Optimizing the Risk and Cost of Materials QA Programs

NCHRP 10-92

AASHTO SUBCOMMITTEE ON MATERIALS
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Why is it important?

Resources invested

Materials represent 50% of Federal aid construction dollars

Asphalt represents 20% of the total infrastructure budget

Need for optimization

DOTs' budgets are shrinking

Staffing reductions

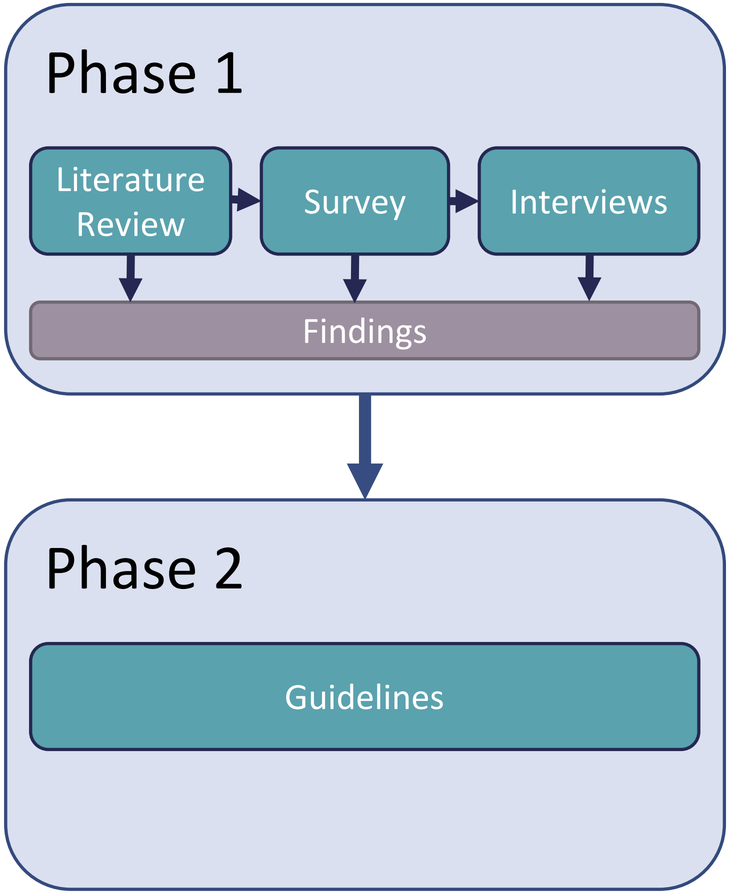
Experience of workforce reducing

Impact of QA

Low bid selection can incentivize contractors/suppliers to cut corners

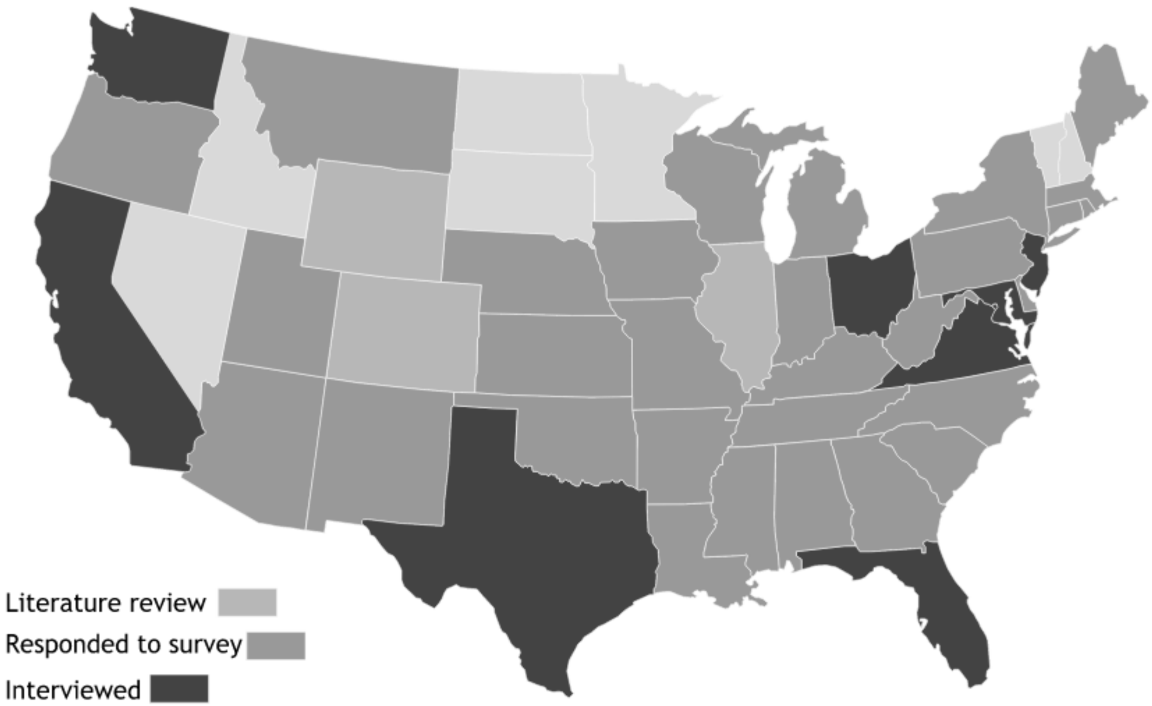
The result of something going wrong can be catastrophic

Method outline



Data collection

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



What are DOTs doing?

Material's QA practices based on legacypractices

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

So what did we learn?

Levels of DOT Acceptance Practices

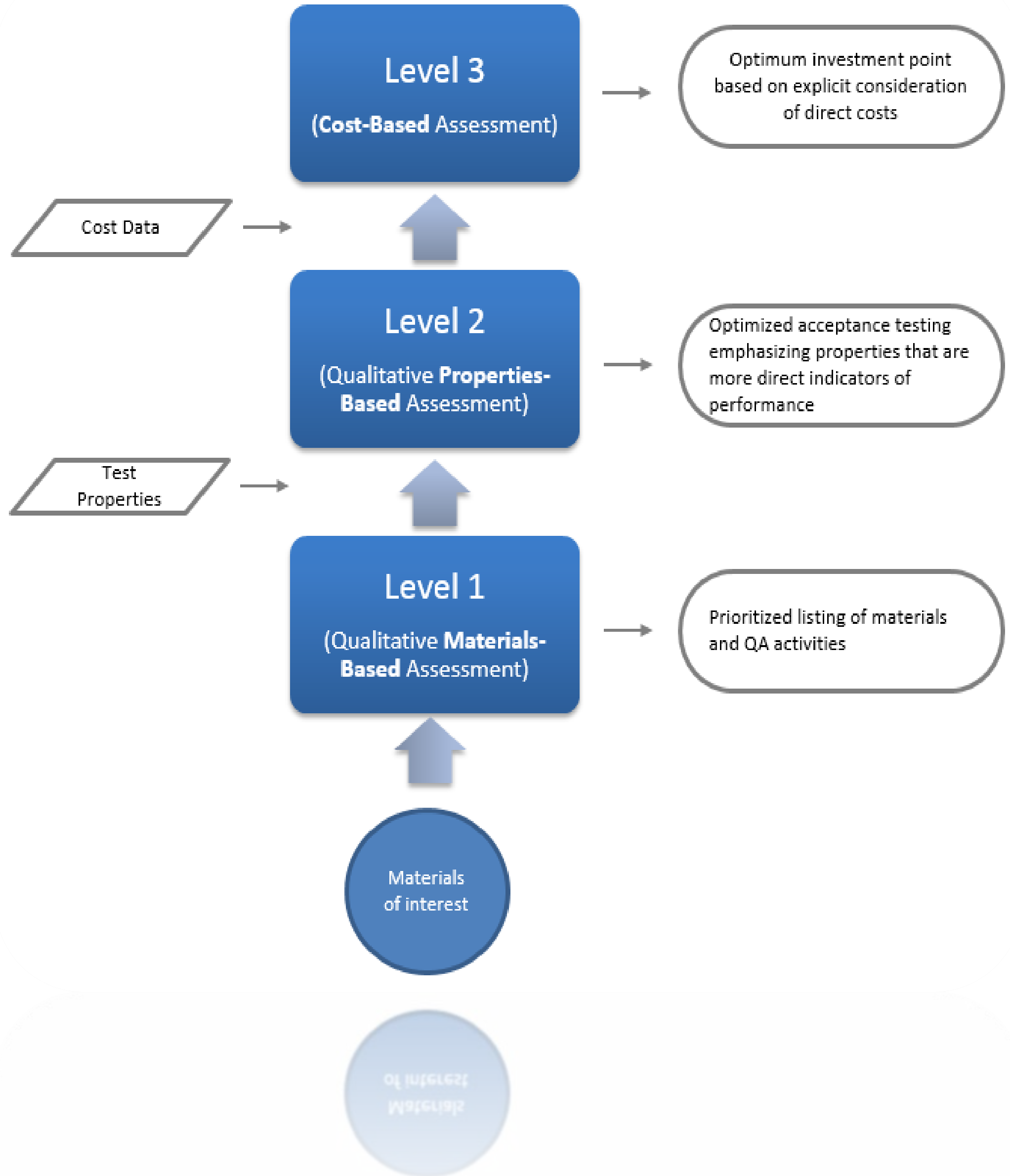
QA Effort Level	Description	Owner	Contractor
Level 1	Visual Inspection	Visually inspects manufacture Visually inspects placement	Process control
Level 2	Certification	Verify that certification complies with specification requirements.	Certifies materials and installation meet specifications Performs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

So what did we learn?

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

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

Phase 2


Level 3
(Cost-Based Assessment)
Optimum investment point based on explicit consideration of direct costs
Cost Data
Level 2
(Qualitative Properties-Based Assessment)
Optimized acceptance testing emphasizing properties that are more direct indicators of performance
Test Properties
Level 1
(Qualitative Materials-Based Assessment)
Prioritized listing of materials and QA activities
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

Risk Impact Definitions

Numerical Rating	Adjectival Description	Definition
1	Minimal Impact	Little if any impact to service life
2	Some Impact	Earlier than planned maintenance needed
3	Significant Impact	Earlier than planned major rehabilitation needed
4	Catastrophic Impact	Immediate intervention needed

Risk Probability Definitions

Numerical Rating	Adjectival Description	Definition
1	Nonconformance is *unlikely*	< X%
2	Nonconformance is *somewhat likely*	≥ X% to < X%
3	Nonconformance is *likely*	≥ X% to < X%
4	Nonconformance is *highly likely*	≥ X% to < X%

Level 1: Qualitative materials based optimization

Risk Score	Material Tier	Description	Suggested Level of QA
Risk Score ≥ 8	Tier 1	Materials having the greatest risk of failure	QA methods designed to provide maximum confidence in the quality of the materials provided.
2 ≤ Risk Score < 8	Tier 2	Moderate risk materials	QA methods designed to provide a high level of confidence in the quality of the materials provided.
Risk Score ≤ 2	Tier 3	Low risk materials	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.

			Impact			
			1	*2*	*3*	*4*
			Minimal	*Some*	*Significant*	*Catastrophic*
Probability	4	*Highly Likely*	4	8	12	16
	3	*Likely*	3	6	9	12
	2	*Somewhat Likely*	2	4	6	8
	1	*Unlikely*	1	2	3	4

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?

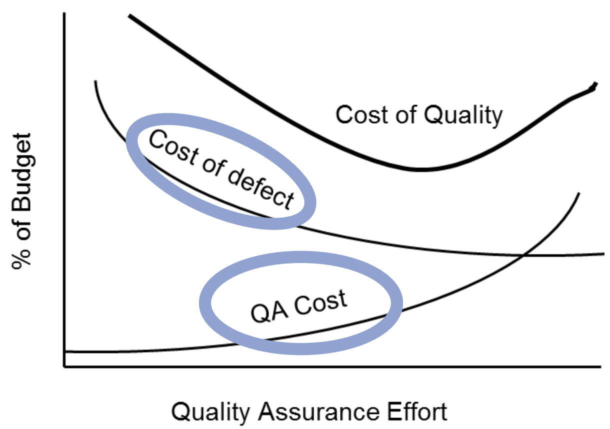
6
- How indicative of performance is the property for acceptance?

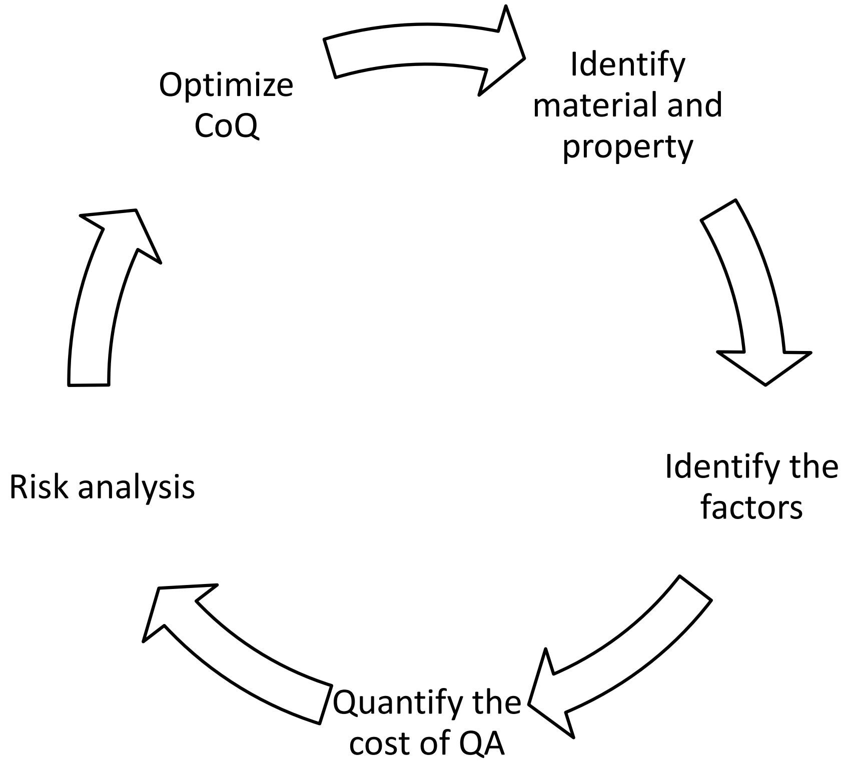
7
- Primary indicator – highest residual risk (default acceptance/verification testing frequencies)
- Secondary indicator – medium residual risk (reduced acceptance/verification testing frequency)
- Observational indicator – low residual risk (observation of contractor QC with random verification testing)

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

Bridge members

	S-1	S-2	S-3	S-4
QA Effort\Scenarios	1	2	3	4
Visual inspection	80%	91%	75%	76%
Certification	65%	75%	61%	55%
Certification w/data	55%	67%	51%	42%
Verification S&T	34%	31%	27%	26%
Full S&T	22%	30%	27%	31%

Bridge members

	QA Effort\Scenarios	1	2	3	4
1	Visual inspection	70%	80%	65%	66%
2	Certification	56%	65%	53%	47%
3	Certification w/data	47%	58%	44%	35%
4	Verification S&T	26%	33%	20%	19%
5	Full S&T	11%	18%	10%	10%

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?

Bridge members

	QA Effort\Scenarios	1	2	3	4
1	Visual inspection	3%	3%	3%	3%
2	Certification	3%	3%	3%	3%
3	Certification w/data	3%	3%	3%	3%
4	Verification S&T	5%	5%	5%	5%
5	Full S&T	10%	10%	10%	10%

	Spec\Scenario	1	2	3	4
1	Bridge members	110%	110%	110%	110%
2	Drainage structure	100%	100%	100%	100%

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)