MSA Type 11)



Performance Data Needs

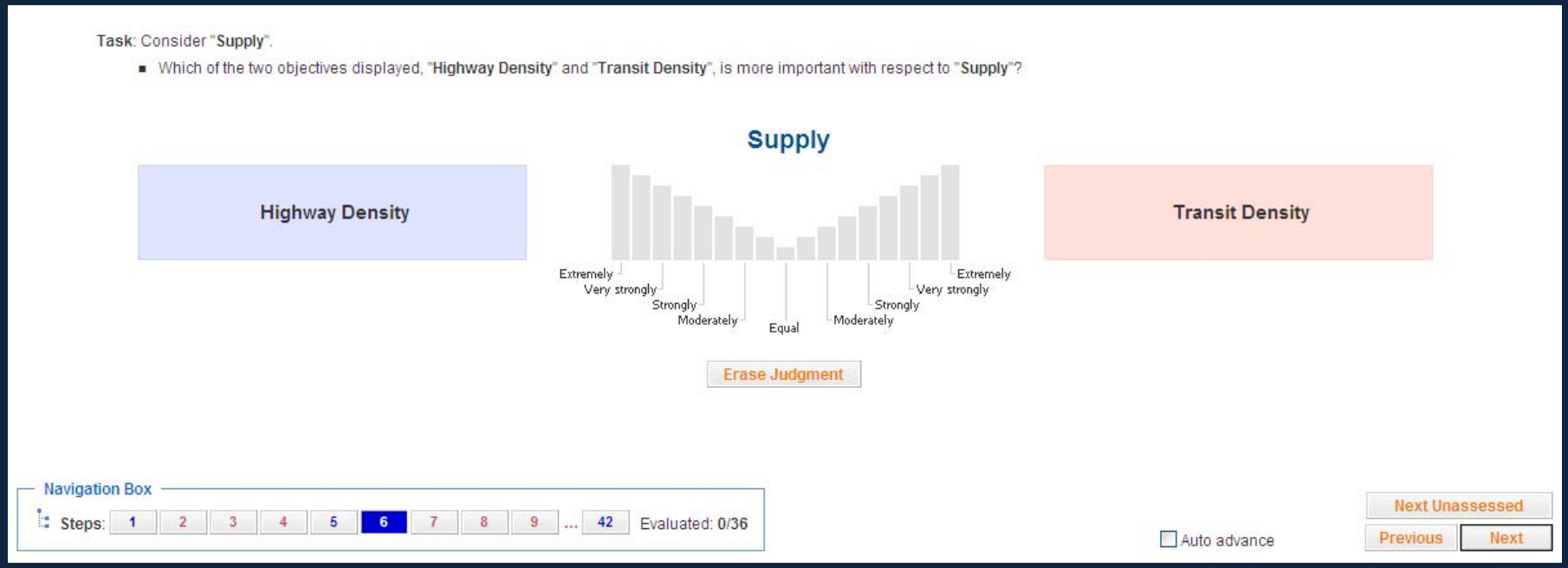
- Capturing
  - Interactions among modes
  - Differing scales
  - Differing geography
- Referencing systems
- Predicting future values
- Access to performance data
- Proactive conversations on the next generation performance measures

Weighting the indicators - AHP

- Use Analytic Hierarchy Process for weighting of indicators
- Pairwise comparisons completed by stakeholders
- Comparion and Expert Choice Software
- Result - final combined weight for each indicator

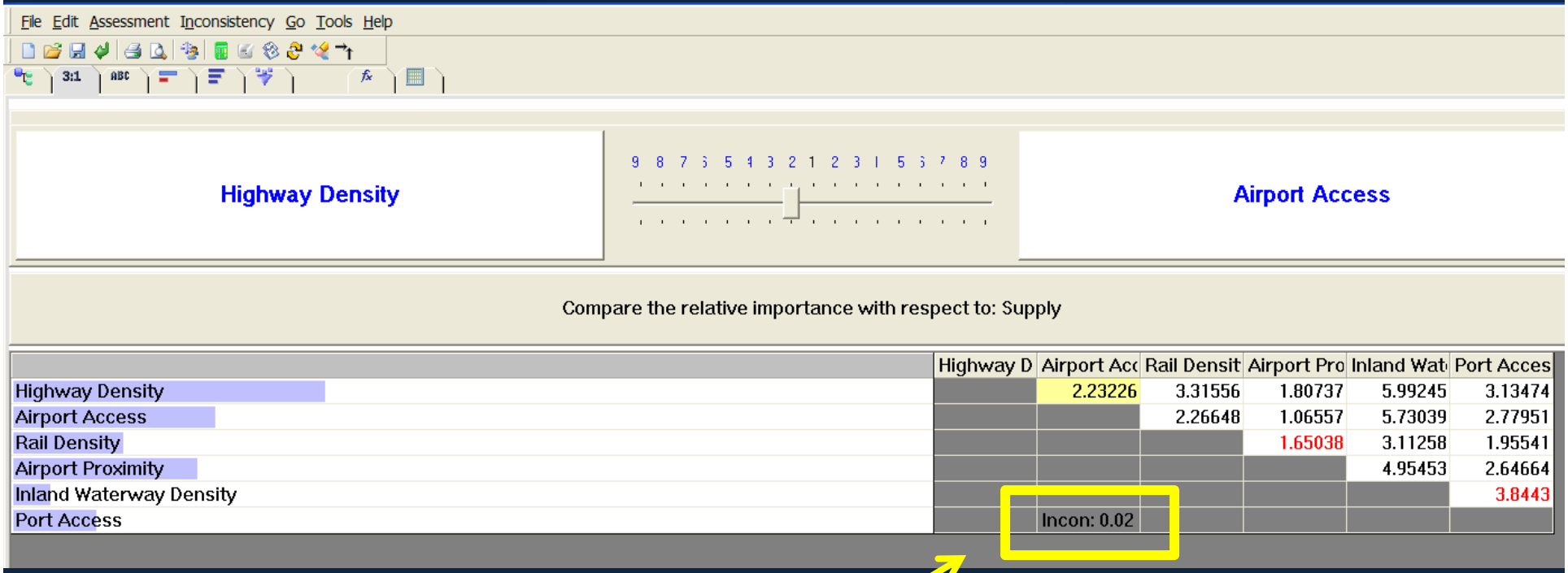
Pairwise Comparisons

- Sample pairwise comparison survey question in Comparion



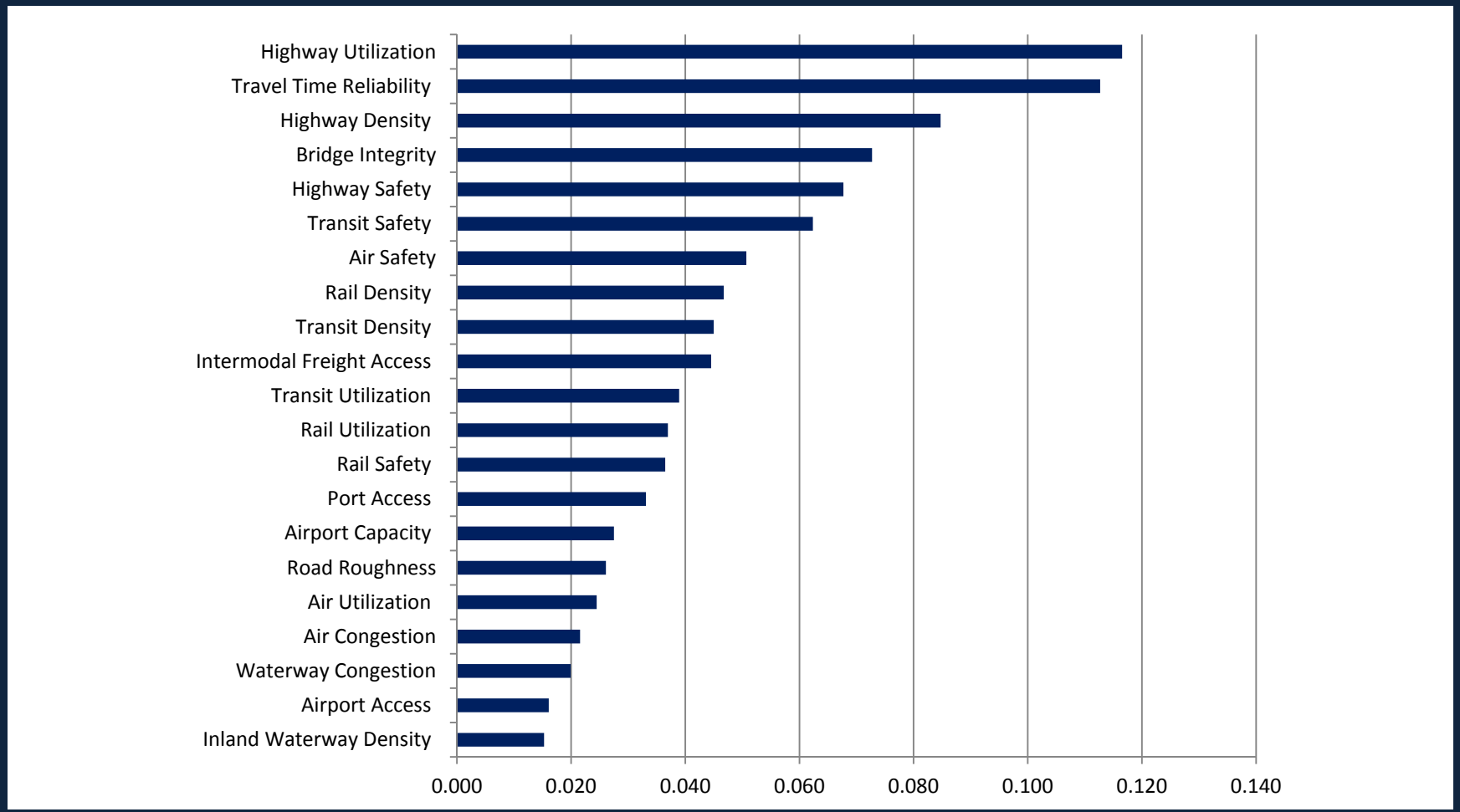
Expert Choice Software

- Import pairwise comparison values



Must be less than 0.1 for consistency

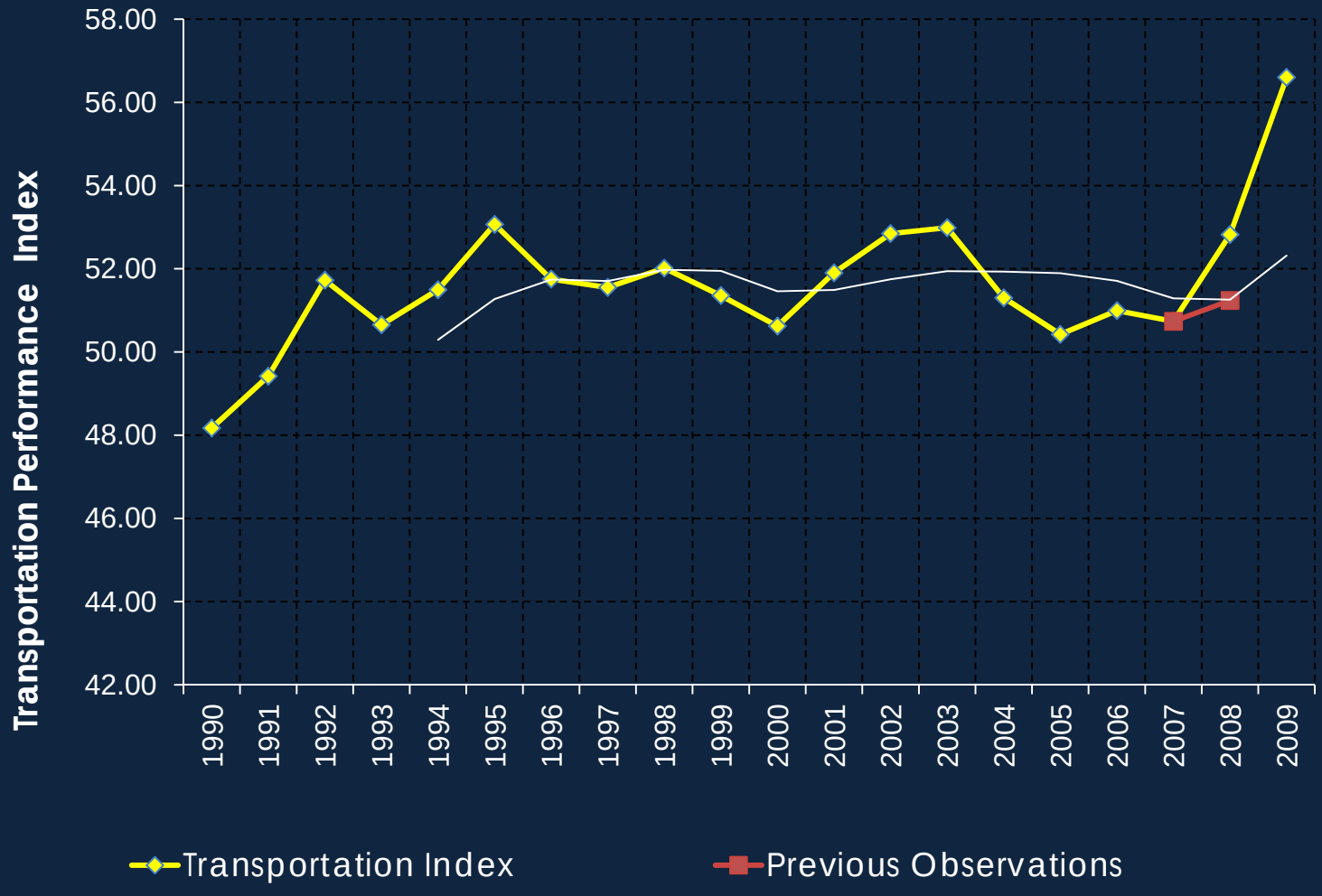
Expert Choice Results



Calculating the Index Number

- Step 1 – Normalize the data
  - 1 is desirable and 0 is undesirable
  - 2000 as the base year
- Step 2 – Correlate indicator to type of MSA
  - Adjust indicator weights to reflect the fact that not all data is collected for all MSAs in the sample
- Step 3- Compute index
  - For each MSA type
    - For each MSA
      - For each indicator
        - (Indicator Weight x normalized indicator measure x contribution to the economy)

Results – Transportation Performance Index (TPI)



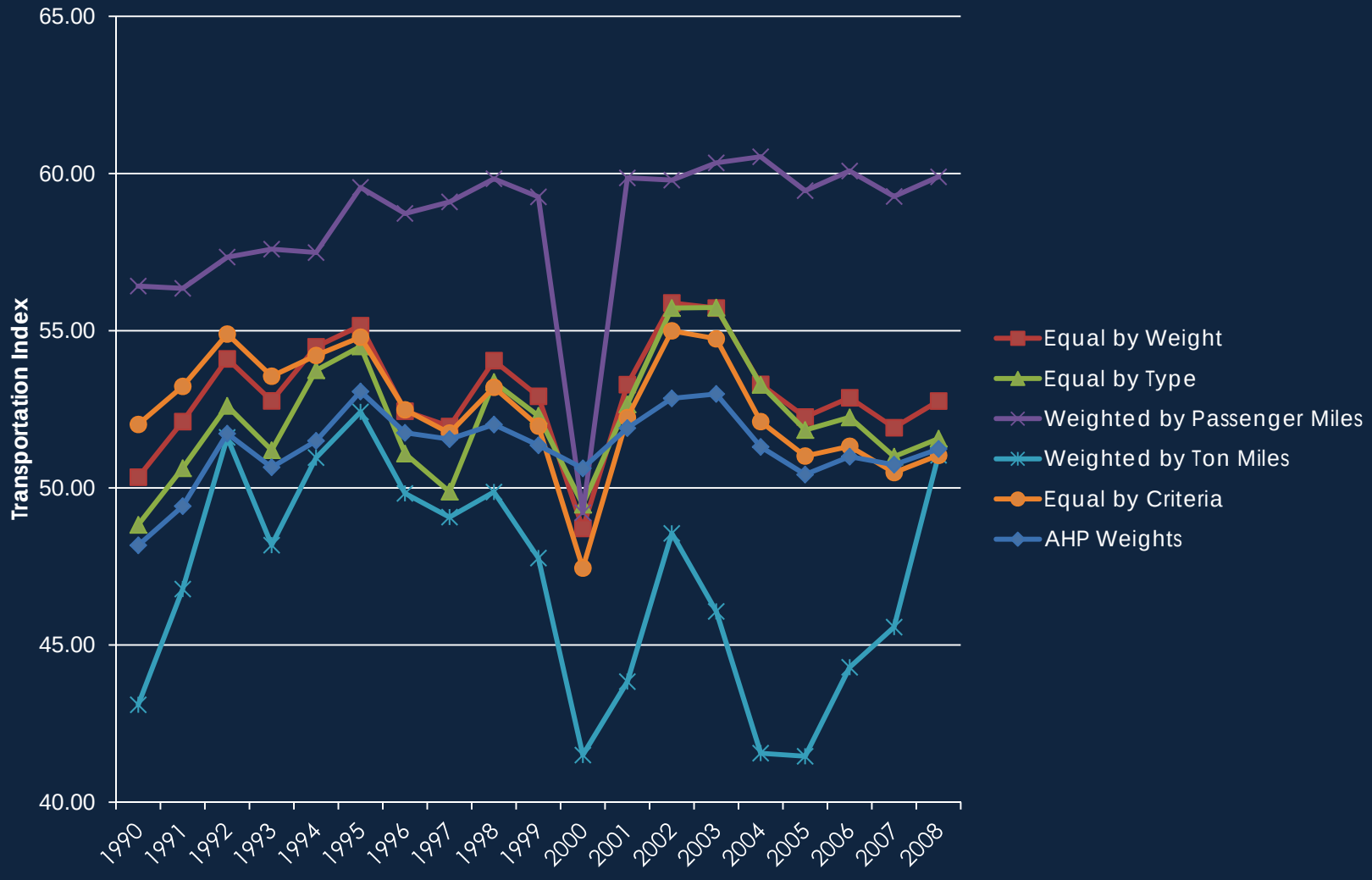
Interpreting the Results

- Larger is better, smaller is worse
- There is no scale (just like the Consumer Price Index or the Dow Jones Industrial Average)
- 95% confidence interval - +/- 2.5
- A change in one indicator in one MSA has little impact on the TPI

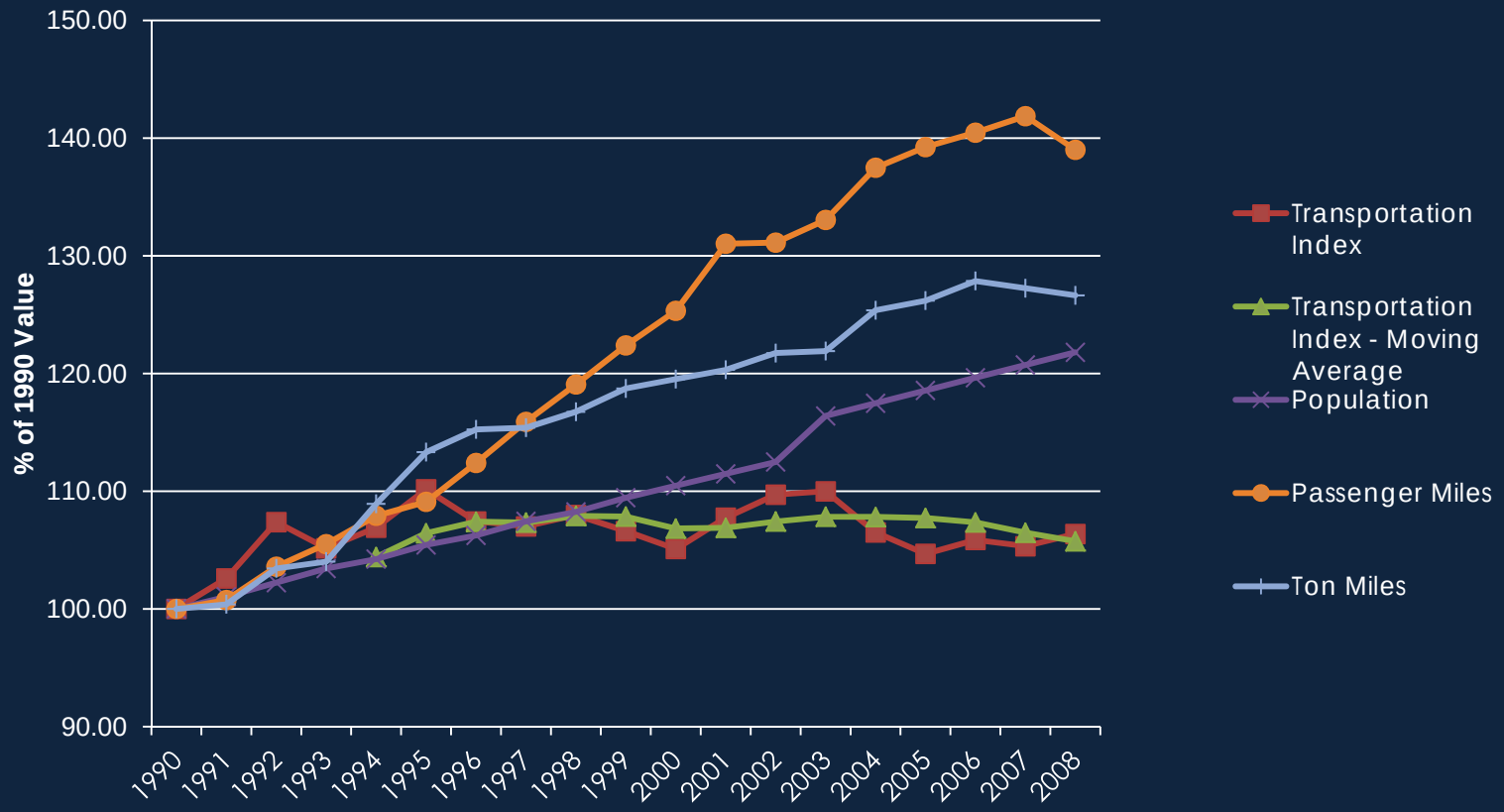
Changes in the period 1990-2009

- Security.
- Sustainable infrastructure
- Burdens of regulation.
- Burdensome project delivery process
- Significant changes in funding (Highway Trust Fund, Aviation Trust Fund and Inland Waterway Trust Fund.)
- Inability of local, state and regional governments' to match federal funds
- Citizens' unwillingness to support infrastructure improvements
- 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
- Improved operations (more throughput), multi-modal approaches, regional and corridor issues, impact of bottlenecks, and synergies between modes.

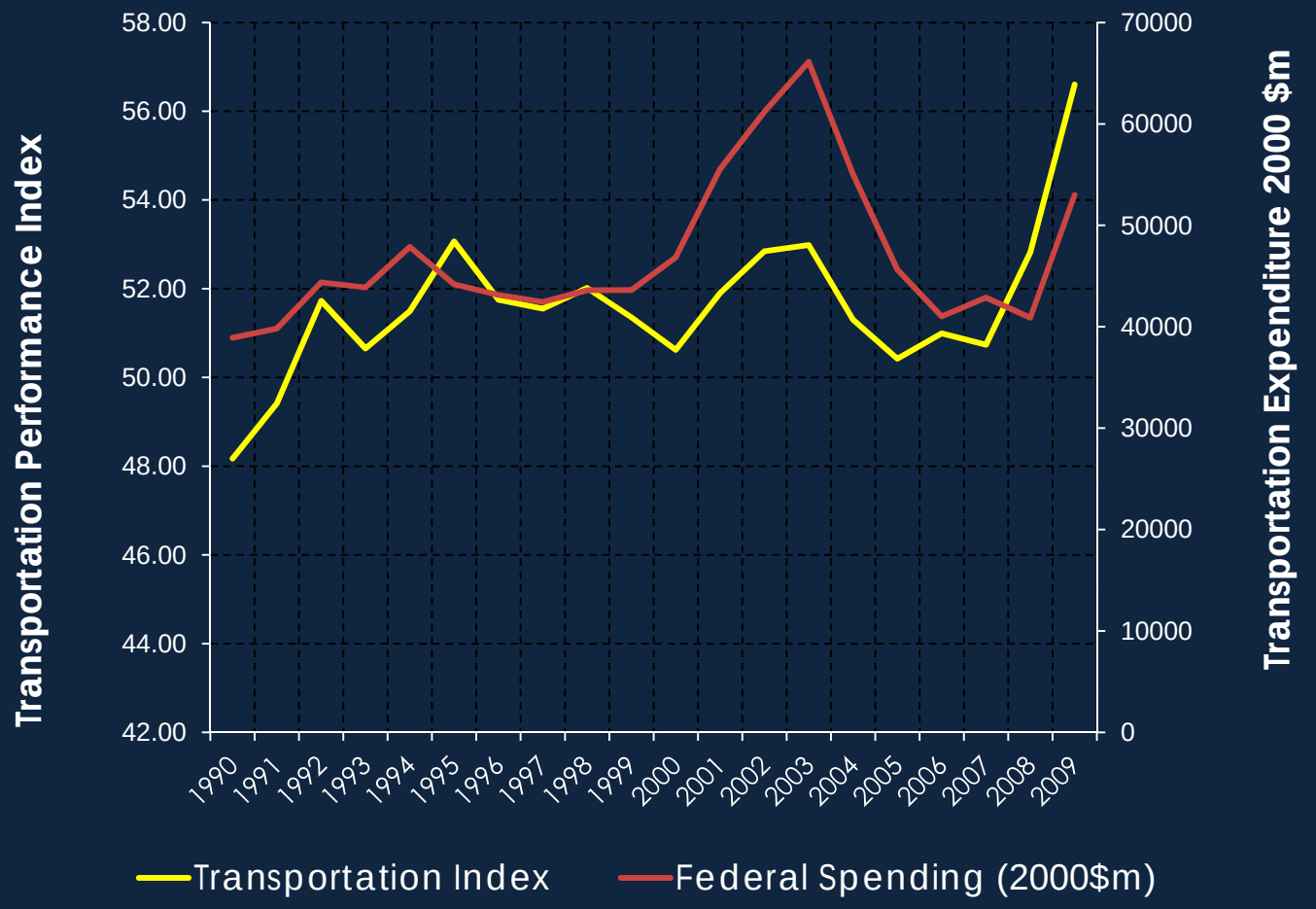
Sensitivity of the Weights



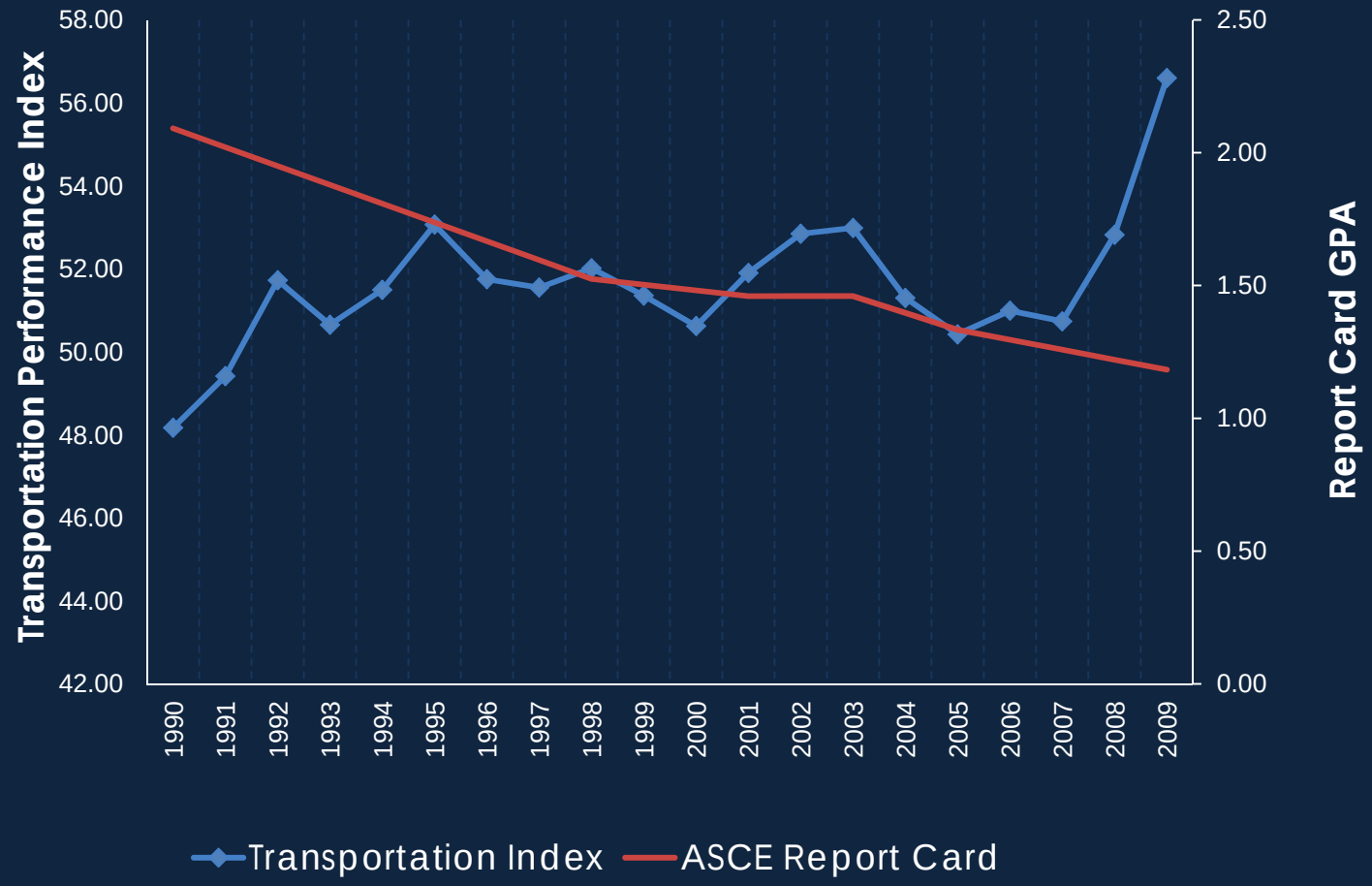
Comparison with Other Time Series



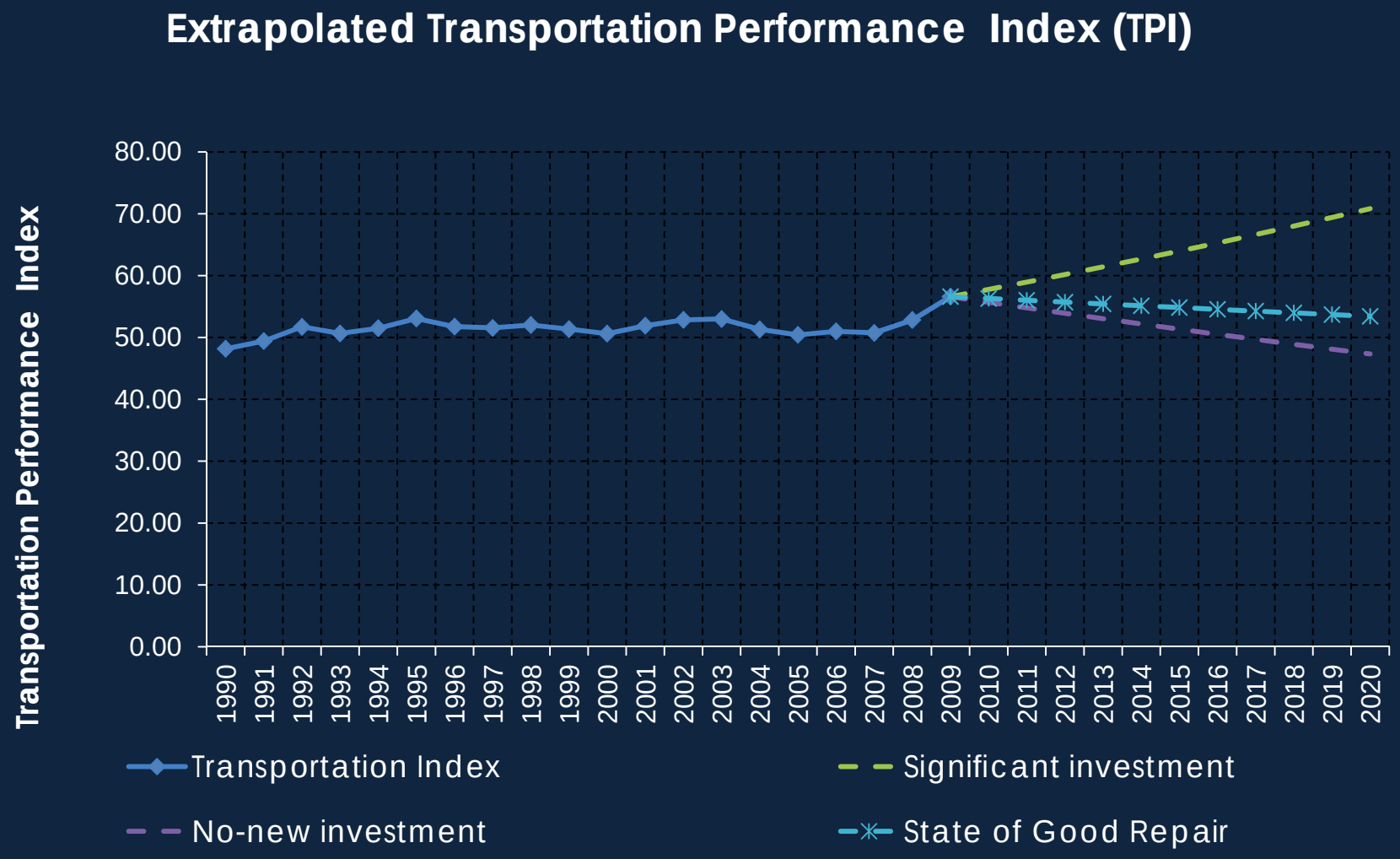
Comparison to Federal Transportation Expenditures



ASCE's Report Card



Extrapolated Future - 2020



Economic Analysis

- Past research has attempted to correlate infrastructure **spending** and economic growth
- Following Sala-i-Martin (1994) and Sanchez-Robles (1998), growth model form is:

  ln GDP per capita

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

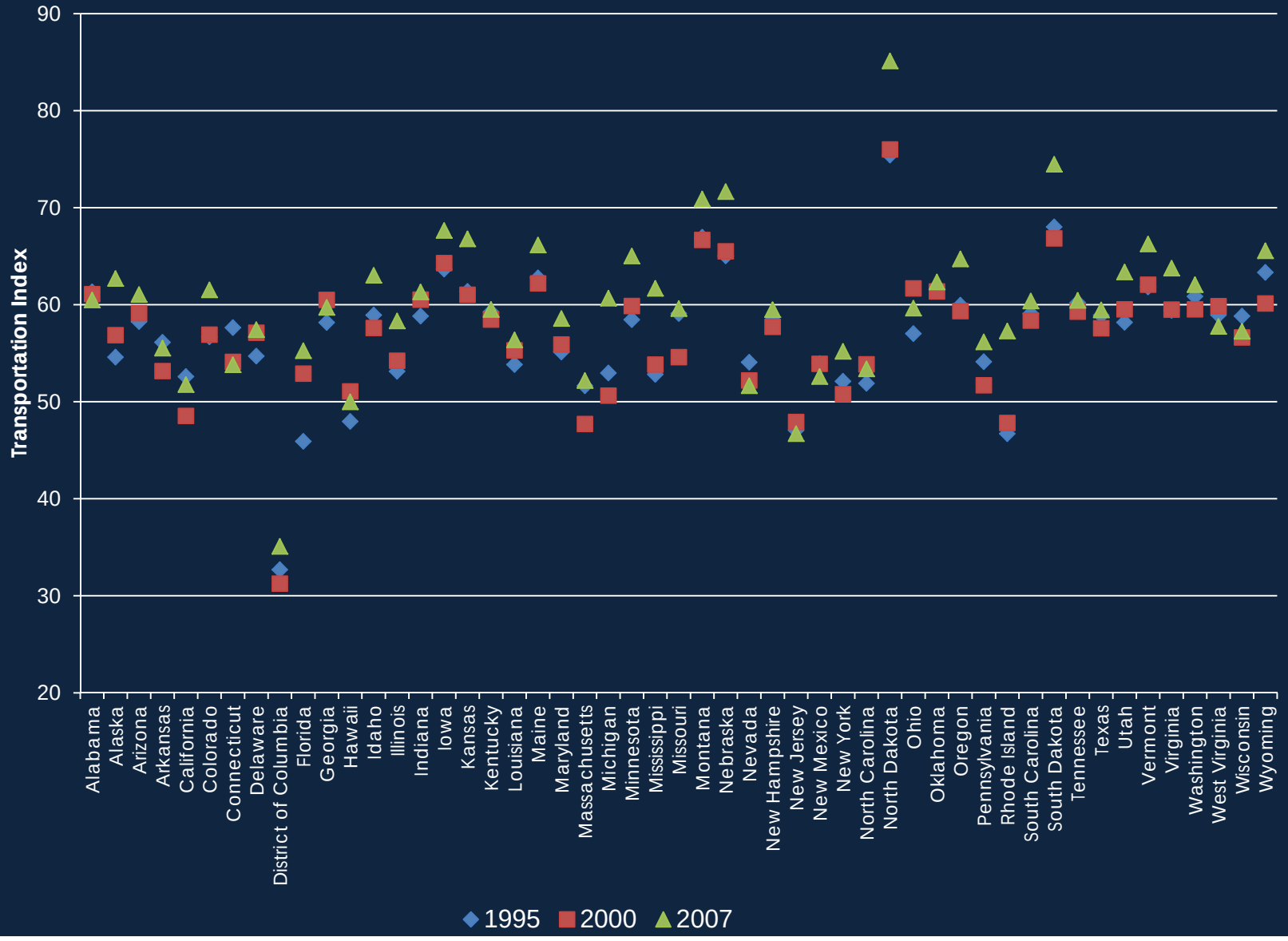
National Results

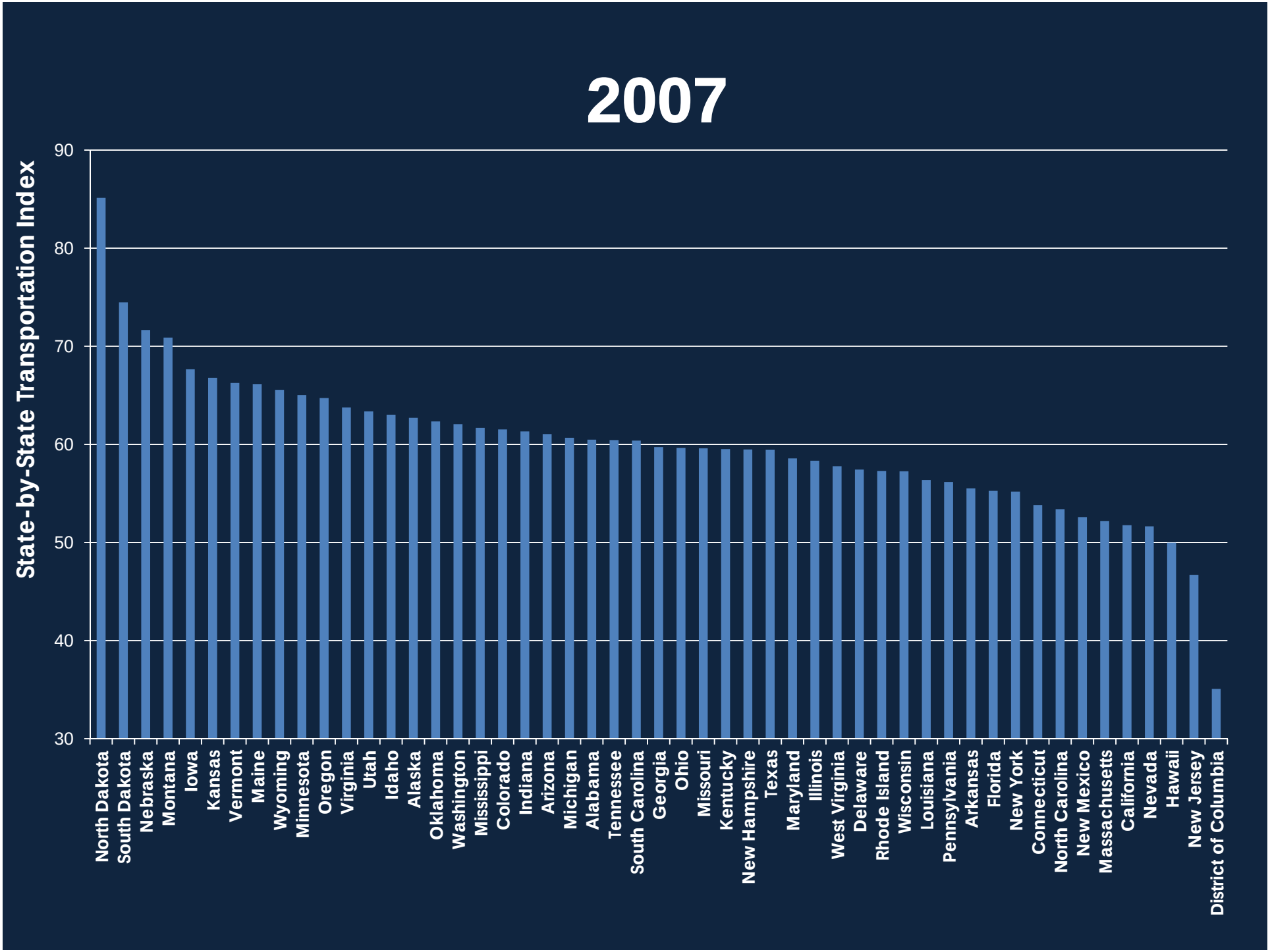
GDP per Capita	Coefficients*
Transportation Index **	0.0037
Real GDP	0.6120
Federal debt	-0.0025
R-squared	0.9953

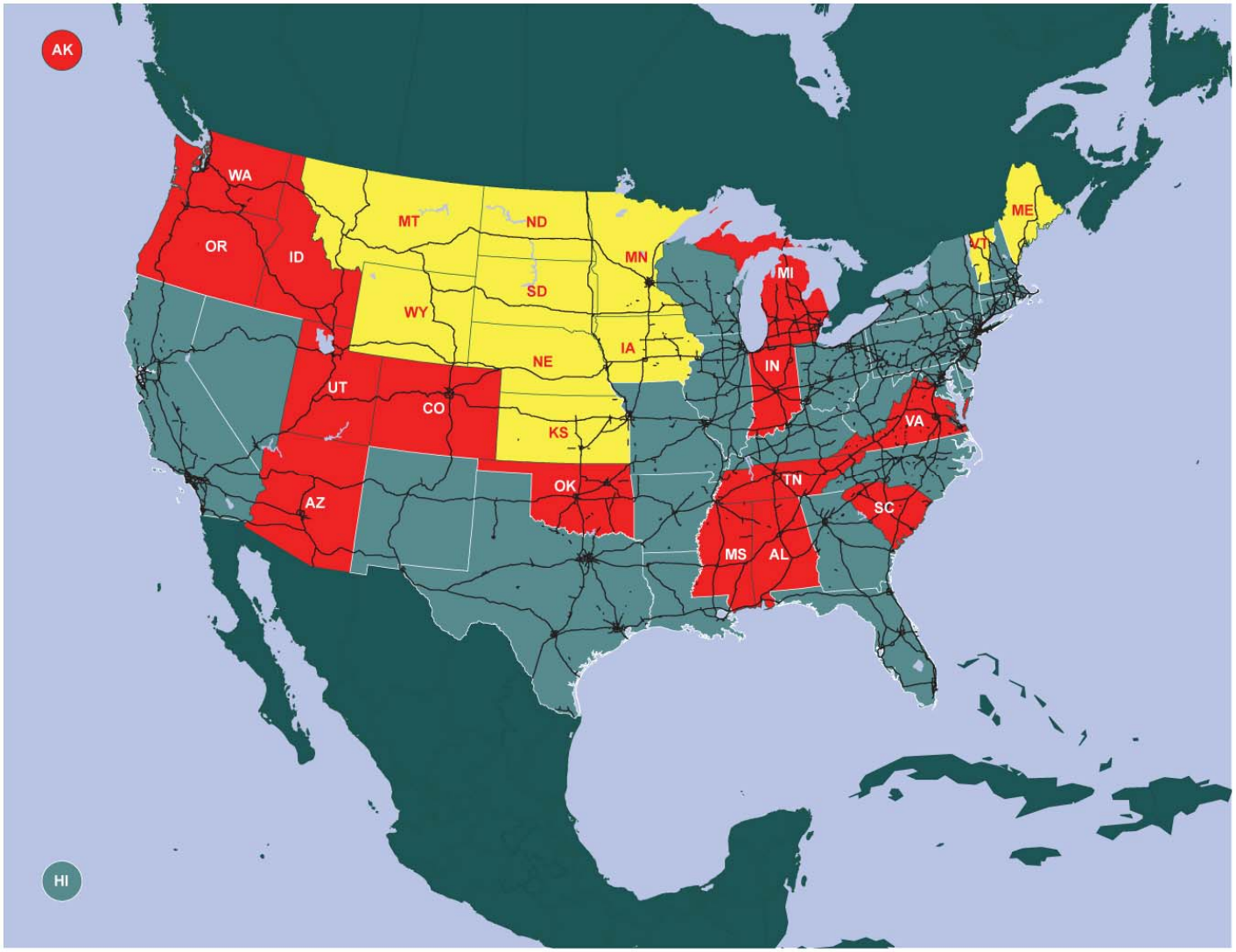
***All coefficients significant at 0.99.**
****Three year lag**

Also positive correlation between the index and foreign direct investment.

State by State Results




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



Let's Rebuild America
Infrastructure Index
NORTH AMERICA

US CHAMBER OF COMMERCE

TRANSPORTATION INDEX - TOP 25 STATES

- Top 10 states
- Next 15 states
- Other 25 states

SOURCE: US CHAMBER OF COMMERCE - INFRASTRUCTURE INDEX

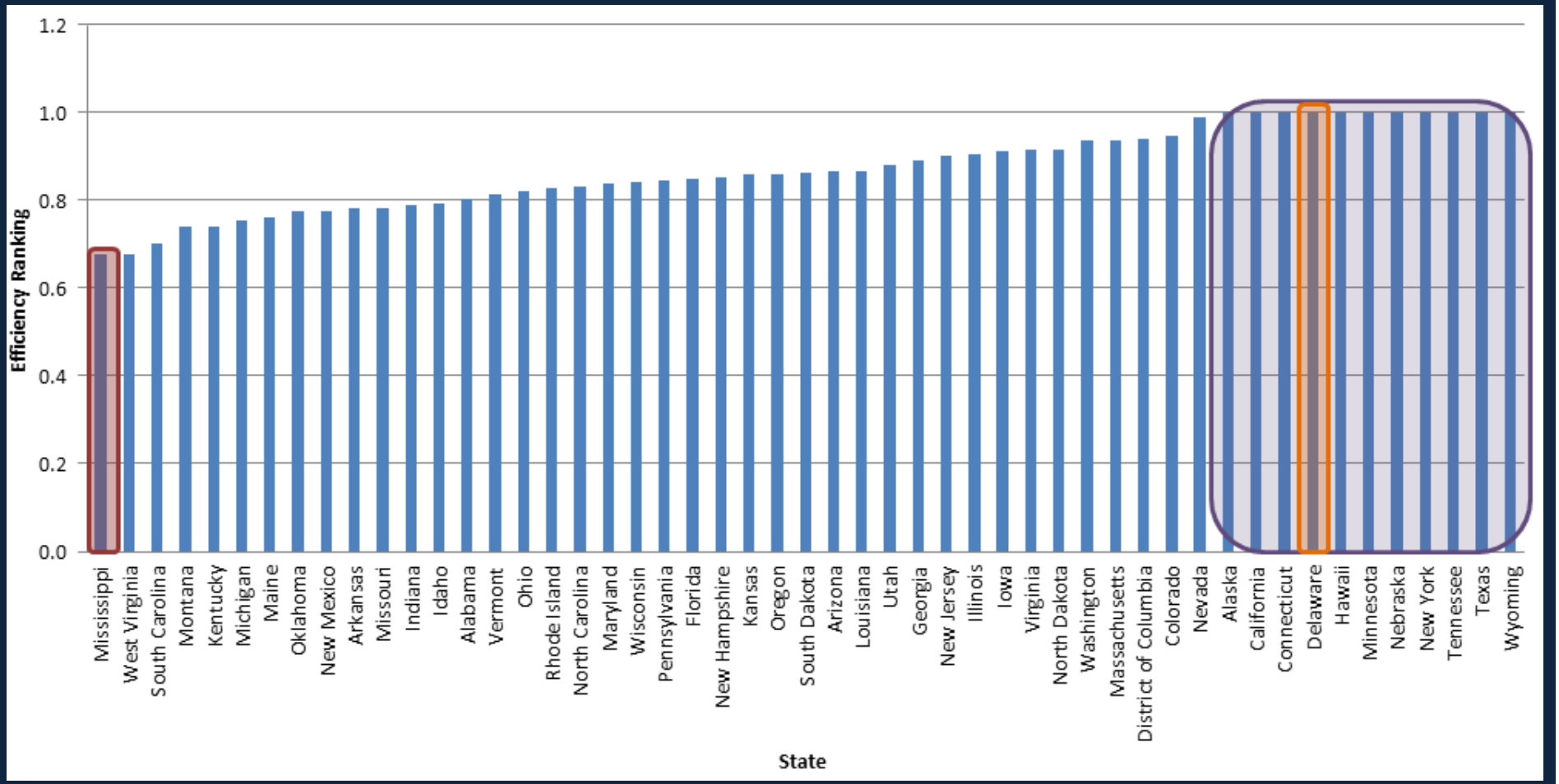
Version 1.2 8.23.10

MICHAEL GALLIS & ASSOCIATES

State by State Analysis

- Objective: to examine the effect environmental influences has on the relationship between GDP per capita and TPI at the state level.
- Used Data Envelopment Analysis to compute an efficiency score for each state.
- Environmental adjustment (population, density, growth, usage)
- Outputs – ln GDP per capita
- Inputs – debt, life expectancy

State-by-State Efficiency



Interpreting the results……

- Delaware's comprehensive efficiency stayed constant, being a benchmark for all 3 data years or having an efficiency value of 1.00. The TPI for Delaware for the data years are:
- 1995: 54.70, 34th Rank
- 2000: 57.11, 28th Rank
- 2007: 57.43, 35th Rank

Ongoing and Future Tasks

- Relate indices to investments and policies
- Develop a strategy for annual updating including refining the indices

What did we learn

- Important to capture temporal and spatial variability (use threshold)
- Decision makers are good at making do (Yankee ingenuity)
- Lots of data, quality is questionable
- Having a vision is probably the most effective tool

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Questions?

For more information see: http://www.uschamber.com/lra/transportation-index