Agenda

Web Resources
Schedule
Factory Physics

(New Assignment

Chapter 11: Study Q’s 1-4
Chapter 12: Problems 1, 2, 4, 5)
Web Resources

http://sdmines.sdsmt.edu/sdsmt/directory/courses/2009fa/tm663M0 21-099

I have most of your exams graded.
Have entered results in D2L.
## Tentative Schedule

<table>
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<tr>
<th>Date</th>
<th>Chapters Assigned</th>
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**Frank Matejciok SD School of Mines & Technology**
The Human Element in Operations Management

For as laws are necessary that good manners may be preserved, so there is a need of good manners that laws may be maintained.

– Machiavelli

We hold these truths to be self-evident.

– Thomas Jefferson
Operations Management Frameworks

Traditional Optimization Framework:
- perfect information
- perfect control
- leverage in quality of solution (policy)

Factory Physics Framework:
- information captured in key measures (e.g., SCV's)
- intuition more important than control
- leverage from working with system's natural tendencies

ICB Portfolio Framework:
- information system part of management problem
- control not always optimal
- buffers explicitly acknowledged
ICB Portfolio Contrasts

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<th>CONWIP</th>
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<td>capacity</td>
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<td>excess WIP</td>
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Human Connections

Information:
- complexity
- “off line” information

Buffers:
- conceptual understanding
- flexibility
- Incentives:
  - piecework
  - “real” measures

Control:
- skill levels
- learning curves

Implementing Change:
- burnout
- champions
Self-Interest

**Self-Interest Law:** *People, not organizations are self-optimizing.*

**Implications:**
- “Optimal” strategies may not produce optimal results.
- Constraints can be good!
Relaxing Constraints in Optimization Problem

Feasible Region

Objective Function

New Constraint

Old Constraint

A  B
Diversity

**Individuality Law:** *People are different.*

**Theory X vs. Theory Y:**
- empowerment
- officer vs. enlisted mentality

**Incentive Systems:**
- team-oriented incentives
- social component of work
Toyota Sewn Products System

Raw Materials

Station 1

Worker 1

Station 2

Worker 2

Station 3

Worker 3

Station 4

Station 5

Station 6

Station 7

Finished Goods

Note: performance best when workers arranged slowest to fastest (i.e., because blocking is minimized).
**Advocacy**

**Advocacy Law:** *For any program, there exists a champion who can make it work—at least for a while.*

**Upside of Champions:**
- selling the “vision”
- motivating the troops

**Downside of Champions:**
- risk of oversell
- overreliance can prevent institutionalization of change
Burnout Law:

People get burned out.

Why?

Can you blame them?
Planning vs. Motivating

*Question:* how high to set the bar?
Responsibility and Authority

**Responsibility Law:** Responsibility without commensurate authority is demoralizing and counterproductive.

**Example:** Deming's Red Bead Experiment
Deming’s Red Bead Experiment
Human Element Takeaways

1. People act according to *self-interest*.
2. Individuals are *different*.
3. *Champions* can have powerful positive and negative consequences.
4. People can *burn out*.
5. There is a difference between *planning* and *motivating*.
6. *Responsibility* should be commensurate with authority.
Total Quality Manufacturing

Saw it on the tube
Bought it on the phone
Now you're home alone
It's a piece of crap.

I tried to plug it in
I tried to turn it on
When I got it home
It was a piece of crap.

– Neil Young
The Opportunity

Rhetoric:
• customer-driven quality
• quality circles
• SQC courses
• “quality speak”

Reality:
• many poor products
• unbelievably rude service
• uncoordinated use of SQC
• complacency?
The Opportunity (cont.)

**Quality Implications:**

- quality promotes cycle time reduction and vice versa
- quality promotes variability reduction and vice versa
- quality promotes better management and vice versa

![Diagram showing the relationship between quality, cycle time, variability, and management]
Attributes of Quality

Quality Definitions:

• **Transcendent**: innate excellence or “I know it when I see it” view.

• **Product-based**: function of product attributes or “more is better” view.

• **User-based**: customer satisfaction or “beauty is in the eye of the beholder” view.

• **Manufacturing-based**: conformance to specifications, related to “do it right the first time” view.

• **Value-based**: price/performance or “affordable excellence” view.
Attributes of Quality (cont.)

**Customer Orientation:**
- customer satisfaction depends on *external* quality
- external quality depends on *internal* quality
- quality must address product, process, system

**Promoting Internal Quality:**
- error prevention
- inspection improvement
- environment enhancement
Dimensions of Quality

- Performance
- Features
- Serviceability
- Aesthetics
- Perceived Quality
- Reliability
- Conformance
- Durability

Quality of design

Quality of process conformance to design = process capability
Statistical Quality Control

Acceptance Sampling:
• 100% inspection
• statistical sampling

Process Control:
• continuous monitoring
• indication of “out of control”

Design of Experiments:
• trace causes of problems
• many tools (factorial, block, nested designs, Taguchi, etc.)
Statistical Process Control

Natural Variation
- relatively small
- due to uncontrollable sources

Assignable Cause Variation
- larger
- can be traced to causes
- cause process to be *out of control*

Challenge of SPC: *separate assignable cause from natural variation.*
Basic SPC Mechanics

Null Hypothesis: samples are coming from a process with mean $\mu$ and standard deviation $\sigma$.

Procedure:
1) Observe samples of size $n$. Under null hypothesis, these will have mean $\mu$ and standard deviation $\sigma_{\bar{x}} = \sigma / \sqrt{n}$.
2) Compare sample mean, $\bar{x}$ to control limits:
   
   \[
   \text{LCL} = \mu - 3\sigma_{\bar{x}} \\
   \text{UCL} = \mu + 3\sigma_{\bar{x}}
   \]
3) If sample mean is outside of range between LCL and UCL, then observation is designated as assignable cause variation, indicating out-of-control situation.
SPC Example

**Problem:** control diameter of hole in steel castings

- desired nominal diameter of $\mu = 10$ mm
- observations have shown $\sigma = 0.025$ mm

**Process:** every 2 hours a casting is randomly selected, so

\[
\bar{x} = \mu / \sqrt{n} = 0.025 / \sqrt{1} = 0.025 \\
LCL = \mu - 3\bar{x} = 10 - 3(0.025) = 9.925 \\
UCL = \mu + 3\bar{x} = 10 + 3(0.025) = 10.075
\]

*Note: variability would be reduced by taking n>1, due to pooling.*
SPC Example Chart

Sample Number

X bar

UCL

LCL

Assignable cause variation

Out of control (mean shift)

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## Control Chart Patterns

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Description</th>
<th>Possible Causes</th>
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</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Random Variation</td>
<td>Assignable (or special) causes (e.g. tool, material, operator, overcontrol)</td>
</tr>
<tr>
<td>Lack of Stability</td>
<td></td>
<td>Tool Wear</td>
</tr>
<tr>
<td>Cumulative trend</td>
<td></td>
<td>Different work shifts, voltage fluctuations, seasonal effects</td>
</tr>
<tr>
<td>Cyclical</td>
<td></td>
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Continuous Improvement

Lower Control Limit

Upper Control Limit

Signal that a special cause has occurred

SQC monitoring

driving improvement

Control

Improvement
Uses of SPC

Product Quality
• dimensions and other physical attributes
• fraction nonconforming
• range of attributes (for monitoring variability)

Times
• process times
• repair times

Other Non-Quality Applications
• tracking throughput
• due date quoting
Six Sigma Foundations

(a)

Centered process

Process shifted by 1.5$\sigma$

Percent Nonconforming
Centered: 4.6%
Shifted: 30.9%

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Six Sigma Foundations

Centered process

Process shifted by 1.5σ

Percent Nonconforming
Centered: 0.27%
Shifted: 6.68%
Six Sigma Foundations

Centered process

Process shifted by 1.5σ

Percent Nonconforming
Centered: $2 \times 10^{-7}\%$
Shifted: $3.4 \times 10^{-4}\%$

USL(6σ) μ USL(6σ)
Six Sigma Terms

DMAIC: Define, Measure, Analyze, Improve, Control

Five Roles:
Executive Leadership
Champions: from ranks of upper management, mentor black belts
Master Black Belts: Support Black Belts in Statistics & $6\sigma$
Black Belts: Lead $6\sigma$ projects
Green Belts: Common training level, may lead projects
Yellow Belts: Common training level, but not lead projects
White Belts: minimal introductory training level
Quality and Logistics

Quality and Cost:
• cost increases with quality? (e.g., better materials)
• cost decreases with quality? (e.g., less correction cost)
• reality is a balance

Quality Promotes Logistics:
• Law: Variability degrades performance.
• Law: Congestion effects increase nonlinearly with utilization.
• yield loss and rework are major sources of variability and lost capacity.

Logistics Promotes Quality:
• excess WIP obscures problems and delays/prevents diagnosis
• excess WIP magnifies losses
• excess cycle time degrades quality of service
Rework Law: For a given throughput level, rework increases both the mean and standard deviation of the cycle time of a process.

Implications: degraded performance through
- lost capacity
- increased variability

Possible Cures:
- eliminate rework
- use non-bottleneck for reworking
- shorten rework loop
Rework on a Single Station

\[ r = \frac{1}{3} \]

\[ t = 1 \]

\[ 1-p \]

\[ p \]

Mean Cycle Time

Graph with axes labeled p and Mean Cycle Time.
Rework in a Line

![Diagram showing the process of rework in a line with throughputs for different values of p: p=0, p=1/3, p=1/2. The graph illustrates the throughput vs. WIP with distinct curves for each probability value.](attachment:image.png)
Defect Detection

Prob $q$ machine goes out of control

Defects detected

Throughput

WIP

Best Case

Exponential

Deterministic with Scrap ($q=0.05$)

Exponential with Scrap ($q=0.05$)
Quality and the Supply Chain

**Importance:**
- all manufacturing systems involve purchased parts
- trend toward outsourcing and “virtual manufacturing”
- a chain is only as good as its weakest link

**Vendor Quality:**
- product quality
- service quality

**Assembly Systems:**
- magnify impacts of vendor quality problems
- require effective vendor selection/management
Safety Lead Times in Assembly Systems

Required Service:

- **Single Component**: 95% service level

- **10 Component Assembly**: If each has 95% service then

  \[
  \text{Prob\{All components arrive on time\}} = (0.95)^{10} = 0.5987
  \]

so to get 95% service on the assembly we need each component to have

\[ p^{10} = 0.95 \]

\[ p = 0.95^{1/10} = 0.9949 \]
Safety Lead Times in Assembly Systems (cont.)

Consequences:

• *Single Component:*
  – Supplier 1: 14 day lead time
  – Supplier 2: 23 day lead time

• *10 Component Assembly:*
  – Supplier 1: 16.3 day lead time
  – Supplier 2: 33.6 day lead time
Effect of Variability on Purchasing Lead Times

PDF of Delivery Time

Days

Supplier 1
Supplier 2
Effect of Variability on Purchasing Lead Times (cont.)

CDF of Delivery Time

Supplier 1
Supplier 2

Days

CDF of Delivery Time
Circuitize: *Current Situation*

**Basic Problems:**
- failure to make 3000 boards per day
- long CT (substantial part of 34 day CT)

**Symptoms:**
- high WIP
- 6% defect level
  - scrap at IP
  - send aheads, test panels, rework at EP
- highly variable expose times (20 min for some operators, 40 min for others)
- clean room not very clean
Circuitize: Capacity Analysis

**Detractors:** must account for setups, failures, rework, operator unavailability.

**IP Line:**
- IP has tighter capacity than EP.
- Trouble spots are preclean/lamination/punch and expose.

**EP Line:**
- EP has capacity for 3000 panels/day at 6% recycle (but not 10%).
- WIP is comparable to IP; EP is a variability bottleneck!
- Can’t make close to 3000 if first job is held for send aheads.
- Holding second job for send aheads has minor impact on capacity.
Circuitize: *Recommendations*

**Keep IP DES loaded as fully as possible**
- Never starve for lack of operator.
- This controls IP throughput.

**Ensure capacity of IP Preclean/Lamination/Punch**
- Cover preclean though breaks when room for WIP in clean room.
- Buy extra punch and maintain parallel dies to eliminate setup.
Circuitize: Recommendations (cont.)

**Improve IP Expose Capacity**
- Certify operators (6 no recycle jobs 3 days in a row)
- Involve operators in hiring process.
- Tighten shift changes and use floaters to cover lunches.
- Use lead technicians to oversee flow (diazos, problems, etc.).
- Pursue extended life diazo program
- Add extra machine if necessary.

**Quality**
- Improve cleanliness to increase yield
- Preserve old diazos to trace cause of defects
- Document effectiveness of policies (e.g., send aheads).
Circuitize: Outcome

Steps:

• Better housekeeping/training reduced recycle below 2%, making send aheads unnecessary.
• Extended life diazo and better personnel management made extra IP expose machine unnecessary.
• Line replicated in improved format to accommodate growing demand.

Results:

• Capacity increased to near 3000 panels/day
• Dramatic decrease in CT to approximately one day.
• Improved line replicated to accommodate increased demand.
Conclusions

• Good quality supports good logistics

• Good logistics supports quality improvement

• Good quality at the supplier level promotes good logistics and quality at the plant level