An Exploratory Aggregate Analysis of Interstate Highway Bridge Deck Expenditure & Condition

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Oversight bodies in USA

- USDOT
- FHWA
- GAO

Oversight body responsibilities include

- Measuring agency outcomes
- Assessing each agency outcomes relative to:
  - previous year’s outcomes
  - agency spending levels
  - outcomes of other agencies.
Introduction

Scope and Objectives of this paper

Scope: Interstate highway bridge decks in USA

Objectives:

- Establish empirical relationship between deck expenditure and deck condition
- Compare relative performance across states
DATA SOURCES

1. FHWA’s Office of Highway Policy Information:
   • Database of state highway expenditures on highway construction and maintenance.
   • Database of highway bridge features:
     – Average daily truck traffic per bridge
     – Deck condition rating (NBI)
     – Total Deck area in a state

2. National Climate Data Center (NCDC) database:
   – For each state, the average freeze index, Annually, Years 1992 to 2012.
# Data

## Data on strength factors:
- **Total expenditure** per ft\(^2\) of deck

## Data on stress factors:
- **Traffic (truck) loads**
- **Climate severity** (Freeze index in degree-days)

## Other data:
- **Total area of interstate bridge decks in a state**
- **Deck condition**
Data

Distribution of the Average Deck Condition across the States, 10-year average
(NBI Indices shown here as continuous variables)

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Methodology

Part 1: The Relationship between Deck Condition and Deck Expenditure

- **Response variable:**
  - Rehabilitation and maintenance expenditure (EXP) in $2010.

- **Explanatory variables are**
  - deck condition in previous year (Cond)
  - freeze index (FRZ)
  - total deck area of bridges in the state (AREA)
  - traffic loading (annual average daily truck traffic (AADT)).

- **Model form**
  
  $$Total_{EXP} = \beta_0 + \beta_1 Cond + \beta_2 FRZ + \beta_3 AADT + \beta_4 AREA$$
Part 2: Assessing the Relative Performance across the States

Inputs:

- Expenditure ($/ft^2$ of deck)
- Average climate severity
- Average truck traffic per bridge
- Average condition of all decks
• **Expenditure ($/ft^2 of deck)**
  - Expenditure $\uparrow$ Deck condition $\uparrow$

• **Average climate severity**
  - Climate severity $\uparrow$ Deck condition $\downarrow$

• **Average truck traffic per bridge**
  - Truck traffic $\uparrow$ Deck condition $\downarrow$

1. In states with favorable (mild) climate, bridge decks suffer less exposure to freezing conditions, free-thaw cycles, ice, and harmful deicing salts.
Methodology

Excellent performing states
  • Low expenditure ($/ft^2 of deck)
  • Unfavorable climate
  • High truck traffic per bridge
  • Yet, good condition of decks

Poor performing states
  • High expenditure ($/ft^2 of deck)
  • Favorable climate
  • Low truck traffic per bridge
  • Yet, poor condition of decks
RESULTS & DISCUSSION
Part 1. The Relationship between Condition and Expenditure

- Inverse relationship between the deck condition and the expenditure
  - A lower average condition in one year leads to higher expenditures the following year.

- The higher the total area of bridge deck, the higher the total expenditure per ft² (but relationship is non-linear; hence, scale economies exist)

- A higher freeze index is generally associated with higher expenditure.

\[ Total_{-}EXP = \beta_0 + \beta_1 Cond + \beta_2 FRZ + \beta_3 AADT + \beta_4 AREA \]

|                      | Coef. | t     | P>|t|  | [95% Conf. Interval] |
|----------------------|-------|-------|-------|----------------------|
| AVG DECK CONDITION (NBI) | -382373.4 | -2.17 | 0.035 | -736482 to -28264.75 |
| TOTAL DECK AREA       | 0.004872  | 2.91  | 0.006 | 0.0015 to 0.0882     |
| FREEZE INDEX          | 29.7635   | 0.35  | 0.730 | -143.1713 to 202.6985|
| AVG TRUCK TRAFFIC     | 0.01444   | 1.32  | 0.194 | 0.007628 to 0.0365110|
| Constant Term         | 2562771   | 2.27  | 0.028 | 289499 to 4836043    |
Results

On average, Low deck condition and unfavorable conditions (high truck traffic and severe climate) and high spending levels ($/ft² of deck)

On average, Low deck condition despite their favorable conditions (low truck traffic and mild climate) and high spending levels ($/ft² of deck)

On average, Good deck condition, favorable conditions (low truck traffic and mild climate) and low spending levels ($/ft² of deck)

On average, High deck condition despite their unfavorable conditions (high truck traffic and severe climate) and low spending levels ($/ft² of deck)


Indiana, Utah, Iowa, Colorado, Minnesota, Ohio, Wisconsin, Wyoming, California, Missouri, Kansas, Nevada, South Dakota, South Carolina, Alabama, Virginia, New Hampshire, New Mexico, Florida, Montana, Maryland, Hawaii, Maine, North Carolina, Nebraska

The position of a state in a quadrat can be a reflection of the prudent use of the taxpayer funds by the state agency.
Conclusion

• The framework shows how oversight agencies can increase the **overall accountability** of individual highway agencies.

• The observed differences in the state performance could be due to differences in:
  - **Agency supervision/audit quality**
  - **Work culture** in the agency
  - **Geotechnical conditions** in the state
  - **Design/construction practices**
  - **Material** quality in the state’s quarries

• Results can help agencies seen/perceived as poorly performing, to carry out **critical self-assessment** to:
  - identify the possible causes of such performance or
  - investigate reasons for any misperception.
Future Work

- Key Assumption In Current Paper: One (1) degree-day of FRZ and One (1) truck have equivalent effects on deck damage, and hence on deck repair expenditure.

- Future papers could relax the above assumption by:
  - Establishing appropriate weights between the deterioration factors and use these weights to determine the agencies’ quadrant positions

- Consider other model specifications; e.g., the lagged panel model.

- Consider average statewide values of other design variables that:
  - Constitute “stressors” or “strengtheners” of deck condition
  - Measure the stability of the state quadrant position (performance ranking) across the years

- Extend the work to the other bridge components (superstructure and substructure) and other highway functional classes
KEY REFERENCES
Key References


THANK YOU FOR YOUR ATTENTION