How Accuracy Impacts the Economic Benefit of Cable Diagnostic Programs

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• Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Department of Energy.
Outline

• Motivation
• Economics Model
• Effects of Accuracy on the Economics Model
• Illustrative example
• Conclusions
Motivation

• The goal of proactive maintenance is to prevent future service failures
  – Wholesale Replacement
  – Targeted Maintenance

• A Targeted Maintenance program uses diagnostic test(s) to identify the “weak” circuits.

• Program carries upfront costs that must be offset by program benefits.

• The economics of diagnostics are difficult to model and even more difficult to quantify. Must be used to quantify the benefits.
Components of Economics Model

• **Selection**
  Data compilation and analysis needed for selecting the target population.

• **Diagnostic Testing**
  Actual performance of the testing on the target population.

• **Maintenance**
  Actions taken on circuits based on results of diagnostic test.

• **Consequence**
  Service failures occurring in target population during diagnostic horizon.
Diagnostic Program Costs

Cost [$]

Selection

Diagnostic

Maintenance

Consequence

Total Diagnostic Program Cost
Where does accuracy have an impact?

Cost [$]

Accuracy Dependent Costs

Consequence

Maintenance

Accuracy Independent Costs

Diagnostic

Selection
Why does accuracy affect these costs?

• Maintenance cost is directly determined by diagnostic testing results
  – Maintenance can be misspent on “Good” circuits
  – “Bad” circuits may not receive maintenance

• Consequence cost is determined by inaccuracy of diagnostic test
  – “Bad” circuits diagnosed as “Good” will lead to service failures.

Will use a two-level diagnostic as an illustration
The target population contains both “Good” and “Bad” circuits
- “Good” – Will not fail within diagnostic horizon
- “Bad” – Will fail within diagnostic horizon
Diagnostic Operation

Applying the diagnostic will separate the population into:
- No Action Required group
- Action Required group

But all diagnostics are imperfect at some level
Population Analysis – Correct Diagnosis

No Action Required

Avoided Maintenance

Action Required

Avoided service failures
Population Analysis – Incorrect Diagnosis

No Action Required

Future service failures

Action Required

Unneeded Maintenance Actions
Accuracies by Diagnostic Condition

- Diagnostic was imperfect at separating “Good” from “Bad”
- “Action Required” and “No Action Required” each contain both “Good” and “Bad” circuits.

<table>
<thead>
<tr>
<th>Group</th>
<th>Correct Diagnoses [#]</th>
<th>Incorrect Diagnoses [#]</th>
<th>Accuracy [%]</th>
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<tbody>
<tr>
<td>No Action Required</td>
<td>25</td>
<td>3</td>
<td>89 %</td>
</tr>
<tr>
<td>Action Required</td>
<td>7</td>
<td>5</td>
<td>58 %</td>
</tr>
<tr>
<td>Overall</td>
<td>32</td>
<td>8</td>
<td>80 %</td>
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**Condition-specific accuracies** – They depend on the overall accuracy and the composition of the target population.
Accuracies by Diagnostic Condition

- Diagnostic was imperfect at separating “Good” from “Bad”
- “Action Required” and “No Action Required” each contain both “Good” and “Bad” circuits.

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**Overall accuracy** - Not the average of the “No Action Required” and “Action Required” accuracies.
Which accuracy should be used?

- Comparison of performance of diagnostic techniques
  - Overall Accuracy

- Calculation of economic benefits from diagnostic program
  - Diagnostic Condition-Specific Accuracies
No Action Required

- No action performed on 70% of the target population
- 3 service failures
Performance of Diagnostic Program

Action Required

- Action performed on 30% of the diagnostic population
- 7 service failures avoided
- Action was unnecessarily performed on “Good” circuits.
Which accuracies impact the components?

Cost [$]

Selection

Diagnostic

Population

Maintenance

Consequence

No Action Accuracy

Action Required Accuracy
# Comparison to Wholesale Replacement

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<tr>
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<th>Diagnostic Program</th>
<th>Wholesale Replacement</th>
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<tbody>
<tr>
<td>Maintenance Actions</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>% of Population Receiving Maintenance</td>
<td>30%</td>
<td>100%</td>
</tr>
<tr>
<td>Service Failures</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Avoided Failures</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Avoided Failures per Maintenance Action</td>
<td><strong>0.583</strong></td>
<td><strong>0.250</strong></td>
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Efficiency of Diagnostic Program is much higher than for Wholesale Replacement
Conclusions

• The economics of a diagnostic program depend heavily on the accuracy of the diagnostic.

• Overall accuracy can be used to compare diagnostics in general terms.
  – Target population independent

• Only diagnostic condition-specific accuracies can be used in economics calculations since the consequences are different for each condition.
  – Target population dependent