The Costs and Benefits of Advanced Maintenance in Manufacturing

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At the Paint Shop in Chrysler Group’s Sterling Heights (Mich.) Assembly Plant, a 2015 Chrysler 200 moves through the Underbody Sealing and Underbody Coating station.
Overview

Estimating national costs/benefits associated with adopting advanced maintenance

• Current literature/data
  • Maintenance costs
  • Benefits of predictive maintenance
  • Barriers to adoption
  • Current maintenance practice

• Data needs
• Feasibility of collecting data

https://doi.org/10.6028/NIST.AMS.100-18
Maintenance Cost: Data

- Economic Census
  - Maintenance outsourcing
  - Includes machinery and buildings
- Bureau of Economic Analysis
  - Maintenance outsourcing
  - Machinery only
- Bureau of Labor Statistics
  - Labor only
  - Excludes overhead/materials
- Estimates of cost require making some assumptions
Maintenance Cost: Literature

- Varying terminology
  - Reactive, Preventive, Predictive

- Cost studies
  - Varying countries (e.g., Sweden, Belgium)
  - Varying economic metrics
  - Case studies with
    - Varying types of machinery
    - Manufacturing and non-manufacturing

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Characteristics of Maintenance Costs from a Selection of Articles, Various Countries/Industries

<table>
<thead>
<tr>
<th>Maintenance</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Goods Sold</td>
<td>15.0%</td>
<td>70.0%</td>
</tr>
<tr>
<td>Sales</td>
<td>0.5%</td>
<td>25.0%</td>
</tr>
<tr>
<td>Cost of Ownership</td>
<td>37.5%</td>
<td></td>
</tr>
<tr>
<td>Replacement Value of Plant</td>
<td>1.8%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Cost of Manufacturing</td>
<td>23.9%</td>
<td></td>
</tr>
<tr>
<td>Percent of Planned Production Time that is Downtime</td>
<td>13.3%</td>
<td></td>
</tr>
</tbody>
</table>
Benefits of Adoption

• Similar challenges
  • Varying countries
  • Varying metrics
  • Varying industries
  • Varying terminology

• Case studies
  • Limits to extrapolating

• Wide range of impacts

Range of Impacts Identified in Various Publications for Implementing Advanced Maintenance Techniques

- Reduction in Maintenance Cost \( (g,h) \)
  -98% -15%
- Reduction in Defects and/or Rework \( (g,h,i) \)
  -90% -18%
- Reduction in Breakdowns \( (h,i,j) \)
  -90% -65%
- Increase in Labor Productivity \( (g,h) \)
- Inventory Reduction \( (h) \)
- Increase in Output/Production \( (g,h,i) \)
- Reduction in Accidents \( (h) \)
- Reduction in Customer rejections \( (h) \)
- Reduction in Downtime \( (j) \)

Wide range of impacts identified in various publications.
## Maintenance Cost Characterization, by Type

<table>
<thead>
<tr>
<th>Maintenance Type</th>
<th>Reactive</th>
<th>Preventive</th>
<th>Predictive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On Demand</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Scheduled, Timed, or Cycle Based</td>
<td>High</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Condition Based</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
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<tr>
<td>Labor Cost</td>
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<td></td>
<td></td>
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<tr>
<td>High</td>
<td></td>
<td></td>
<td>Low</td>
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<tr>
<td>Low</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
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<tr>
<td>Labor Utilization</td>
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<td></td>
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<tr>
<td>High</td>
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<td>Low</td>
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<td>Low</td>
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<tr>
<td>Part Cost</td>
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<tr>
<td>High</td>
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<td>Medium</td>
<td>Medium</td>
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<tr>
<td>Low</td>
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<td>Medium</td>
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<tr>
<td>Throughput Impact</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
<td>Medium</td>
<td>Very Low</td>
</tr>
<tr>
<td>Urgency</td>
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<td></td>
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<tr>
<td>High</td>
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<td>Low</td>
<td>Low</td>
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<tr>
<td>Low</td>
<td></td>
<td>Medium</td>
<td>High</td>
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<tr>
<td>ROI</td>
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<tr>
<td>High</td>
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<td>Medium</td>
<td></td>
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<tr>
<td>Low</td>
<td></td>
<td>Medium</td>
<td></td>
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<tr>
<td>Initial Investment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Profitability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not cost effective</td>
<td></td>
<td>Satisfactory cost-effectiveness</td>
<td>Significant cost savings</td>
</tr>
<tr>
<td>Cost effectiveness</td>
<td>Labor intensive</td>
<td>Costly due to potential over maintenance or ineffective &amp; inefficient maintenance</td>
<td>Cost-effective due to extended life and less failure-induced costs</td>
</tr>
</tbody>
</table>
Current Maintenance Practice

• Studies have varying factors (e.g., country)
• Firm competition
  • Cost comp. – higher reactive
  • Quality comp. – higher predictive
• Swedish study – 50% of maintenance time is planned tasks
  • 13% planning
  • 37% unplanned

Alsyouf, 2009
Objectives and Prevalent Barriers to the Adoption of Advanced Maintenance Techniques

- Quality
- Productivity
- Availability and Reliability
- Safety and Environment
- Organizational Readiness
- Human Resource
- Technology Support
- Cost

Potential Objectives
Potential Barriers

Sources: Jin et al., 2016
Assessing the costs and benefits

• To assess costs/benefits at National level
  • Identify data needs
  • Develop a data collection strategy
  • Develop a scaling strategy
  • Assess the minimum sample size
Data Needs Map

**Predictive**
- Maintenance and Repair

**Reactive**
- Materials
  - IO Estimates (limitations)

**Preventive**
- Labor
  - BLS data
  - IO Model

Indirect
- Impact on quality
- Cascading effects (i.e., additional damage)
- Down time
  - ASM (flow time)

Lost sales
- Lost sales
- Rework/ Defects
- Capital (machinery and buildings)
  - ASM (total)
  - Econ Census (total)
- Labor
  - BLS Data (total)
  - IO Model (total)

Increased time to market
- Increased uncertainty
- Increased Inventory
- Capital (machinery and buildings)
Data Collection via Survey

• Collect data through survey
  • Direct maintenance costs
  • Downtime
  • Defects/rework
  • Separate costs into predictive, preventive, and reactive
  • Separate planned maintenance from repair
  • Lost sales → quality

• Scale using payroll data by industry by establishment size
Data Collection via Survey

- Disproportional amount of small firms
- Scale by establishment size
  - Census data
- Anonymous survey
- Short survey
  - Target: 1 Page
Feasibility of Data Collection

- Discussions with manufacturers suggest
  - It is reasonable to expect manufacturers to be willing and able to share data

- However,
  - Apprehensiveness from a few in sharing some of the variables
  - A number of variables are not tracked → approximations
Required Sample Size for Survey

It’s complicated

\[
\text{Sample Size} = \left(\frac{z\sigma}{e}\right)^2
\]

where
\[
\sigma = \text{Standard deviation}
\]
\[
e = \text{Margin of error}
\]
\[
z = z\text{-score}
\]

Estimate standard deviation using census data on maintenance cost
Sample Size to Estimate Maint. Cost

- Graph sample size
- Standard deviation from Census
- Different confidence intervals
- 10% margin of error w/95% confidence interval: 77
- 20% margin of error w/90% confidence interval: 14
Summary

• Current maintenance cost data has limitations
  • Outsourcing only
  • Includes buildings + machinery

• Literature has
  • Varying metrics
  • Varying countries
  • Wide range of values

• Feasibility of data collection
  • Firms are willing/able
  • Approximations
  • Minimum sample size: 14-77 needed
How You Can Help

• Your participation would be appreciated

• What’s in it for you?
  • Receive a copy of the report
  • See how you compare with others
  • Develop the business case for advanced maintenance

How to participate in Survey
Contact Douglas Thomas
douglas.thomas@nist.gov

Thank You
Sources


• gNakajima, S. Introduction to Total Productive Maintenance (TPM). (Portland, OR: Productivity Press, 1988).


Other Sources


