Knowledge – based Condition Assessments

Presentation for:

Predicting Outcomes of Investments in Maintenance and Repair of Federal Facilities Report Dissemination Forum

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Presentation Outline

This presentation encompasses:

- A defining of terms
- An explanation of what a knowledge – based condition survey is and how it compares to a “traditional” approach
- A listing of condition survey objectives
- A discussion of the different types of condition survey inspection types
- A look at a building component-section life cycle, including M&R needs, condition zones, and condition survey inspection needs at different periods in the life-cycle
- A discussion regarding creating a condition survey plan
- Some experiences from the field
- A note on sampling
- Some thoughts regarding costs
Terms

**Component-section (a.k.a. section):** The basic “management unit.” Buildings are a collection of components grouped into systems. Sections define the component by material or equipment type and age.

**Condition Survey Inspection (a.k.a. Condition Survey; Inspection):** The gathering of data for a given component-section for the primary purpose of condition assessment.

**Condition Assessment:** The analysis of condition survey inspection data.

**Component Section Condition Index (CSCI):** An engineering – based condition assessment outcome metric (0 – 100 scale) and part of the Building Condition Index (BCI) series.
“Traditional” Condition Survey Inspection and Condition Assessment

- Identify and record condition related problems (deficiencies) that need to be (or should be) fixed
- Inspectors may provide an evaluation regarding priority (in a given priority class) and/or estimate of remaining service life, and perhaps flag other factors such as life – safety risk
- A scoping quantity and cost estimate is usually provided
- Inspections are usually planned and scheduled based on calendar and available budget
- Resulting condition assessment is usually monetary based and “backward” looking due to “as of” estimate date

<table>
<thead>
<tr>
<th>Deficiency:</th>
<th>Re-point brick retaining wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work Quantity:</td>
<td>200 sf</td>
</tr>
<tr>
<td>Scoping Estimate:</td>
<td>$4400</td>
</tr>
<tr>
<td>Urgency/Priority:</td>
<td>3</td>
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Knowledge – based Condition Survey Inspection - KBCSI (a.k.a. KBI) and Condition Assessment (rethinking the inspection and condition assessment process)

- Asset management decision making information needs vary over time
- “No data before its time” (get more detail, when, where needed)
- Use “knowledge” (quantifiable information about a building’s inventory, such as: component-section condition history, expected condition, importance, etc.) to determine what to inspect, how often, and what inspection type (i.e. inspection intensity) to do
Recognizing that component-section life-cycles vary, tailor the frequency and level of inspection detail to the condition assessment objectives (i.e. why are we conducting an assessment?), expected component-section condition at the time of the inspection (determined from condition prediction model), importance, and risk tolerance.

Component-sections are planned (by year) for a given inspection type based on a logical set of business rules.

Will result in the various component-sections in a given building being inspected on different frequencies.

Goals are to manage risk, increase the utility of inspection data and condition assessment results, and reduce inspection costs.

Condition assessment is “forward” looking.
## Condition Survey Inspection Objectives

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1.</td>
<td>Determine Condition (i.e. CSCI) of Component-Section</td>
</tr>
<tr>
<td>2.</td>
<td>Determine Roll-Up Condition of System, Building, etc.</td>
</tr>
<tr>
<td>3.</td>
<td>Provide a Condition History</td>
</tr>
<tr>
<td>4.</td>
<td>Compute Deterioration Rates</td>
</tr>
<tr>
<td>5.</td>
<td>Calibrate/Re-calibrate Condition Prediction Model Curves</td>
</tr>
<tr>
<td>6.</td>
<td>Compute/Re-compute Remaining Maintenance Life</td>
</tr>
<tr>
<td>7.</td>
<td>Determine Broad Scope of Work for Planning Purposes</td>
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<tr>
<td>8.</td>
<td>Quantify/refine Work Needs (incl root cause analysis, if needed)</td>
</tr>
<tr>
<td>9.</td>
<td>Establish when Cost Effective to Replace (vs. Repair)</td>
</tr>
<tr>
<td>10.</td>
<td>Compute/Re-compute Remaining Service Life</td>
</tr>
<tr>
<td>11.</td>
<td>QC/QA (Post-work Assessment)</td>
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</table>
Condition Survey Inspection Types

Deficiency: The “traditional” inspection discussed previously.

Distress Survey: The identification of distress types (i.e. crack, damage, etc.), severity (low, medium, high) and density (percentage) present. Data directly used in the calculation of the CSCI. No estimate of cost or priority.

Distress Survey with Quantities: Same as distress survey except that distress quantities are measured or counted. The resulting density is more accurate than a distress survey, thus the CSCI is more precise.

Direct Rating: A one-step process that combines inspection and condition assessment. An alphanumeric rating (three categories, three subcategories each) is assigned to the component-section by the inspector. Rating is directly correlated to a CSCI value, but is less accurate than a CSCI derived from a distress survey. Quick, but no record of what’s wrong.
Distress Type(s): Deteriorated and Cracked
Severity Level(s): Low and Med
Quantity/Density: 200 SF and 12 LF
<table>
<thead>
<tr>
<th>Rating</th>
<th>Work Needs</th>
<th>Rating Definition</th>
</tr>
</thead>
</table>
| Amber (+) | Maintenance or repair to any of the following:  
Minor repairs to several subcomponents; or  
Significant repair, rehabilitation, or replacement of one or more subcomponents, but not enough to encompass the component-section as a whole; or  
Combinations thereof. | Component-section or sample serviceability or reliability is degraded, but adequate. A very few, major (critical) subcomponents may suffer from moderate deterioration with perhaps a few minor (non-critical) subcomponents suffering from severe deterioration. |
| Amber   | Significant repair, rehabilitation, or replacement of one or more subcomponents, but not enough to encompass the component-section as a whole; or  
Combinations thereof. | Component-section or sample serviceability or reliability is definitely impaired. Some, but not a majority, major (critical) subcomponents may suffer from moderate deterioration with perhaps many minor (non-critical) subcomponents suffering from severe deterioration. |
| Amber (-) | Component-section or sample has significant serviceability or reliability loss. Most subcomponents may suffer from moderate degradation or a few major (critical) subcomponents may suffer from severe degradation. |
Condition/Maintenance Life/RML/Service Life/RSL Relationships for a Given Component - Section

Specific Component-Section Maintenance Life and Service Life are a Function of Desired Standards.

The life-cycle curve results from a condition prediction model calibrated for each unique component-section.

Condition/Maintenance Life/RML/Service Life/RSL Relationships for a Given Component - Section

Source: D.R. Uzarski, Ph.D., P.E.
Component-Section Life Cycle Condition Curve After Maintenance/Repair

Component - Section Condition Index (CSCI)

CSCI_{Repair}

CSCI_{Terminal}

Source: D.R. Uzarski, Ph.D., P.E.
Component-Section Maintenance/Repair Needs vs. Condition

*Except PM and E/S Calls

Source: D.R. Uzarski, Ph.D., P.E.
Condition Zones for a Component-Section Life-Cycle

Component - Section Condition Index (CSCI)

1. Preventive Maintenance (PM) Sustainment Zone
2. Corrective Maintenance (CM) Approach Zone
3. Corrective Maintenance (CM) Zone
4. Missed Opportunity Zone
5. Failed Zone

Source: D.R. Uzarski, Ph.D., P.E.
Zone 1 – Preventive Maintenance (PM) Sustainment Zone

- Little, if any, corrective work needed
- Condition surveys needed to satisfy objectives 1 – 6, 11
  1. Determine Condition of Component-Section
  2. Determine Roll-Up Condition of System, Building, etc.
  3. Provide a Condition History
  4. Compute Deterioration Rate
  5. Calibrate/Re-calibrate Condition Prediction Model Curve
  6. Compute/Re-compute Remaining Maintenance Life
  11. QC/QA (Post-work Assessment)
Corrective maintenance usually not planned for this zone
Approaching the “Sweet Spot”
CSCI “Sweet Spot” value, rate of deterioration, and planning horizon set the upper limit for this zone
Condition surveys needed to satisfy objectives 1 – 7
1. Determine Condition of Component-Section
2. Determine Roll-Up Condition of System, Building, etc.
3. Provide a Condition History
4. Compute Deterioration Rate
5. Calibrate/Re-calibrate Condition Prediction Model Curve
6. Compute/Re-compute Remaining Maintenance Life
7. Determine Broad Scope of Work for Planning
Zone 3 – Corrective Maintenance (CM) Zone

- Zone defined by the “Sweet Spot”
- Begins one year prior to “Sweet Spot” year
- Zone extends beyond “Sweet Spot” because needs will likely exceed funding in a given year and work is often deferred
- Condition surveys needed to satisfy objectives 1 – 9 (6 – 9 are main focus)
  6. Compute/Re-compute Remaining Maintenance Life
  7. Determine Broad Scope of Work for Planning
  8. Quantify/refine Work Needs
  9. Establish when Cost Effective to Replace
- 100% of component-section should be inspected (if sampling conducted previously)
- However, condition survey may be skipped in lieu of a “Just-in-time (JIT)” detailed job plan field survey to finalize scope and quantities (if important and funding is assured).
Zone 4 – Missed Opportunity Zone

- “Missed Opportunity” because penalty costs are incurred
- Replacement (or major rehab/reconstruction) generally is the most economical option
- Condition surveys needed to satisfy objective 10
  10. Compute/Re-compute Remaining Service Life
- Objectives 1 – 5 and 7 – 9 are less important in this zone
- Objective 6 is meaningless
  6. Compute/Re-compute Remaining Maintenance Life
• Replacement (or major rehab/reconstruction) only viable option
• Condition surveys no longer needed
• Estimated CSCI values will satisfy objectives 1 – 3
  1. Determine Condition of Component-Section
  2. Determine Roll-Up Condition of System, Building, etc.
  3. Provide a Condition History
• All other objectives either can be met though model estimation or they are meaningless
## Objective

<table>
<thead>
<tr>
<th>Objective</th>
<th>Direct</th>
<th>Distress</th>
<th>Distress w/Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Determine Condition of Component-Section</td>
<td>Good</td>
<td>Better</td>
<td>Best</td>
</tr>
<tr>
<td>2. Determine Roll-Up Condition of System, Building, etc.</td>
<td>Good</td>
<td>Better</td>
<td>Best</td>
</tr>
<tr>
<td>3. Provide a Condition History</td>
<td>Good</td>
<td>Better</td>
<td>Best</td>
</tr>
<tr>
<td>4. Compute Deterioration Rates</td>
<td>Limited</td>
<td>Better</td>
<td>Best</td>
</tr>
<tr>
<td>5. Calibrate Condition Prediction Model Curves</td>
<td>Limited</td>
<td>Better</td>
<td>Best</td>
</tr>
<tr>
<td>6. Compute/Re-compute Remaining Maintenance Life</td>
<td>Limited</td>
<td>Better</td>
<td>Best</td>
</tr>
<tr>
<td>7. Determine Broad Scope of Work for Planning</td>
<td>Limited</td>
<td>Better</td>
<td>Good</td>
</tr>
<tr>
<td>8. Quantify/refine Work Needs</td>
<td>No</td>
<td>No</td>
<td>Good</td>
</tr>
<tr>
<td>9. Establish when Cost Effective to Replace</td>
<td>No</td>
<td>Good</td>
<td>Better</td>
</tr>
<tr>
<td>10. Compute/Re-compute Remaining Service Life</td>
<td>Good</td>
<td>Better</td>
<td>Best</td>
</tr>
<tr>
<td>11. QC/QA (Post-work Assessment)</td>
<td>Limited</td>
<td>Good</td>
<td>Better</td>
</tr>
</tbody>
</table>

### Table: Ability of Condition Survey Inspection Types to Meet Condition Survey Objectives
Matching of Condition Survey Inspection Type to Specific Condition Zones (balancing objectives and cost)

*For sections large and complex enough to warrant sampling. Sampling to be discussed later.

Source: D.R. Uzarski, Ph.D., P.E.
Exceptions

Exceptions exist that may warrant a different condition survey strategy for a given component-section

- **Non-maintainable**
  - Do not maintain/repair
  - Replace when needed
  - Two cases:
    - Run-to-failure with minimal disruption
      - Low risk case
      - No condition surveys needed
    - Replace prior to failure
      - High risk or “no surprises” case
      - Perform a condition survey at some point prior to end of expected service life
      - Additional condition surveys may be scheduled to mitigate disruption risk
      - *Or*, simply replace prior to end of expected service life
Exceptions (con’t)

• **Catastrophic Event**
  – Event, large or small, may affect life-cycle in an unpredictable way
  – Often, some type of a condition survey is needed

• **Computerized Maintenance Management System (CMMS) Trend Analysis**
  – Service call analysis may flag a problem
  – Condition survey may be needed to verify component-section condition

• **Rapid Deterioration Rate or Short Service Life**
  – Zones 1 and 2 may be compressed and combined with Zone 3
  – “Sweet Spot” rapidly approaching

• **Certifications**
Knowledge – Based Condition Survey Inspection Planning

- Brings together the ideas of what to inspect, how often, and what inspection type to use for scheduling condition surveys in a given year
- Consider risk
- Establish a set of business rules using:
  - Building importance (based on, for example, the Mission Dependency Index – MDI)
  - Component-section importance
  - Service life
  - Remaining service life
  - Maintenance life
  - Remaining maintenance life
  - Rate of deterioration
  - Condition zone
  - Condition standards and policies
  - Max interval between condition surveys
Example Knowledge – based Condition Survey Inspection Plan
Knowledge – based Inspection Plan

Inspection Type Summary

Note: The percentages of each condition survey inspection type will vary by year and by portfolio.
Recall, a current estimate of each CSCI is always known based on the prediction model calibrated for each unique component-section. So, all component-sections receive either a real or simulated condition assessment and all metrics are normalized to the same timeframe.
From Experience…

• Combining condition surveys with preventive maintenance (PM) work is logical and beneficial
  – Equipment is likely shut down (at least for a little while) and PM crews have both the experience and opportunity to conduct the surveys
  – A condition survey is not required at every PM
  – The appropriate condition survey inspection type should be used
• High security building access issues may alter the condition scheduling
• Local situations will alter the condition survey plan
• Clustering may be practical and beneficial in some cases
• Be flexible!
Condition Survey Sampling

- Use when component-section is complex, separated, or very large (exceeds field of vision)
- Can sample with either the distress survey or the direct rating method
- In general, sampling reduces inspection effort and cost, but some accuracy regarding quantities may be lost. If larger sampling percentages are used, quantity accuracy is improved
- CSCI accuracy may actually be improved
- Use discreet discontinuities to delineate sample boundaries
- Condition assessment manual addresses sampling
What About the Cost?

Or

Do We Save Any Money?

“It Depends…”

Recall, the “Predicting Outcomes” report cited condition assessment costs ranging from $0.07 - $0.60 per SF. KBCSI field experience is still evolving, but testing conducted during the KBCSI development showed an approximate 75% reduction in cost when compared to a baseline of 100% annual inspection. But…

• Each portfolio will be somewhat different
• Baselines differ
• Costs per year will vary depending on “mix”

Rather…

The KBCSI provides a targeted approach

• Address risk
• Focus on what’s important
• Some component sections are inspected sooner and some later
• Maximize value for inspection dollar spent
Is There More to the KBCSI Story?

YES

• This presentation focused on knowledge-based inspection and condition assessment (“Predicting Outcomes” Report Finding 5 and Recommendation 6.)

• However, what about setting risk-based project priorities (Report Recommendation 3)? KBCSI data can be used not only to prepare an inspection plan, but also to assist in assigning Component Probability of Failure Ratings and Component Failure Consequence Ratings as addressed in Chapter 7 (another discussion for another time...)
Questions?