Fundamentals of Asset Management

Step 3. Determine Residual Life

A Hands-On Approach
Tom’s bad day...
First of 5 core questions, continued

1. What is the condition of my assets? How well do they perform?
   - What is the *importance* of *remaining useful life*?
   - How might we *determine* remaining useful life?
AM plan 10-step process

1. What is the current state of my assets?

Develop Asset Registry ➔ Assess Performance, Failure Modes ➔ Determine Residual Life ➔ Determine Life Cycle & Replacement Costs ➔ Set Target Levels of Service (LOS)

Determine Business Risk (“Criticality”) ➔ Optimize O&M Investment ➔ Optimize Capital Investment ➔ Determine Funding Strategy ➔ Build AM Plan
Determining Residual Life

- Serviceable
- Unserviceable
- Threshold Value
- Performance Curve
- Remaining Service Life
- Current Condition

Time (years)

Performance

Threshold Value
But – when has an asset “failed”?

- When it cannot do what it is required to do
- Technical perspective – when the asset is not “available”:
  - When the asset stops functioning or does not function when called on
  - When performance deteriorates to point of insufficient service
  - When it is taken out of service (maintenance, renewal)
- Does your maintenance management business process (think work order) identify when an asset goes out of service and when service is restored?
- Thought exercise: when exactly has a sewer pipe “failed”?
What do we mean by “remaining asset life”?

- **End of financial life** – when an asset is fully financially depreciated on the “books”
- **End of physical life** – when an asset is physically non-functioning (e.g., failed, collapsed, stopped working)
- **End of service level/capacity life** – when an asset can no longer do what we/our customers/stakeholders require it to do
- **End of economic life** – when an asset ceases to be the lowest cost alternative to satisfy a specified level of performance or service level
The role of failure modes in determining residual life

Start

Decision Issues

Is capacity an issue?
  - Yes
  - Likely before other modes?
    - Yes
      - Capacity
        - 18 months
    - No
      - Has LOS changed from design?
        - Yes
          - Likely before other modes?
            - Yes
              - LOS
              - 3 years
            - No
              - Is physical reliability an issue?
                - Yes
                  - Likely before other modes?
                    - Yes
                      - Mortality
                      - 10 years
                    - No
                      - Is cost to operate an issue?
                        - Yes
                          - Likely before other modes?
                            - Yes
                              - Efficiency
                              - Now
                        - No
                          - Redo—it has to fail somehow

Redo—it has to fail somehow
Key definition: “effective asset life”

- “Effective asset life” is the lowest expected life for a selected asset given its operating environment where that life is derived from a determination of the most imminent trigger among the three asset life triggers (service level life, capacity life, physical life, economic life).

- Example (remaining life):
  - service level/capacity life – 3 breaks, estimated 2 years to next break (“no more than 4 breaks in 5 years”)
  - Physical life – 30 years
  - Economic life – 10 years
## Determining remaining physical life

### Age Based

- **Approach 1**  Effective life table
- **Approach 2**  Effective life table, plus modification factors

### Condition Based

- **Approach 3**  Direct observation table
- **Approach 4**  Condition and decay curve table
## Approach 1, effective life table ("design life")

<table>
<thead>
<tr>
<th>Class</th>
<th>Asset Type</th>
<th>Effective Life</th>
<th>Class</th>
<th>Asset Type</th>
<th>Effective Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Civil</td>
<td>75</td>
<td>6</td>
<td>Motors</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>Pressure pipework</td>
<td>60</td>
<td>7</td>
<td>Electrical</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>Sewers</td>
<td>100</td>
<td>8</td>
<td>Controls</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>Pumps</td>
<td>40</td>
<td>9</td>
<td>Building assets</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Valves</td>
<td>30</td>
<td>10</td>
<td>Land</td>
<td>NA</td>
</tr>
</tbody>
</table>

Sources: manufacturers, industrial associations, GASB, colleagues, consulting engineers, research (professional associations, universities), international community
So, how do we move forward - review: “Percent of effective life consumed” concept
Example: simple determination of “% remaining physical life”

1. Calculate physical life consumed

\[
\text{% physical life consumed} = \frac{\text{Life to date}}{\text{Estimated useful life}}
\]

2. Determine % remaining physical life

\[
\text{% remaining physical life} = 1.0 - \text{% physical life consumed}
\]

Example calculation - % remaining physical life

Asset acquired 1992; current year 2012; useful life 25 years

\[
20\% \text{ remaining physical life} = 1.0 - \left(\frac{20 \text{ yr. LTD}}{25 \text{ yr. EUL}}\right)
\]
Approach 2, amending standard effective lives

Diminished Effective Life
From impacts that reduce life

Enhanced Effective Life
From impacts that increase life

*Asset design life is from average effective life tables
## Modification factors for effective life tables

<table>
<thead>
<tr>
<th>Condition Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design standards</td>
<td>+10%</td>
<td>+5%</td>
<td>0</td>
<td>-5%</td>
<td>-10%</td>
</tr>
<tr>
<td>Construction quality</td>
<td>+10%</td>
<td>+5%</td>
<td>0</td>
<td>-5%</td>
<td>-10%</td>
</tr>
<tr>
<td>Material quality</td>
<td>+10%</td>
<td>+5%</td>
<td>-5%</td>
<td>-10%</td>
<td></td>
</tr>
<tr>
<td>Operational history</td>
<td>+10%</td>
<td>+5%</td>
<td>0</td>
<td>-5%</td>
<td>-10%</td>
</tr>
<tr>
<td>Operating environment</td>
<td>+10%</td>
<td>+5%</td>
<td>0</td>
<td>-5%</td>
<td>-10%</td>
</tr>
<tr>
<td>External stresses</td>
<td>+10%</td>
<td>+5%</td>
<td>0</td>
<td>-5%</td>
<td>-10%</td>
</tr>
</tbody>
</table>

*Values are for example purposes only.*
### Approach 3: “Direct observation” table

<table>
<thead>
<tr>
<th>Assessment (Likelihood of Occurrence within One Year)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost certain</td>
<td>Expected to occur within 1 year</td>
</tr>
<tr>
<td>Very high</td>
<td>Likely to occur within 1 year</td>
</tr>
<tr>
<td>High</td>
<td>Estimated 50% chance of occurring within any year</td>
</tr>
<tr>
<td>Quite likely</td>
<td>Expected to occur within 5 years; estimated 20% chance of occurring in any year</td>
</tr>
<tr>
<td>Moderate</td>
<td>Expected to occur within 10 years; estimated 10% chance of occurring in any year</td>
</tr>
<tr>
<td>Low</td>
<td>Expected to occur within 50 years</td>
</tr>
<tr>
<td>Very low</td>
<td>Expected to occur within 100 years</td>
</tr>
</tbody>
</table>
Challenge: Age versus condition based renewal

Courtesy of Manatee County
Tod Phinney, P.E.
John Paterson, Ph.D., P.E., BCEE

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Strategy: Condition based rather than age based

- Assess condition of targeted cast iron and ductile iron force mains using sonar technology
- Conduct failure analysis to understand failure modes
- Focus only on assessment of those (short) sections of force main that are likely in worst condition (high points where pipes rise)
- Use work orders and GIS to locate candidate sections
- Assess condition in one day or less
In the trenches...

Courtesy of Manatee County
Tod Phinney, P.E.
John Paterson, Ph.D., P.E., BCEE
Results: Manatee County, Florida

- Condition assessments were programmed for 14 force mains that were already programmed for replacement (combined total length – 12 miles)
- Immediate replacement was not required for 90% (by length); stately alternatively – 90% of pipe scheduled for replacement based on age had useful service life left.
- Reduced CIP by $5.5 million
- Delayed an additional $2 million pending condition assessment in lieu of replacement
Approach 4, Condition assessment and the decay curve

Condition assessment assists in recognizing…

- **Nature** and **shape** of the failure or decay (or deterioration) curve
- **Where** on the curve is asset’s current condition
- Asset’s **remaining useful life**, an estimate
Developing a decay curve

- **Longitudinal** study—uses data collected *over the life* of a *single* asset (or set of assets)
- **Latitudinal** study—uses data collected from *multiple* assets of the same type but of different ages
Challenge: tying condition score and % physical life consumed

Relating asset condition to percent of physical life consumed

- Data distribution of asset condition
- Decay or failure curve
- Physical Failure

![Graph showing asset condition vs. percent of effective life consumed]
Alternative: tying condition score to asset failure

Decay or failure curve

Data distribution of asset condition

Condition

Performance

Percent of Effective Life Consumed

Fundamentals of Asset Management
Alternative: tying condition to remaining life using % Physical Life Consumed

<table>
<thead>
<tr>
<th>% of Physical Life Consumed</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10%</td>
<td>1</td>
</tr>
<tr>
<td>20%</td>
<td>2</td>
</tr>
<tr>
<td>30%</td>
<td>3</td>
</tr>
<tr>
<td>40%</td>
<td>4</td>
</tr>
<tr>
<td>50%</td>
<td>5</td>
</tr>
<tr>
<td>60%</td>
<td>6</td>
</tr>
<tr>
<td>70%</td>
<td>7</td>
</tr>
<tr>
<td>80%</td>
<td>8</td>
</tr>
<tr>
<td>90%</td>
<td>9</td>
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<tr>
<td>Failed</td>
<td>10</td>
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</tbody>
</table>
Enter: “management strategy groups”

- Grouping of assets with similar renewal / behavioral patterns
- Purpose - to assist:
  - Assigning asset lives and decay curves
  - Calculating current replacement costs
  - Calculating risk
    - Consequence of failure
    - Probability/likelihood of failure
  - Developing life-cycle management plans
- Examples
  - Gravity Pipes, RCP, Built < 1950, in High H₂S areas
  - Submersible sewage pumps, ABC Co., 123 series, 1983 - 1995
Key points from this session

What is its remaining life?

Key Points:
- Determining remaining useful life is as much art at this point as science.
- Although good information is better, asset “decay curves” need not be highly detailed to be useful.
- Good CMMS data is key to building agency specific failure curves.
- Good condition information is vital to assigning remaining useful life.
- Incorporating good failure codes into the work order is important to building good failure curves.

Associated Techniques:
- Remaining useful life assessment
- Decay curves, useful-life tables
- Survivor curves
- Major failure modes
Tom’s spreadsheet

<table>
<thead>
<tr>
<th>Asset Register and Hierarchy</th>
<th>Installed Date</th>
<th>Asset Class</th>
<th>Original Cost</th>
<th>Estimated Effective Life</th>
<th>Condition Rating</th>
<th>Annual Day</th>
<th>Annual Hour</th>
<th>Current Loss</th>
<th>Minimum Condition</th>
<th>Back-Up Reduction (Redundancy)</th>
<th>Probability of Failure</th>
<th>Consequence of Failure</th>
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Table continues with data entries...