Data-driven approach to estimate maintenance life cycle cost of assets

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Maintenance in the lifecycle of a product

Design → Manufacture → Install → Commission → Operate

End of Life?

Maintain

Decommission
Opportunities and potential from maintenance data

**OEM:**
- Understand the gap between intended and actual use
- Information from operating context can help design improvements for future versions

**O/O**
- Insights to manage & improve asset performance
Who am I and what do I do?

Software for industrial applications such as APM

Asset Answers aggregates work history data from many industrial facilities around the world by asset type, manufacturers, and many other characteristics.
Having **accurate** data is a common struggle. Primarily driven by **humans**.

Significant limiting factor in reliability analytics.

**Cultural Barriers** – Viewed as an administrative burden.

Might take months to do a simple bad actor analysis.

Reliability Engineers spend 80% of their analysis time in processing and normalizing data.

**Differences between sites** – usage of Maintenance Management systems or work processes.
Three Main Challenges

Trust in Data

Utilization of Data

Effort to Standardize Data
Standards for collecting, measuring, and analyzing industrial data

ISO 14224 – standards for data collection and coding
SMRP Best Practice Metrics – standards for calculating KPIs

Challenges

Codes may be used differently by different individuals (various levels of precision, different interpretations)
Codes may exclude certain conditions
Local customizations based on context of use – standards may tend to only be guides in some cases
Standardization Woes – Example 1

Most Common Failure Modes for ABC Refining Company - across multiple sites

- Lube Oil Contaminated
- PHYSICAL DAMAGE
- Regulatory
- INSPECTION FREQUENCY REACHED
- VIBRATION
- INCORRECT INDICATION
- Overheated
- Leaks Externally
- NO OPERATION
- Leaking
- Engineered Change
- Vibration
- Mechanical Distortion
- LEAKING

Frequency as a percentage of observations

0% 1% 2% 3% 4% 5% 6% 7% 8% 9%
Standardization 1 Woes – Resolved
Standardization Woes – Example 2

Functional Location Hierarchy

Level 1
Level 2
Level 3
Level 4
Level 5
Level 6
Level 7
Level 8
Level 9
Level 10

Site 1
Site 2
Site 3
Site 4
Site n

FL
FL
FL
FL
FL

EQ
EQ
EQ
EQ
EQ

EQ

Area
Area
Area
Area

Unit
Unit
Unit
Unit

Site
Site
Site
Site

1 million equipment

Sites
Standardization 2 Woes – Resolved

Functional Location Hierarchy

- **Level 1**: Site
- **Level 2**: Area
- **Level 3**: Unit
- **Level 4**: EQ

Sites
Completeness and Accuracy in maintenance data quality

Data largely missing and miscoded
Breakdown indicator not often used
Cost (or Claims) data generated for financial reporting may lack engineering information

<table>
<thead>
<tr>
<th>Free Text Work Order Description</th>
<th>Miscoded Event Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair leaking safety valve</td>
<td>PM</td>
</tr>
<tr>
<td>Daily Inspection of Analyzers</td>
<td>Repair</td>
</tr>
</tbody>
</table>

Data Quality: Failure mode reporting frequency for centrifugal pumps in the past 3 years

- Missing: 31%
- Miscoded: 69%
- Unknown failure modes: 31%
Importance of measuring data quality

Track data improvement efforts

Identify areas where the data is good –
   And use good data for benchmarking and developing analytics

By identifying where you have good data, you can get value from it now.
Perfect Data is a myth and a futile endeavor!

Data should be suitable for its application – serve the business purpose.

Should accurately reflect the real asset performance.
Key information often present in unstructured fields

### Failure Mode information in unstructured field:

<table>
<thead>
<tr>
<th>Free Text Work Order Description</th>
<th>Failure Mode</th>
<th>What I want to see:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need to re-grout base to reduce long time vibration problem</td>
<td>Unknown</td>
<td>Vibration</td>
</tr>
<tr>
<td>Clear blocked piping/pump</td>
<td>Unknown</td>
<td>Plugged/Choked</td>
</tr>
<tr>
<td>The stuffing box was replaced not long ago because of a water leak in the drive head, the leak is back</td>
<td>Unknown</td>
<td>Leakage</td>
</tr>
</tbody>
</table>

### Data Quality Problem: Incorrectly coded work orders

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### Recording when a failure occurred:

<table>
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<tr>
<th>Free Text Work Order Description</th>
<th>Breakdown?</th>
</tr>
</thead>
<tbody>
<tr>
<td>WATER PUMP FAILURE. Water pump has failed and has leaked all the coolant out through the tattle hole</td>
<td>FALSE</td>
</tr>
<tr>
<td>Sump level sensor has failed. Cannot run plant without this sensor.</td>
<td>FALSE</td>
</tr>
<tr>
<td>Compressor lube box oil seal has failed. Requires seal replacement ASAP</td>
<td>FALSE</td>
</tr>
</tbody>
</table>
Case study: maintenance data for information sharing across product life cycle
Life Cycle Cost (LCC) Elements:

- **Life Cycle Cost**
  - Decommissioning Costs
  - Initial Costs
    - Purchase
    - Installation
    - Commissioning
  - Annual Costs
    - Energy
    - Operations
    - Maintenance
    - Downtime

**Maintenance Life Cycle Costs (MLCC)** are 1 piece of the **Total Cost of Ownership (TCO)**
LCC Cost Distribution

Cost for LCC Elements - Pumps
- Energy: 44%
- Operational: 9%
- Purchase & Installation: 12%
- Downtime: 16%
- Maintenance: 17%
- Decommissioning: 2%


Cost for LCC Elements - Valves
- Maintenance: 70%
- Purchase & Installation: 25%
- Decommissioning: 5%

Resolving data quality challenges through analytics to provide information & knowledge

Case study: Estimating elements of MLCC for different manufacturer and models of an asset

Selected 2 manufacturer and models

• Characterize of different failure events
• Evaluate benchmarking metrics, such as:
  • Maintenance cost,
  • Mean time to repair (MTTR),
  • Downtime, etc.
• Characterize risk mitigating actions
The missing breakdown indicator challenge

**Strengths of models**

- **Consistency**
  - Two similar inputs will always have the same classification by a computer model

- **Scalability**
  - Thousands of work orders in a very short period of time

**Challenges with models**

- **Consistency**
  - Variation in definition of “functional failure”

- **Models only as good as the data they are trained on**
  - Inconsistent training data
  - Cases that are “obvious to a human, not to a machine”
Results: comparison of reliability estimates

Of ~8,000 repair events, ~5,800 identified as failures

<table>
<thead>
<tr>
<th>Work description</th>
<th>Is A Failure?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seal is leaking badly</td>
<td>True</td>
</tr>
<tr>
<td>Block valve is broken open and inoperable</td>
<td>True</td>
</tr>
<tr>
<td>00120-Pump 1 Work Request</td>
<td>False</td>
</tr>
<tr>
<td>Check impeller size</td>
<td>False</td>
</tr>
</tbody>
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Before: inability to calculate Mean Time Before Failure (MTBF)

After: Comparison of MTBF (days)

Model 1: 470 days
Model 2: 314 days
Characterizing failure information through description

In scalable, repeatable way

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<th>Maintainable Item</th>
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<td>Seal is leaking badly</td>
<td>Seal failure</td>
</tr>
<tr>
<td>Block valve is broken open and inoperable</td>
<td>Valve failure</td>
</tr>
<tr>
<td>G5 Seal failure</td>
<td>Seal failure</td>
</tr>
<tr>
<td>P001-A NRV is passing</td>
<td>Valve failure</td>
</tr>
</tbody>
</table>

Comparison of MTBF (months) for most frequent maintainable items

- Model 1
- Model 2
Other maintenance & reliability benchmarking measures

Valve failure events generally have shorter time to repair and cost less
Simulating the cost of unreliability over 10 years

System reliability analysis: simple system with pump and motor

Assumed:

• Reliability is the only variation between the two models
• Production loss of $10,000 per day per pump (at the pump asset level)

Under these assumptions, production losses dominate the cost of unreliability.
Simulated consequences by risk

Total Cost ($) over 10 years by Risk

- **Total unplanned corrective work cost**

Total Downtime over 10 years by Risk

- **Total unplanned downtime (factor for production losses)**
Model 1 is the more reliable pump, and costs twice as much to purchase…

Model 1: $100,000
Model 2: $50,000

2 years payback period – justifies the higher price tag
Discussion points

Maintenance data contains relevant information about the usage of industrial equipment, but not in its raw form

Need for development of adaptable work processes in which actionable information extracted from the maintenance data can be shared across different stakeholders in a product lifecycle.