Prioritization for Infrastructure Investment in Transportation

Jeremy Sage
Prioritization for Infrastructure Investment in Transportation

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School of Economic Sciences
Washington State University
Presentation Overview:

• Motivation
  • Why do we (and should we) care about the productivity of Freight Transportation?

• The Cost of Congestion in Washington State

• Framework for Determining Truck Freight Benefits and Economic Impacts.

• Further Exploration of Reliability.
<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>…Individual Congestion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yearly delay per auto commuter (hrs)</td>
<td>16</td>
<td>39</td>
<td>43</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Travel Time Index</td>
<td>1.07</td>
<td>1.19</td>
<td>1.23</td>
<td>1.18</td>
<td>1.18</td>
</tr>
<tr>
<td>Planning Time Index (Freeway Only)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3.09</td>
</tr>
<tr>
<td>&quot;Wasted&quot; fuel per auto commuter (gallons)</td>
<td>8</td>
<td>19</td>
<td>23</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>CO2 per auto commuter during congestion (lbs)</td>
<td>160</td>
<td>388</td>
<td>451</td>
<td>376</td>
<td>380</td>
</tr>
<tr>
<td>Congestion cost per auto commuter (2011 dollars)</td>
<td>$342</td>
<td>$795</td>
<td>$924</td>
<td>$810</td>
<td>$810</td>
</tr>
</tbody>
</table>

| **…The Nation's Congestion Problem**              |      |      |      |      |      |
| Travel Delay (billion hrs)                        | 1.1  | 4.5  | 5.9  | 5.5  | 5.5  |
| "Wasted" fuel ($billion)                          | 0.5  | 2.4  | 3.2  | 2.9  | 2.9  |
| CO2 produced during congestion (billions of lbs)  | 10   | 47   | 62   | 56   | 56   |
| Truck congestion cost ($billion)                  | -    | -    | -    | $27  | $27  |
| Congestion cost ($billion)                        | $24  | $94  | $128 | $120 | $121 |

Drawn from TTI’s Urban Mobility Report
Small = <500,000  
Medium = 500,000 to 1 million  
Large = 1 million to 3 million  
Very Large = >3 million
…and this is just to operate the trucks.

Which brings us to the first FPTI project.
Project Overview:

• Congestion on the urban road network in the United States is estimated to cost the nation in excess of $100 billion, as each and every vehicle using the public roadway system experiences some degree of:

  • Wasted fuel
  • Lost productivity
  • Reduced mobility

• The cost value is large, but can it inform state level policy?

  • Additional knowledge is needed to understand:
    • How industries are impacted by congestion
    • What their likely response will be to increasing congestion
    • The net impact of these industry responses to the Washington State economy.
**Step 1: Survey Freight Dependent Industries in Washington State**
- Design CATI
- Administer CATI to 6,624 private-sector freight companies and carriers
- 1,062 Respondents

**Step 2: Calculate Direct Costs of Congestion to Freight Dependent Industries**
- Calculate total revenue of freight dependent industries from IMPLAN
- Calculate increased trucking and inventory costs due to congestion by industry
- Estimate the direct costs of congestion to freight dependent industries (*Assuming 60% of costs are passed to consumers*)

**Step 3: Translate Rising Business Costs into Gains or Losses of Jobs and Output for Each Industry**
- Enter direct costs into IMPLAN models
- Link trade flow data from each regional IMPLAN model
- IMPLAN multipliers translate costs into direct, indirect, and induced impacts:
  - *Industry output*
  - *Industry employment*

**Step 4: Evaluate the Losses and Gains (in Employment and Industry Output) to Determine the Regional and Statewide Impacts of Congestion**
### Step 2: Calculate the Direct Costs of Congestion to Freight-Dependent Industries

<table>
<thead>
<tr>
<th>Industry</th>
<th>Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, Forestry, Fishing*</td>
<td>$ 14,025,087,392</td>
</tr>
<tr>
<td>Mining*</td>
<td>$ 1,722,882,632</td>
</tr>
<tr>
<td>Construction</td>
<td>$ 39,590,105,088</td>
</tr>
<tr>
<td>Manufacturing*</td>
<td>$ 160,187,755,858</td>
</tr>
<tr>
<td>Retail Trade**</td>
<td>$ 111,814,709,161</td>
</tr>
<tr>
<td>Wholesale Trade**</td>
<td>$ 142,323,314,397</td>
</tr>
<tr>
<td>Transportation/Warehousing*</td>
<td>$ 16,754,995,185</td>
</tr>
<tr>
<td>Waste Management</td>
<td>$ 3,589,177,344</td>
</tr>
</tbody>
</table>

- **Calculating Total Revenue:**
  - Two modifications from IMPLAN’s output values:
    - Subtracted the value of inventory from output to reflect actual sales (*)
    - Adjusted using margins (sales receipts less the cost of the goods sold) to show the total value of the goods sold (**)
## Step 2: Calculate the Direct Costs of Congestion to Freight-Dependent Industries

<table>
<thead>
<tr>
<th>Industry</th>
<th>Inventory Cost</th>
<th>Trucking Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, Forestry, Fishing</td>
<td>0.01%</td>
<td>6.00%</td>
</tr>
<tr>
<td>Mining</td>
<td>0.00%</td>
<td>9.24%</td>
</tr>
<tr>
<td>Construction</td>
<td>0.04%</td>
<td>8.28%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>0.42%</td>
<td>6.04%</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>0.34%</td>
<td>2.59%</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>0.23%</td>
<td>3.16%</td>
</tr>
<tr>
<td>Transportation/Warehousing</td>
<td>0.04%</td>
<td>6.51%</td>
</tr>
<tr>
<td>Waste Management</td>
<td>0.00%</td>
<td>2.86%</td>
</tr>
</tbody>
</table>

- **Inventory Costs** (as percent of total revenue) based on need to hold inventory to combat congestion.

- **Trucking Costs** represent need for additional trucks, and used in conjunction with reported hourly trucking costs ($55-light, $76-heavy, $59-mixture)
### Step 2: Calculate the Direct Costs of Congestion to Freight-Dependent Industries

<table>
<thead>
<tr>
<th>Industry</th>
<th>Direct Cost of Congestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, Forestry, Fishing</td>
<td>$505,744,651</td>
</tr>
<tr>
<td>Mining</td>
<td>$95,516,613</td>
</tr>
<tr>
<td>Construction</td>
<td>$1,976,338,046</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>$6,208,877,417</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>$1,965,702,587</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>$2,894,856,215</td>
</tr>
<tr>
<td>Transportation/Warehousing</td>
<td>$658,471,311</td>
</tr>
<tr>
<td>Waste Management</td>
<td>$61,590,283</td>
</tr>
</tbody>
</table>

- Totals nearly $14.4 billion
- 20% congestion increase
- 60% cost realization
Step 3: Translate Rising Business Costs into Gains or Losses of Jobs and Output for Each Industry:
Step 3: Translate Rising Business Costs into Gains or Losses of Jobs and Output for Each Industry: Consumer Costs

- Consumers must decrease purchases of services and non-freight dependent goods to pay for the increased costs of freight dependent goods.

- Household consumption function in IMPLAN was modified to incorporate the spending decrease.
  - Weighted by population and income
Step 3: Translate rising business costs into gains or losses of jobs and output for each industry:
STEP 3: TRANSLATE RISING BUSINESS COSTS INTO GAINS OR LOSSES OF JOBS AND OUTPUT FOR EACH INDUSTRY: SOCIETAL BENEFITS

- Freight dependent business must increase spending on resources to counteract increased congestion.
  - Congestion as an inefficiency
  - Spending on Insurance and Capital is placed in corresponding IMPLAN industries.
  - Wages modeled as an increase to employee compensation
Step 4: Evaluate the Losses and Gains to Determine the Statewide and Regional Impacts of Congestion
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Positive Economic Impacts: Industries add employees and assets to combat congestion

Negative Economic Impacts: Costs to consumers rise and lead to decreased spending on other industries
Step 4: Evaluate the Losses and Gains to Determine the Statewide and Regional Impacts of Congestion

Positive Economic Impacts:
Industries add employees and assets to combat congestion

Negative Economic Impacts:
Costs to consumers rise and lead to decreased spending on other industries

Industries add 17,831 jobs
Industry output grows $3.03 billion
**Step 4: Evaluate the Losses and Gains to Determine the Statewide and Regional Impacts of Congestion**

**Positive Economic Impacts:**
- Industries add employees and assets to combat congestion

**Negative Economic Impacts:**
- Costs to consumers rise and lead to decreased spending on other industries

- Industries add 17,831 jobs
- Industry output grows $3.03 billion

- Industries lose 45,088 jobs
- Industry output declines $6.34 billion
Step 4: Evaluate the Losses and Gains to Determine the Statewide and Regional Impacts of Congestion

Positive Economic Impacts: Industries add employees and assets to combat congestion

- Industries add 17,831 jobs
- Industry output grows $3.03 billion

Negative Economic Impacts: Costs to consumers rise and lead to decreased spending on other industries

- Industries lose 45,088 jobs
- Industry output declines $6.34 billion
**Step 4: Evaluate the Losses and Gains to Determine the Statewide and Regional Impacts of Congestion**

**Positive Economic Impacts:** Industries add employees and assets to combat congestion

**Negative Economic Impacts:** Costs to consumers rise and lead to decreased spending on other industries

- Industries add 17,831 jobs
- Net loss of 27,257 jobs (0.7 percent of statewide total) and $3.3 billion (0.5 percent of statewide total) of industry output
**Step 4: Evaluate the Losses and Gains to Determine the Statewide and Regional Impacts of Congestion**

<table>
<thead>
<tr>
<th>Industries incurring additional expenditures (positive impacts) in order to combat congestion</th>
<th>Industries suffering from reduced expenditures (negative impacts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation and Information</td>
<td>Health and Social Services</td>
</tr>
<tr>
<td>Administrative Services</td>
<td>Real Estate and Rental</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>Finance and Insurance</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>Accommodation and Food</td>
</tr>
<tr>
<td>Government</td>
<td>Arts and Entertainment</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Construction and Utilities</td>
</tr>
<tr>
<td>Management of Companies</td>
<td>Professional and Scientific</td>
</tr>
<tr>
<td>Mining</td>
<td>Educational Services</td>
</tr>
<tr>
<td>Ag, Forestry, and Fishing</td>
<td></td>
</tr>
</tbody>
</table>
Step 4: Evaluate the Losses and Gains to Determine the Statewide and Regional Impacts of Congestion

<table>
<thead>
<tr>
<th>Region</th>
<th>Employment</th>
<th>Output ($millions)</th>
<th>Percentage of Regional Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northwest</td>
<td>-1,786</td>
<td>-$162</td>
<td>-0.48%</td>
</tr>
<tr>
<td>Southwest</td>
<td>-1,622</td>
<td>-$266</td>
<td>-0.52%</td>
</tr>
<tr>
<td>Central Basin</td>
<td>-1,793</td>
<td>-$244</td>
<td>-0.47%</td>
</tr>
<tr>
<td>Northeast</td>
<td>-2,213</td>
<td>-$290</td>
<td>-0.77%</td>
</tr>
<tr>
<td>Southeast</td>
<td>-345</td>
<td>-$31</td>
<td>-0.31%</td>
</tr>
<tr>
<td>Puget Sound</td>
<td>-21,741</td>
<td>-$3,600</td>
<td>-0.90%</td>
</tr>
<tr>
<td>Statewide Total</td>
<td>-29,500</td>
<td>-$4,600</td>
<td>-0.76%</td>
</tr>
</tbody>
</table>

Statewide Total:
- $4.6 billion output
- 29,500 jobs

Northeast:
- $290 million output
- 2,200 jobs

Puget Sound Metro:
- $3.6 billion output
- 21,700 jobs

Southwest:
- $266 million output
- 1,600 jobs

Central Basin:
- $244 million output
- 1,800 jobs

Southeast:
- $31 million output
- 345 jobs
Lessons Learned and Recommendations:

• What do these Findings Suggest for WSDOT’s Policies Towards Addressing Congestion on Corridors Used by Trucks?
  • The state’s economic vitality and livability depend on reliable, responsible, and sustainable transportation.
  • Congestion causes increased direct transportation costs to freight-dependent industries – which translate to increased costs of goods and services to consumers in Washington State.
    • Creates an operational efficiency problem for freight dependent firms: Trip Time ↑ Unproductive time in Traffic ↑ Productivity ↓ resulting in $14 Billion of increased operating costs.
  • These demonstrated economic impacts suggest that WSDOT should prioritize investments that enhance mobility for trucks and freight industries as a way to support the State’s goals of a strong economy.
Lessons Learned and Recommendations:

- Imbedding investment Principles into WSDOT’s *Moving Washington*:
A Framework for Determining Highway Truck–Freight Benefits and Economic Impacts
**Background**

Truck-freight related benefits should be recognized and acknowledged through quantitative project prioritization process.

Most existing project assessment frameworks do not separately evaluate the truck-freight benefits of proposed highway infrastructure projects.

Unable to capture full-range of truck-freight related impacts stemming from highway investments.

- Direct benefits
- Indirect benefits
Research Objectives

• Propose a transparent methodology for calculating both the direct freight benefits and the larger economic impacts of freight projects.
• Apply the methodology for projects assessment.
Methodology

Identify benefits

- Literature review
- WSDOT current project prioritization process
- Three technical groups (urban goods movement, global gateway, and rural economies)
Methodology

Direct freight benefits:
• Truck travel time savings
• Truck operating cost savings
• Truck emission changes

Economic impacts
• Employment changes
• Regional economic output changes
Methodology

**INPUTS**
- Project Specific Data Inputs

**MODEL FRAMEWORKS**
- Travel Demand Model
- Modeling Transportation Related Benefits
- Modeling Economic Impacts Using
  - Washington State CGE

**FRAMEWORKS**
- CGE: computable general equilibrium model

**OUTPUTS**
- Benefits from:
  - Travel Time Savings
  - Operating Cost Savings
  - Emissions Changes
- Employment Changes
- Regional Economic Output
Methodology—Economic Impacts Analysis (EIA)—Data

- Utilizes Social Accounting Matrices (SAM) from the 2010 IMPLAN data.
- Aggregate into 20 industrial Sectors:

<table>
<thead>
<tr>
<th>Aggregation Code</th>
<th>Freight Dependent Industries</th>
<th>Aggregation Code</th>
<th>Other Industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGFOR</td>
<td>Agriculture and Forestry</td>
<td>INFO</td>
<td>Information Services</td>
</tr>
<tr>
<td>MIN</td>
<td>Mining</td>
<td>FININS</td>
<td>Financial and Insurance</td>
</tr>
<tr>
<td>UTIL</td>
<td>Utilities</td>
<td>REAL</td>
<td>Real Estate</td>
</tr>
<tr>
<td>CONST</td>
<td>Construction</td>
<td>PROTEC</td>
<td>Professional and Technical</td>
</tr>
<tr>
<td>MANUF</td>
<td>Manufacturing</td>
<td>MANAG</td>
<td>Management</td>
</tr>
<tr>
<td>WTRAD</td>
<td>Wholesale Trade</td>
<td>ADMIN</td>
<td>Administration</td>
</tr>
<tr>
<td>RTRAD</td>
<td>Retail Trade</td>
<td>SOCSER</td>
<td>Social Services</td>
</tr>
<tr>
<td>TRAWAR</td>
<td>Transportation and Warehousing</td>
<td>ARTS</td>
<td>Arts and Entertainment</td>
</tr>
<tr>
<td>TRUCK</td>
<td>Transport by Truck</td>
<td>FOOD</td>
<td>Food Services</td>
</tr>
<tr>
<td>WMAN</td>
<td>Waste Management</td>
<td>OTHR</td>
<td>Other (Including Government)</td>
</tr>
</tbody>
</table>
Methodology—Economic Impacts Analysis (EIA)

- Create four regional CGE models.
  - 2 Geographic scales
  - Long-Run (LR) and Short-Run (SR) scenarios
- Model the infrastructure investment as an improvement in technology.
  - Improves the productivity of the transportation system
  - Initiate the CGE through a counterfactual that shifts the industry supply curve: (Cobb-Douglas shown for simplicity)

\[ Q = S(K^\alpha L^{1-\alpha}) \]

- Value of the shift is dependent upon the percent change in operating costs to the trucking industry
Case Study

Interstate-highway widening project
• 10 mile, 2 lanes each direction.
• A critical connector for the region and serves approximately 9,000 trucks daily.
• Freight demand is projected to increase by 30% over the next 10 years.
• Adding one lane each direction.
### Case Study -- Transportation Benefits

#### 2016-2035, Thousands of 2010 Dollars

<table>
<thead>
<tr>
<th>Benefit Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHT reduction</td>
<td>295 hours</td>
</tr>
<tr>
<td>Truck travel time savings</td>
<td>$ 8,704</td>
</tr>
<tr>
<td>Truck operating cost savings</td>
<td>$14,613</td>
</tr>
<tr>
<td>Emission impacts</td>
<td>-$5,370</td>
</tr>
<tr>
<td>Total</td>
<td>$17,947</td>
</tr>
</tbody>
</table>
## Case Study -- Economic Impacts

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Demand Model Benefit Output</td>
<td>$4,533,563</td>
</tr>
<tr>
<td>Spokane County Intermediate Expenditures (TRUCK)</td>
<td>$139,875,763</td>
</tr>
<tr>
<td>Statewide Intermediate Expenditures (TRUCK)</td>
<td>$1,760,368,000</td>
</tr>
<tr>
<td>Change in Truck Transport Productivity - Spokane County</td>
<td>3.24%</td>
</tr>
<tr>
<td>Change in Truck Transport Productivity - State</td>
<td>0.26%</td>
</tr>
</tbody>
</table>
Case Study -- Economic Impacts

<table>
<thead>
<tr>
<th>Region</th>
<th>Initial Employment Level</th>
<th>Change in Employment</th>
<th>Change in Activity Quantity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SR</td>
<td>LR</td>
</tr>
<tr>
<td>County</td>
<td>264,128</td>
<td>25.5</td>
<td>77.9</td>
</tr>
<tr>
<td>State</td>
<td>5,647,012</td>
<td>22.4</td>
<td>47.2</td>
</tr>
</tbody>
</table>

- **Price for truck services and regional output sales change:**
  - **County**
    - SR: 1.94% decrease in price and $9.8 million increase in sales
    - LR: 1.67% decrease in price and $28.7 million increase in sales
  - **State**
    - SR: 0.18% decrease in price and $10.5 million increase in sales
    - LR: 0.14% decrease in price and $22.2 million increase in sales
Limitations and Future Work

Limitations of using TDMs
Limited feedback loops between TDM and Impact Models

Future work
• Freight performance data
• Enhancing dynamic nature of models
Freight Performance Data: Reliability

Find a measure of reliability that will be useful and meaningful in a Benefit-Cost (B-C) analysis

This requires:

• Deciding on a measurable definition for travel time reliability.
• Identifying a value to use for reliability in freight transportation.
Current Measures of Reliability

The mean versus variance approach:

- uses the mean travel time as well as the standard deviation of travel times.
- This method is straightforward and relies upon extensive dataset collected from loop detectors, radar detectors, GPS devices, and other technical sensors.
- The larger the size of the standard deviation from the mean, the lower travel time reliability.
Current Measures of Reliability

**Percentiles:**

- Unreliability is measured and commonly valued as the 95th percentile travel time.
- This approach is presented as a numerical difference between the average travel time and a predictable upper deviation from the average.
- This difference (a real number) is then directly used to monetize the value of unreliability.
Current Measures of Reliability

**Percentiles (cont.):**

- Estimates the time travelers need to plan their trips in order to be on time

*Buffer time* is defined as the 95\textsuperscript{th} percentile of the travel time distribution minus the mean time.

\[
\text{Buffer time index} = \frac{95 \text{ percent travel time} - \text{mean travel time}}{\text{mean travel time}} \times 100\%
\]
Current Measures of Reliability

*Planning Time Index*: 
- Estimates the total travel time that should be planned
- The planning time index differs from the buffer time index in that it considers both recurrent delay and unexpected delay

\[
\text{Planning time index} = \frac{95\text{ percent travel time}}{\text{Free flow travel time}} \times 100\%
\]
Measure Recommendations

If sufficient travel time data is available, e.g. every 5 minute loop detector data
• Use the *buffer time index*
• Represents the extra travel time travelers must to add to ensure on-time arrival.

When data is sparse, e.g. low reading frequency GPS data
• Use the *bimodal approach* employed by WSDOT
• Does not require extensive travel time data, but still can examine and classify the reliability based on spot speed data.
Bimodal Method

- Identifies if travel time is:
  - Reliably fast,
  - Reliably slow,
  - Unreliable.

- Travel speeds (in a given time and location segment) follows a mixture of two normal distributions as traffic is composed of two stages: free-flow condition and congestion condition. We can represent truck spot speed distribution by 5 parameters:
  - mean \((\mu_1)\) & standard deviation \((\sigma_1)\) of congested speed.
  - mean \((\mu_2)\) & standard deviation \((\sigma_2)\) of free-flow speed.
  - Proportion of the two distribution \((\alpha)\)
Travel defined as unreliable \textit{iff}:

\[ |\mu_1 - \mu_2| \geq |\sigma_1 + \sigma_2|, \alpha \geq 0.2, \text{ and } \mu_1 \leq 0.75 \times V_f \]
<table>
<thead>
<tr>
<th></th>
<th>Night (12 AM – 6 AM)</th>
<th>AM Peak (6 AM – 9 AM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_1$</td>
<td>47.641</td>
<td>24.011</td>
</tr>
<tr>
<td>$\mu_2$</td>
<td>60.763</td>
<td>54.437</td>
</tr>
<tr>
<td>$\sigma_1$</td>
<td>9.512</td>
<td>11.780</td>
</tr>
<tr>
<td>$\sigma_2$</td>
<td>4.652</td>
<td>6.189</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.226</td>
<td>0.547</td>
</tr>
<tr>
<td>If $</td>
<td>\mu_1 - \mu_2</td>
<td>\geq</td>
</tr>
</tbody>
</table>
Conclusion

• A quantitative and transparent methodology capturing freight benefits can be used for freight project impacts assessment and project prioritization.

• Industrial base of a geographical region significantly impacts model outputs.

• The inclusion of a defendable and quantifiable reliability measure will be a significant contribution to the understanding of freight performance measures.
For more Information:

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