Preventive Maintenance Principles
SPL 7.2
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Presentation for:
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Overview

Learning Objectives

- Familiarity with the different types of maintenance activities
- Appreciation of the benefits of preventive maintenance
- Understanding of lean principles for designing a preventive maintenance schedule
- Awareness of specific challenges to implementing preventive maintenance

Session Design (20-30 min.)

- **Part I:** Introduction and Learning Objectives (1-2 min.)
- **Part II:** Key Concept or Principle Defined and Explained (3-5 min.)
- **Part III:** Exercise or Activity Based on Field Data that Illustrates the Concept or Principle (7-10 min.)
- **Part IV:** Common “Disconnects,” Relevant Measures of Success, and Potential Action Assignment(s) to Apply Lessons Learned (7-10 min.)
- **Part V:** Evaluation and Concluding Comments (2-3 min.)
Types of Maintenance

- **Breakdown Maintenance:**
  - Waiting until equipment fails before repairing or servicing it

- **Preventive Maintenance (PM):**
  - (Time-based or run-based) Periodically inspecting, servicing, cleaning, or replacing parts to prevent sudden failure
  - (Predictive) On-line monitoring of equipment in order to use important/expensive parts to the limit of their serviceable life

- **Corrective or Predictive Maintenance:**
  - Improving equipment and its components so that preventive maintenance can be carried out reliably
Benefits of Preventive Maintenance

“…the cost of breakdown maintenance is usually much greater than preventive maintenance.”

Preventive maintenance…

- Keeps equipment in good condition to prevent large problems
- Extends the useful life of equipment
- Finds small problems before they become big ones
- Is an excellent training tool for technicians
- Helps eliminate rework/scrap and reduces process variability
- Keeps equipment safer
- Parts stocking levels can be optimized
- Greatly reduces unplanned downtime

1 http://www.prenhall.com/divisions/bp/app/russellcd/PROTECT/CHAPTERS/CHAP15/HEAD01.HTM
The Manufacturing Game

- Similar to the Beer Game
- Simulates a typical plant with three roles:
  - Operations Manager
  - Maintenance Manager
  - Spare Parts Stores Manager
- Each round, participants make decisions such as:
  - Which equipment to take down for PMs
  - How to allocate maintenance resources
  - How many spare parts to order
- Revenue, cost, output, uptime, inventory are recorded

The Manufacturing Game Results

Teams who follow a cost-minimization strategy (reactive maintenance policies) are able to keep costs low for a while. However, as defects build up they find their uptime falling and costs rising.

Teams who follow a preventive maintenance strategy initially find higher costs and reduced uptime as equipment is taken offline for planned maintenance. Soon, however, these teams begin to greatly outperform teams following a cost-minimization strategy.

When Does PM Make Sense?

- PM makes sense when the cost of doing PM is less than the cost of NOT doing PM.

\[ PM \text{ makes sense if } C_{\text{DoingPM}} < C_{\text{NotDoingPM}} \]

- \( C_{\text{DoingPM}} = f(\text{hours of not running equipment, loss in employee morale from doing PM instead of “real work”, materials and man-hours consumed in PM, potential for making things worse, etc.}) \)

- \( C_{\text{NotDoingPM}} = f(\text{cost of losing/reworking a failed batch (unless PM makes no difference in preventing the failure), materials and man-hours spent repairing equipment, loss of equipment lifetime, loss in employee morale from NOT doing PM, reduced employee familiarity with equipment, etc.}) \)
Optimizing a PM Schedule

Question:
- If a certain piece of production equipment requires ~10 hours of preventive maintenance per week, how should those 10 hours be scheduled?

Answer:
- In a 24x7 manufacturing operation, it is typically better to perform the ~10 hours of activities in several smaller periods of time, for instance 5 PM activities that take ~2 hours each.
- Duration and variability in preventive maintenance are key factors in whether equipment will be able to maintain a steady flow of output.
PM Durations: Simulation 1

- Simulation of equipment with a 10 hour average PM duration, std dev 20 hours (85% availability)

Trend of Queues for the Toolset

Data from a simulation run at Intel Fab 11X.
PM Durations: Simulation 2

- Simulation of equipment with a 5 hour average PM duration, std dev 10 hours (85% availability)

Data from a simulation run at Intel Fab 11X.
PM Durations: Simulation 3

- Simulation of equipment with a 2 hour average PM duration, std dev 4 hours (85% availability)

Trend of Queues for a Toolset

Data from a simulation run at Intel Fab 11X.
PM Durations: Simulation 4

- Simulation of equipment with a 2 hour average PM duration, std dev 6 hours (85% availability)

Trend of Queues for a Toolset

Data from a simulation run at Intel Fab 11X.
PM Durations: Why they matter

- For the **exact same** availability on a piece of equipment:

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Avg QueueLength</th>
<th>StdDev QueueLength</th>
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</thead>
<tbody>
<tr>
<td>1) $\mu=10h$, $\sigma=20h$</td>
<td>56</td>
<td>63</td>
</tr>
<tr>
<td>2) $\mu=5h$, $\sigma=10h$</td>
<td>38</td>
<td>52</td>
</tr>
<tr>
<td>3) $\mu=2h$, $\sigma=4h$</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>4) $\mu=2h$, $\sigma=6h$</td>
<td>56</td>
<td>57</td>
</tr>
</tbody>
</table>

- Shorter PM durations mean a difference in days of lot cycle time!
  - Each day of factory cycle time = millions of $\$$
  - Regardless of the mean, performing PMs inconsistently is functionally equivalent to consistently having much longer downtime durations

Data from simulations run at Intel Fab 11X.
The “Waddington Effect”

- First observed by C.H. Waddington during WWII for British aircraft maintenance
- Background theory: unscheduled downtime should be a random phenomenon
- If all unscheduled downtime events are plotted with respect to the last PM, there should not be any pattern evident
- A pattern of increased unscheduled downtime immediately following PM’s is a “Waddington Effect”
The “Waddington Effect”

"Waddington Effect" Report - Trend of Unscheduled Downtime Frequency Following PMs for the last 12 work weeks

- Impact of Waddington Effect = 1.4% Availability

Data from a set of production tools at Intel Fab 11X.
Challenges to Implementing Preventive Maintenance

Social Factors

- Organizations are frequently structured in ways that promote local optimums (cost, shiftly output goals, etc.)
- The benefits of preventive maintenance are not always well understood
- The focus on minimizing maintenance costs has to shift to maximizing overall organizational performance

Technical Factors

- Breakdown maintenance is typically cheaper than preventive maintenance in the short-term
- Under-trained technicians can cause more damage than they prevent
Concluding Comments

- Performing preventive maintenance is almost always the best long-term strategy to maintain equipment.

- PM scheduling and strategy are keys to maximizing output while reducing work-in-process inventory.

- Due to short-term cost increases and local optimums, there are barriers to implementing a preventive maintenance strategy at some plants.
PM is an important tool for establishing stability necessary for other lean elements:
- Andon, 5s, etc.

How do you escape the crisis management whirlpool?
- Social disconnects:
  - Change the mindset of management, maintenance group from reaction to prevention
  - May need to be done in steps
## Appendix: Instructor’s Guide

<table>
<thead>
<tr>
<th>Slide</th>
<th>Time</th>
<th>Topic</th>
<th>Additional Talking Points</th>
</tr>
</thead>
</table>
| 1-3   | 2-3 min| Introduction, overview and learning objectives | • Acknowledge contributors to the presentation  
• Provide an overview of the learning objectives                                      |
| 4-5   | 3-5 min| Key Concepts                            | • Describe the 3 types of maintenance  
• Explain the benefits of preventive maintenance                                          |
| 6-15  | 7-15 min| Exercises/Activities                    | • Go through the key learnings of the Manufacturing Game  
• Go through a PM optimization example  
• Discuss “Waddington Effect”                                                           |
| 16    | 2-3 min| Disconnects                              | • Discuss the difficulties of implementing preventive maintenance in a reactive maintenance culture |
| 17    | 1-2 min| Concluding comments                      | • Summarize key points of preventive maintenance                                         |