Estimating the Construction Cost Associated with Accelerated Bridge Construction

Project Team:

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Outline

• Project Background
• Current Practices in ABC Decision Making
• Project Objectives
• Cost Breakdown
• Total Cost Estimation:
  ◦ Construction Cost Estimation Tool
  ◦ Agency & Indirect Cost Estimation
  ◦ ABC vs. Conventional
Background

- ABC methods can have high initial costs.
- Present a major barrier for the wide adoption of ABC.
- Current decision making tools consider construction cost as user input.
- Need to provide decision makers with a quantitative tool to estimate the construction cost.
- Limited information about agency and indirect cost.
Decision Making Tools

Current Tools

Qualitative Tools
- Qualitative
  - Examples:
    1. FHWA Flowchart.
    2. FHWA “Yes/No” Matrix.

AHP Tools
- Pair-wise Comparison
  - Examples:
    1. Oregon-led Tool.
    2. MRTUC Tool.
    3. Mi-ABCD Tool

DOTs’ Practices
- Subjective
  - Examples:
    1. Utah DOT
    2. Colorado DOT.
    3. Iowa DOT.
Project Objectives

• Better understand the construction costs associated with the ABC methods.
• Develop a tool/tools to estimate the different construction cost components associated with the ABC projects.
Cost Breakdown

Total Project Cost

Indirect Cost

Direct Cost
- Labor
- Material
- Equipment

Indirect Construction

ROW
- Agency Overhead
- Design
- Insurance
- Preliminary Engineering
- Inspection
- Financing
- Geotechnical Services
- Training
- Public Outreach

Construction Equipment
- Road & Site Vehicles
- Small Tools & Consumables
- Major Construction Equipment

Project Supervision
- Project Management
- Field Supervision
- Project Admin

Temporary Construction
- Temporary Roads
- Temporary Enclosures
- Utilities
- Mobilization

Temporary Facilities
- Temporary Offices
- Temporary Facilities
- Scaffolding
- Computers
I. Construction Cost Tool

1. Data Collection

- A total of 65 projects from 1998-2013.
- Projects from 29 different states
1. Construction Cost

2. Data Analysis

Bridge Location

<table>
<thead>
<tr>
<th>Bridge Location</th>
<th># of Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>26</td>
</tr>
<tr>
<td>Rural</td>
<td>39</td>
</tr>
</tbody>
</table>

# of Projects

AADT

<table>
<thead>
<tr>
<th>AADT</th>
<th># of Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1000</td>
<td>15</td>
</tr>
<tr>
<td>1001-5000</td>
<td>10</td>
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<tr>
<td>5001-10000</td>
<td>5</td>
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<tr>
<td>10001-20000</td>
<td>3</td>
</tr>
<tr>
<td>20001-50000</td>
<td>2</td>
</tr>
<tr>
<td>50001-100000</td>
<td>1</td>
</tr>
<tr>
<td>&gt;100000</td>
<td>0</td>
</tr>
</tbody>
</table>

Bridge Types

<table>
<thead>
<tr>
<th>Bridge Types</th>
<th># of Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>50</td>
</tr>
<tr>
<td>Steel</td>
<td>15</td>
</tr>
</tbody>
</table>

# of Projects

# of Spans

<table>
<thead>
<tr>
<th># of Spans</th>
<th># of Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>6-10</td>
<td>10</td>
</tr>
</tbody>
</table>

8
1. Construction Cost Analysis

C&RT Tree Analysis

- A total of 65 projects (cost/sq.ft)
- Data normalized for time & location using RS Means indices.

### Independent Variable Importance

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Importance</th>
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</thead>
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<tr>
<td>AADT</td>
<td>100.0%</td>
</tr>
<tr>
<td>Number of Span</td>
<td>99.2%</td>
</tr>
<tr>
<td>Type</td>
<td>59.4%</td>
</tr>
<tr>
<td>Location</td>
<td>35.3%</td>
</tr>
</tbody>
</table>
I. Construction Cost Tool

Inputs:
1. Location
2. AADT
3. Bridge Type
4. # of Spans

Regression Model

Concrete = “0”  Steel = “1”
Rural = “0”  Urban = “1”

Spreadsheet Tool

Construction Cost

90.9%

<table>
<thead>
<tr>
<th>Category</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<tbody>
<tr>
<td>Range ($/ft^2)</td>
<td>0-100</td>
<td>101-200</td>
<td>201-300</td>
<td>301-400</td>
<td>401-500</td>
<td>501-600</td>
<td>601-700</td>
<td>701-800</td>
<td>801-900</td>
<td>901-1000</td>
</tr>
<tr>
<td>Categorical Value</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>0 to 1000</td>
<td>0</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1001 to 5000</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5001 to 10000</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>10001 to 20000</td>
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<tr>
<td>20001 to 50000</td>
<td>4</td>
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<tr>
<td>50001 to 100000</td>
<td>5</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100001 to 200000</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 200001</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
II. Indirect & Agency Cost Tool

1. Data Collection

- Data for indirect costs will be collected from a number of agencies:
  - ODOT
  - MassDOT
  - TDOT
  - TxDOT
  - VDOT
II. Indirect & Agency Cost Tool

2. Data Analysis

- **PE**
  - High: 41.70%
  - Low: 2.20%
  - Average: 14.90%

- **ROW**
  - High: 19.60%
  - Low: 3.10%
  - Average: 14.70%

- **CE**
  - High: 34.70%
  - Low: 9.90%
  - Average: 20.70%

- **Inspection**
  - High: 5.30%
  - Low: 1.80%
  - Average: 3.20%
II. Indirect & Agency Cost Tool

2. Data Analysis

**Avg % of CN Costs**

- PE: 14.9%
- ROW: 3.1%
- CE: 9.9%
- Inspection: 1.8%

**Avg $/sq.ft**

- PE: 69.7
- ROW: 10.5
- CE: 39.6
- Inspection: 8.0

**Avg % of Total Costs**

- PE: 10.3%
- ROW: 2.1%
- CE: 7.1%
- Inspection: 1.2%
## (ABC vs. Conventional)

### 1. Construction Cost

<table>
<thead>
<tr>
<th></th>
<th>ABC</th>
<th>Conventional</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>275</td>
<td>228</td>
<td>20%</td>
</tr>
<tr>
<td>Min</td>
<td>33</td>
<td>28</td>
<td>17%</td>
</tr>
<tr>
<td>Max</td>
<td>1061</td>
<td>1257</td>
<td>-16%</td>
</tr>
</tbody>
</table>

Number of case studies where the cost of ABC was less than Conventional = 21%

### Hypothesis Testing

**Paired Samples Test**

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference Lower</th>
<th>Upper</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC - Conventional</td>
<td>46.609</td>
<td>110.091</td>
<td>15.122</td>
<td>16.265</td>
<td>76.954</td>
<td>3.082</td>
<td>52</td>
<td>.003</td>
</tr>
</tbody>
</table>

1- Significant evidence that Means are not equal.

2- ABC > Conventional
(ABC vs. Conventional)

2. Preliminary Engineering Cost (PE)

<table>
<thead>
<tr>
<th></th>
<th>ABC</th>
<th>Conventional</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>11.2%</td>
<td>10.8%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Min</td>
<td>2.1%</td>
<td>1.8%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Max</td>
<td>25.1%</td>
<td>23.7%</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

Number of case studies where the cost of ABC was less than Conventional
= 50%

Hypothesis Testing

Paired Samples Test

<table>
<thead>
<tr>
<th></th>
<th>Paired Differences</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Std. Deviation</td>
<td>Std. Error Mean</td>
<td>95% Confidence Interval of the Difference</td>
<td>Lower</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>3.387</td>
<td>-7.281</td>
<td>8.041</td>
</tr>
</tbody>
</table>

1- NO Significant evidence that Means are not equal.
(ABC vs. Conventional)

3. Construction Engineering Cost (CE)

<table>
<thead>
<tr>
<th></th>
<th>ABC</th>
<th>Conventional</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>6.8%</td>
<td>8.3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Min</td>
<td>0.9%</td>
<td>4.1%</td>
<td>-3.2%</td>
</tr>
<tr>
<td>Max</td>
<td>12%</td>
<td>13.5%</td>
<td>-1.5%</td>
</tr>
</tbody>
</table>

Number of case studies where the cost of ABC was less than Conventional = 70%

Hypothesis Testing

Paired Samples Test

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC - Conventional</td>
<td>-1.51</td>
<td>5.429</td>
<td>1.717</td>
<td>Lower -5.394 Upper 2.374</td>
<td>-880</td>
<td>9</td>
<td>.402</td>
</tr>
</tbody>
</table>

1- NO Significant evidence that Means are not equal.
Conclusion

• A tool to estimate the construction cost associated with ABC at the early stages of the projects (in terms of $/sq.ft)

• Better understanding of the different types of indirect costs associated with ABC projects, their magnitude, and impacts.

• Comparison between ABC and conventional construction methods to determine the significant sources of difference between the two methods.
Thank You