Optimizing the Risk and Cost of Materials QA Programs
NCHRP 10-92

AASHTO SUBCOMMITTEE ON MATERIALS
GREENVILLE, SOUTH CAROLINA
AUGUST 2, 2016

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DIVERSIFIED ENGINEERING SERVICES, INC
1. Introduction

2. Methods

3. Phase 1: Current Practice
   - Data Collection
   - Findings

4. Phase 2: Developing Guidelines
   - Level 1: Qualitative materials-based assessment
   - Level 2: Qualitative property-based optimization
   - Level 3: Quantitative cost-based optimization

5. Conclusions
NCHRP Project Team

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- Jo Sias Daniel, University of New Hampshire
Why is it important?

Materials represent 50% of Federal aid construction dollars

Asphalt represents 20% of the total infrastructure budget

DOTs’ budgets are shrinking

Staffing reductions

Experience of workforce reducing

Low bid selection can incentivize contractors/suppliers to cut corners

The result of something going wrong can be catastrophic
Method outline

Phase 1
- Literature Review
- Survey
- Interviews
- Findings

Phase 2
- Guidelines
Data collection

<table>
<thead>
<tr>
<th>Research Methodology</th>
<th>Source of Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literature review</td>
<td>More than 80 relevant papers, manuals, schedules and reports.</td>
</tr>
<tr>
<td>Survey</td>
<td>Responses from 58 people out of 37 DOTs.</td>
</tr>
<tr>
<td>Interview</td>
<td>Maryland, Washington, Ohio, California, New Jersey, Texas, Virginia, Florida</td>
</tr>
</tbody>
</table>

The map shows the states where literature reviews were conducted, responded to surveys, and interviewed.
What are DOTs doing?

Material’s QA practices based on legacy practices

QA approaches change from DOT-to-DOT and sometimes even within departments

Informal hierarchy based on materials type:

- Project produced
- Plant produced
- Standard manufactured material
What factors influence DOT’s QA approach?

- Material variability and level of control
- Criticality of materials or products – difficulty to repair or replace, safety, maintenance cost or cost of rework
- Project characteristics – size and complexity
- Industry experience
- The use of alternative delivery methods

45% of the responders did not vary their QA approach for ACMs

Vs

Research DBOM contracts guidelines, schedules, and manuals
### Levels of DOT Acceptance Practices

<table>
<thead>
<tr>
<th>QA Effort Level</th>
<th>Description</th>
<th>Owner</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Visual Inspection</td>
<td>Visually inspects manufacture</td>
<td>Process control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visually inspects placement</td>
<td></td>
</tr>
<tr>
<td>Level 2</td>
<td>Certification</td>
<td>Verify that certification complies with specification requirements.</td>
<td>Certifies materials and installation meet specifications</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Performs testing and maintain data to support certification</td>
</tr>
<tr>
<td>Level 3</td>
<td>Certification with backup data attached</td>
<td>Verification of data (audit certification data for compliance including option to perform additional tests)</td>
<td>Performs testing and submits backup data to support certification (i.e. mill test or other tests attached to certification)</td>
</tr>
<tr>
<td>Level 4</td>
<td>Reliance on contractor data for acceptance with agency verification</td>
<td>Tests material on a reduced frequency and compares it to the contractor's results. Also responsible for IA.</td>
<td>Performs sampling and testing and provides results to owner</td>
</tr>
<tr>
<td>Level 5</td>
<td>Sampling and testing performed by agency</td>
<td>Performs sampling and testing and accepts materials using their results. Also responsible for IA.</td>
<td>Process control</td>
</tr>
</tbody>
</table>

**Inspection happens at all levels**
So what did we learn?

Four scenarios to control the QA approach and quantify the impact of QA

<table>
<thead>
<tr>
<th>Factors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry Experience</td>
<td>The confidence or reliability an owner has on the contractor and/or supplier.</td>
</tr>
<tr>
<td>Material Quantity</td>
<td>The planned quantity or volume of material.</td>
</tr>
<tr>
<td>Project delivery method</td>
<td>The system used by the owner for organizing and financing design, construction, operation, and maintenance services for this project.</td>
</tr>
<tr>
<td>Criticality/Complexity</td>
<td>Project size, location, criticality (urban)</td>
</tr>
</tbody>
</table>
Phase 2

Introduction

Methods

Phase 1

Phase 2

Conclusions

Level 1
(Qualitative Materials-Based Assessment)

Optimized listing of materials and QA activities

Level 2
(Qualitative Properties-Based Assessment)

Optimized acceptance testing emphasizing properties that are more direct indicators of performance

Level 3
(Cost-Based Assessment)

Optimum investment point based on explicit consideration of direct costs

Cost Data

Test Properties

Materials of interest
Level 1: Qualitative materials based optimization

1. Identify goals of (or drivers for) optimization – constraints due to staffing, experience, testing capabilities, or an interest in emerging QA methods
2. Identify materials of interest
3. Identify production mode (project produced vs. fabricated vs. standard manufactured-slide 7)
4. Assess risk of non-conformance for each material of interest
5. Identify appropriate QA methods given material tier
6. Refine selection of QA method(s) as necessary
7. If chosen QA approach involves sampling and testing go to level 2 assessment
   • If cost data available to refine QA methods go to level 3 assessment
### Level 1: Qualitative materials based optimization

<table>
<thead>
<tr>
<th>Numerical Rating</th>
<th>Adjectival Description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minimal Impact</td>
<td>Little if any impact to service life</td>
</tr>
<tr>
<td>2</td>
<td>Some Impact</td>
<td>Earlier than planned maintenance needed</td>
</tr>
<tr>
<td>3</td>
<td>Significant Impact</td>
<td>Earlier than planned major rehabilitation needed</td>
</tr>
<tr>
<td>4</td>
<td>Catastrophic Impact</td>
<td>Immediate intervention needed</td>
</tr>
</tbody>
</table>

### Risk Impact Definitions

<table>
<thead>
<tr>
<th>Numerical Rating</th>
<th>Adjectival Description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nonconformance is unlikely</td>
<td>&lt; X%</td>
</tr>
<tr>
<td>2</td>
<td>Nonconformance is somewhat likely</td>
<td>≥ X% to &lt; X%</td>
</tr>
<tr>
<td>3</td>
<td>Nonconformance is likely</td>
<td>≥ X% to &lt; X%</td>
</tr>
<tr>
<td>4</td>
<td>Nonconformance is highly likely</td>
<td>≥ X% to &lt; X%</td>
</tr>
</tbody>
</table>
Level 1: Qualitative materials based optimization

<table>
<thead>
<tr>
<th>Risk Score</th>
<th>Material Tier</th>
<th>Description</th>
<th>Suggested Level of QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Score &gt; 8</td>
<td>Tier 1</td>
<td>Materials having the greatest risk of failure</td>
<td>QA methods designed to provide maximum confidence in the quality of the materials provided.</td>
</tr>
<tr>
<td>2 ≤ Risk Score &lt; 8</td>
<td>Tier 2</td>
<td>Moderate risk materials</td>
<td>QA methods designed to provide a high level of confidence in the quality of the materials provided.</td>
</tr>
<tr>
<td>Risk Score ≤ 2</td>
<td>Tier 3</td>
<td>Low risk materials</td>
<td>QA methods entailing greater use of certificates of compliance from the contractor/producer combined with intermittent to random inspection, sampling, and testing of in-progress work.</td>
</tr>
</tbody>
</table>

Impact table:

<table>
<thead>
<tr>
<th>Probability</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some</td>
<td></td>
<td></td>
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<tr>
<td>Catastrophic</td>
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<td></td>
</tr>
</tbody>
</table>

**Probability**

- Highly Likely: 4
- Likely: 3
- Somewhat Likely: 2
- Unlikely: 1
Level 2: Property based optimization

1. Identify materials of interest
   - Project-produced materials with greatest variability

2. Identify acceptance material properties (density, AC content, strength, air content, etc.)

3. Identify QA acceptance plan
   - Test methods, sampling plan, targets, responsibilities

4. Identify appropriate types/levels of owner acceptance or verification testing

5. Can acceptance testing can be reduced based on significance of property and material use?

6. How indicative of performance is the property for acceptance?

7. Primary indicator – highest residual risk (default acceptance/verification testing frequencies)
   - Secondary indicator – medium residual risk (reduced acceptance/verification testing frequency)
   - Observational indicator – low residual risk (observation of contractor QC with random verification testing)
Level 3: Cost-based optimization

Need of better understanding of:
- Cost of QA
- Rationale behind acceptance method
- Probability of non-conforming material
- Impact of a non-conforming material
Level 2: Property based optimization

1. Identify materials of interest
2. Identify project factors influencing QA effort (complexity, delivery method, etc.)
3. Identify levels of QA effort
4. Determine the cost of QA (actual costs or Delphi process)
5. Quantify probability of non-conforming material
6. Quantify the cost of non-conforming material (based on data or expert panel)
7. Quantify the expected value of a non-conforming material
   • Optimize QA based on the total cost of quality (CoQ)
Level 3: Cost-based optimization

<table>
<thead>
<tr>
<th>Spec\Scenario</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Bridge members</td>
<td>110%</td>
<td>110%</td>
<td>110%</td>
<td>110%</td>
</tr>
<tr>
<td>2 Drainage structure</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

### QA Effort\Scenarios Table

<table>
<thead>
<tr>
<th>QA Effort\Scenarios</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual inspection</td>
<td>70%</td>
<td>80%</td>
<td>65%</td>
<td>66%</td>
</tr>
<tr>
<td>Certification</td>
<td>56%</td>
<td>65%</td>
<td>53%</td>
<td>47%</td>
</tr>
<tr>
<td>Certification w/data</td>
<td>47%</td>
<td>58%</td>
<td>44%</td>
<td>35%</td>
</tr>
<tr>
<td>Verification S&amp;T</td>
<td>26%</td>
<td>33%</td>
<td>20%</td>
<td>19%</td>
</tr>
<tr>
<td>Full S&amp;T</td>
<td>11%</td>
<td>18%</td>
<td>10%</td>
<td>10%</td>
</tr>
</tbody>
</table>

### Given that:

1) The precast material is a bridge member;
2) The contractor has a high industry experience, the project has a large amount of material and is a complex or critical project, and the delivery method is a traditional design-bid-build; and
3) The agency performed verification sampling and testing.

A) What is the probability that the material is non-conforming after the agency accepts it?
B) What is the cost of performing that level of QA as a percentage of the material total installed or in-place cost?
Findings

1. DOTs have generally downsized (materials QA and inspection staff)

2. Greater use of alternative delivery methods are shifting quality management to industry

3. Greater reliance on Industry QA
   a) Use of contractor QC Tests in acceptance decision
   b) Industry self-certification (fabricated, manufactured, and constituent materials)

4. Several DOTs use a risk-based approach to optimize materials management and inspection (in manuals and specifications)

5. Key factors that influence level of QA include material variability, criticality of materials, project characteristics, industry experience, and delivery method.
Conclusions

1. Agencies can significantly benefit from optimizing their materials QA

2. Potential applications
   a) Entire Program
   b) Project level
   c) All classifications of materials (but most beneficial for jobsite produced materials)

3. Framework includes 3 levels of optimization
   a) Materials-based (qualitative risk-based material assessment)
   b) Properties-based (qualitative risk-based property assessment)
   c) Cost-based (analysis of total cost of QA)