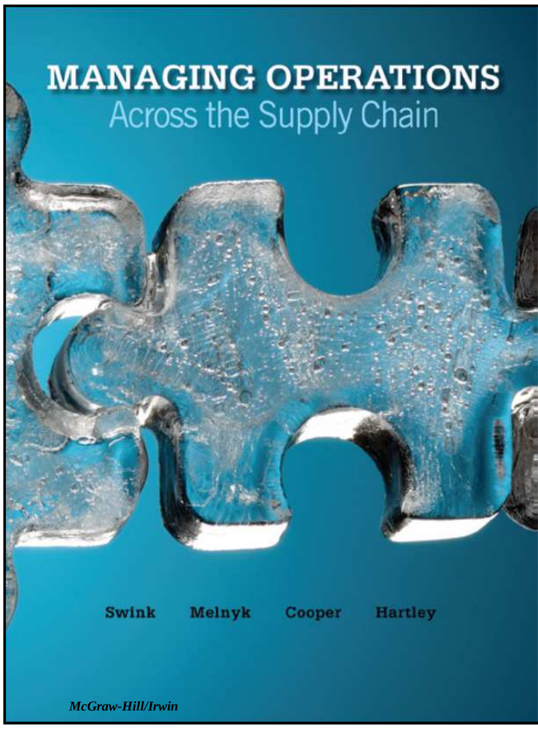

CHAPTER SIX

SUPPLEMENT

Quality Improvement Tools

Learning Objectives

1. Apply quality management tools for problem solving
2. Identify the importance of data in quality management

Quality Improvement tools

- ***Variable Data*** (continuous): quantifiable conditions along a scale, such as speed, length, density, etc.

- ***Attribute Data*** (discrete): qualitative characteristic or condition, such as pass/fail, good/bad, go/no go.

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Quality Improvement tools

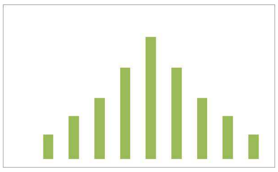
Quality Tools	**Typical Usage**
Histogram	Uncover patterns in data variability
Cause and effect analysis	Uncover contributors to problem; facilitate brainstorming
Check sheets	Identify frequency and location of problems
Pareto analysis	Identify most critical cause of problems
Scatter diagrams	Determine relationship between variables
Process flow analysis	Graph of process steps
Process capability analysis	Compare process variability and specifications
Process control charts	Monitor process output for 'normality' of variance
Taguchi method/DoE	Track effects of different factors on outputs

Table 6S-1

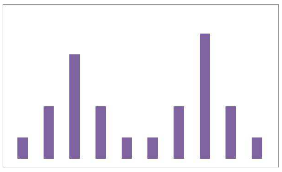
6S–4

Histograms

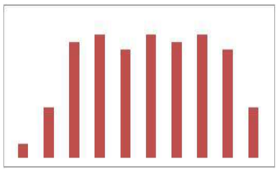
Review center, width and shape



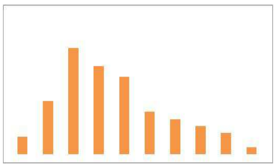
Bell-shaped
Normal distribution



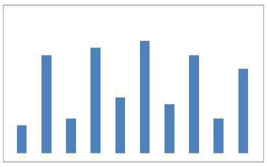
Double peak
Two processes?



Plateau
Combined data sets?



Skewed
System limitation?



Comb
Error in process or data collection

Figure 6S-1

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Cause and Effect Diagram

1. Identify the problem to examine
2. Identify the major categories of causes
3. Identify more specific causes
4. Circle likely causes
5. Verify the causes

Figure 6-1

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Cause and Effect Diagram

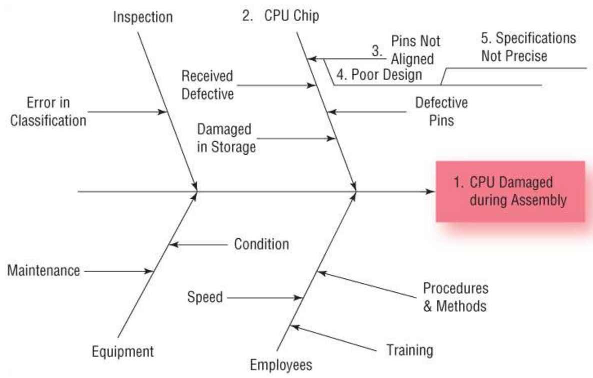

FIGURE 6S-2 Cause and Effect Diagram for Pear's CPU Damage Problem

Figure 6S-2

Check Sheet

- Tool for collecting, organizing and displaying data to uncover patterns

FIGURE 6S-3 Example of Attribute Check Sheet

Reason for Reject	Number Rejected
Item damaged	✓✓✓✓✓✓✓✓✓✓✓✓✓
Wrong case shipped	✓✓✓✓✓✓✓✓
Part does not work	✓✓✓✓
Component(s) missing from part	✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓
Not properly marked (no bar code on inside of case)	✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓ ✓✓✓✓✓✓✓✓
Scratches found on case	✓✓✓✓✓✓✓✓✓✓✓✓
Other (factors not noted above)	✓✓✓✓

Figure 6S-3

Pareto Analysis

- Separates the critical few form the trivial many
  1. Indentify categories about which to collect data
  2. Gather data and calculate frequency of observations in each category for an appropriate time period
  3. Sort into descending order by percentage
  4. Graph and identify the few areas that account for most of the variation

Pareto Analysis

FIGURE 6S-4
Pareto Analysis for Pear Computers

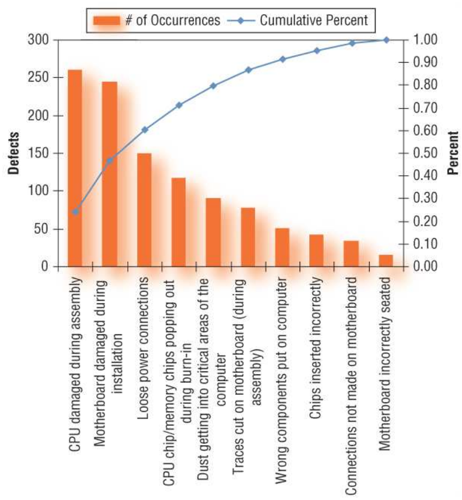

Figure 6S-4

Scatter Diagram

- Graphical representation of the relationship between two variables

FIGURE 6S-5
Scatter Diagram for Conveyor Speed and Cut Length

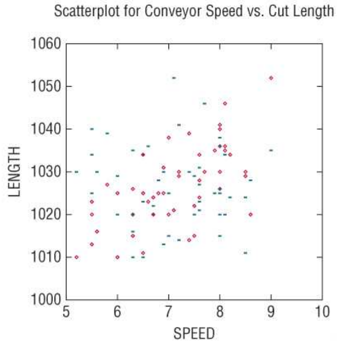

Figure 6S-5

Process Flow Diagram

FIGURE 3S-3 Process Flow Diagram: Dry-Mill Ethanol Process for Converting Corn to Fuel Grade Ethanol[5]

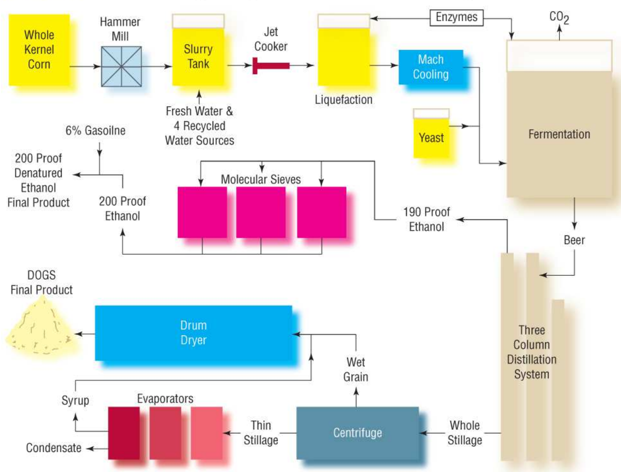

Figure 3S-3

Process Capability (C_p)

- Assess ability of a process to meet (or exceed) design specifications

$$C_p = \frac{Specification\ width}{Process\ width} = \frac{S}{P}$$

Where:
S = Upper specification limit – Lower specification limit
P = 6σ (99.7% of variation)
σ = Standard deviation of process output

Figure 6S-5

Process Capability (C_p)

$C_p < 1$ observed spread larger than desired spread
$C_p = 1$ observed and desired spread exactly equal
$C_p > 1$ desired spread larger than observed spread

When +/- 3σ is used to calculate C_p

$C_p = 1.00$ is 3σ quality (3σ to either side)

$C_p = 1.33$ is 4σ quality

$C_p = 1.67$ is 5σ quality

$C_p = 2.00$ is 6σ quality

Figure 6-1

Process Capability (C_p)

$$C_p = \frac{20}{6*5} = 0.67$$

When σ = 5 mils,
the process is NOT capable
Cp < 1

$$C_p = \frac{20}{6*2} = 1.67$$

When σ = 2 mils,
the process IS capable
Cp > 1

Where:
- S = designed to be 1,030 mil +/- 10 mil, so = 20 mils
- USL = 1,040 and LSL = 1,020
- P = 6σ (99.7% of variation)

Figure 6S-5

Process Capability (C_p)

FIGURE 6S-6
Sample Distributions and their Associated C_p Measures

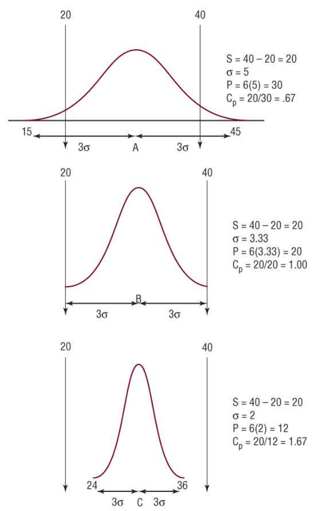

Figure 6S-6

Improving on the C_p Statistic with C_{pk}

- ***C_{pk}***: compares process output and specification widths, and examines process centering

$$C_p = \frac{S}{P} = \frac{(USL - LSL)}{6\sigma}$$

$$K = \frac{|D - \overline{X}|}{S/2}$$

$$C_{pk} = (1 - K) * C_p$$

Where:

USL & :LSL = Upper & Lower specification limit
D = Center of product specification range = (USL+LSL)/2
$\overline{X}$ = Mean of process output distribution
K = Adjustment of centeredness of process and specifications

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Improving on the C_p Statistic with C_{pk}

$$K = \frac{|1030 - 1020|}{20/2} = 1$$

$$C_{pk} = (1 - 1) * 1.67 = 0$$

Process is NOT centered

Where:

USL & :LSL = 1,040 and 1,020
S = 20
D = 1,030
$\overline{X}$ = 1,020 (given)
Cp = 1.67 (from previous example)

6S–18

Process Capability (C_{pk})

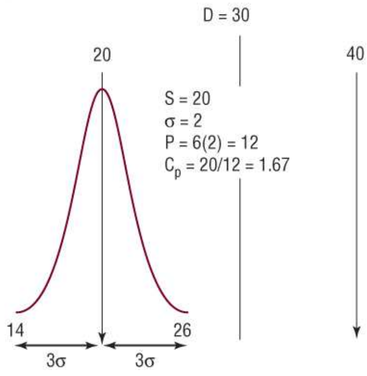

FIGURE 6S-7
Deceptive C_p Value: The Problem of Lack of Centering

Figure 6S-7

6S–19

Process Control Charts

- Statistical tool to monitor process output to detect significant changes

FIGURE 6S-8
Process Control Limits

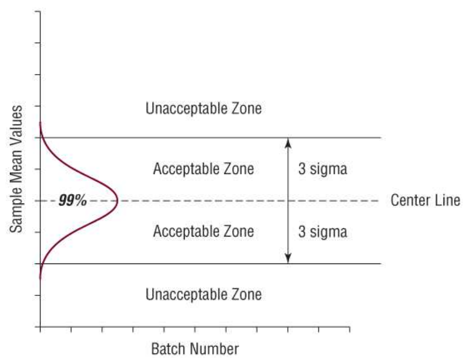

Figure 6S-8

6S–20

Process Control Charts

TABLE 6S-3 Types of Control Charts and Data Covered[1]

Type of Data	Control Chart Used	Types of Data
Variables—Continuous/Indiscrete	$\bar{x}-R$	measurement (inches, mm) volume product weight power consumed
Attributes—Discrete	*pn* (probability of defect)*(number in batch)	number of defects
Attributes	*P*	fraction defective
Attributes	*U*	number of pin holes in pieces of plated sheet, differing in area (area/volume is not fixed)
Attributes	*C*	number of pin holes in a specified area (area is fixed)

[1]Kaoru Ishikawa, *Guide to Quality Control*, Second Revised Edition. (Tokyo: Asian Production Organization, 1982.) Reprinted with permission.

Table 6S-3

Process Control Charts

- Constructing and using x-bar and R charts
  1. Collect data to calculate control limits
  2. For each sample, calculate the sample mean $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$
  3. For each sample find the range (R)
  4. Calculate the overall 'grand' mean $(\bar{\bar{X}})$
  5. Calculate the mean range $(\bar{R})$
  6. Compare control limits and construct the charts

Process Control Charts

Equations for the $\bar{x}$ and R charts

$\bar{x}$ chart: $Central\ line = \bar{\bar{x}}$

$$Lower\ control\ limit = \bar{\bar{x}} - A_2\bar{R}$$

$$Upper\ contrl\ limit = \bar{\bar{x}} + A_2\bar{R}$$

R chart: $Central\ line = \bar{R}$

$$Lower\ control\ limit = D_3\bar{R}$$

$$Upper\ contrl\ limit = D_4\bar{R}$$

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Process Control Charts

- A process has 20 sample means, with a 'grand' mean of 12.14 and an average range of 0.69

TABLE 6S-6 Control Limits Calculated for the Example Control Chart

Data Points	$\bar{x}$ Chart	*R* Chart
Central Line	12.14 ms	0.69
Lower Control Limit (LCL)	12.14 − 0.577*0.69 = 11.74	0
Upper Control Limit (UCL)	12.14 + 0.577*0.69 = 12.54	2.115*0.69 = 1.459

Table 6S-6

6S–24

Process Control Charts

FIGURE 6S-9 $\overline{X}$ and R Chart for the Example Data Set

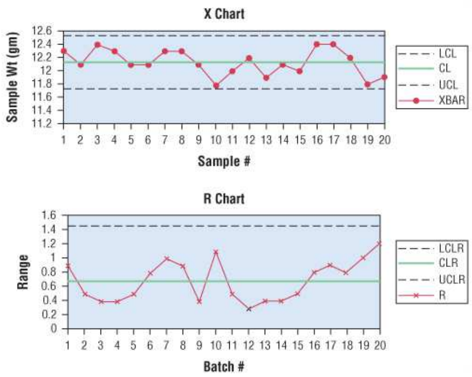

Figure 6S-9

Taguchi Methods

- Statistical methods for improving the design of a product and the processes that improve it
- Goal is to identify easily controllable factors that can be used to reduce variation

Managing Quality Summary

1. Effective quality management is data driven
2. There are multiple tools to identify and prioritize process problems
3. There are multiple tools to identify the relationships between variables
4. Process capability compares actual process output with design specifications

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