

# **Statistical Thinking: An Approach to Management**

1. Introduction
2. Notion of Process
3. Concepts and Dealing with Variation
4. Statistical Tools
5. Systematic Approach
6. Tying the Elements Together
7. Improving the Level of Statistical Thinking

*"To compete and win, we must redouble our efforts - not only in the quality of our goods and services, but in the quality of our thinking, in the quality of our response to customers, in the quality of our decision making, in the quality of everything we do."*

E.S. Woolard  
Chairman and CEO  
E.I. du Pont de Nemours & Co.  
ASQC Newsletter, Feb. 1991

*"Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write."*

H G Wells

*"When you can measure what you are speaking about and express it in numbers, you know something about it. When you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind."*

Lord Kelvin

# OUTLINE

- Introduction
  - what is statistical thinking
  - why is it valuable
  - where does it fit within Total Quality Management (TQM)
- The elements of statistical thinking
  - what, why, how
  - tying the elements together
- Improving the level of statistical thinking
  - self-improvement
  - getting others to improve their statistical thinking

# STATISTICAL THINKING

## What is Statistical Thinking?

It is well recognized that in order to maintain and improve our competitiveness, we need to continually improve all aspects of our business at an increasing rate. Statistical Thinking provides a common methodology for Continuous Improvement that is applicable to everything we do.

Moreover, Statistical Thinking will ensure that we improve efficiently and in a real and lasting manner.

The practice of Statistical Thinking consists of the application of the following elements to all business activities in conjunction with Corporate values and objectives.

1. notion of process
2. understanding and dealing with variation
3. understanding and appropriate use of statistical tools
4. systematic approach to improvement

- Statistical Thinking
  - is much more than statistical tools, more than numbers and charts
  - is unavoidable; some are better at it than others
  - is not extra work; you are doing it already
  - is not a new program but has strong links to many business strategies
  - is not a panacea
- Improved Statistical Thinking will lead to
  - better business decisions
  - increased success in implementing programs such as Variation Reduction, Synchronous Manufacturing, JIT, SPC etc
  - better human relations

*" SQC (statistical quality control) makes it possible to attain both traditional aspirations: high quality and productivity on one hand, work worthy of human beings on the other."*

( Peter Drucker, The Emerging Theory of Manufacturing,  
Harvard Business Review, May-June, 1990.)

- Statistical Thinking can be applied throughout an organization, not only in manufacturing
  - large gains possible in non-manufacturing processes
  - high percentage of work in a manufacturing organization is devoted to service activities (Management, Engineering, Maintenance, Purchasing, Finance etc)
- Many organizations have reaped benefits by applying statistical thinking widely

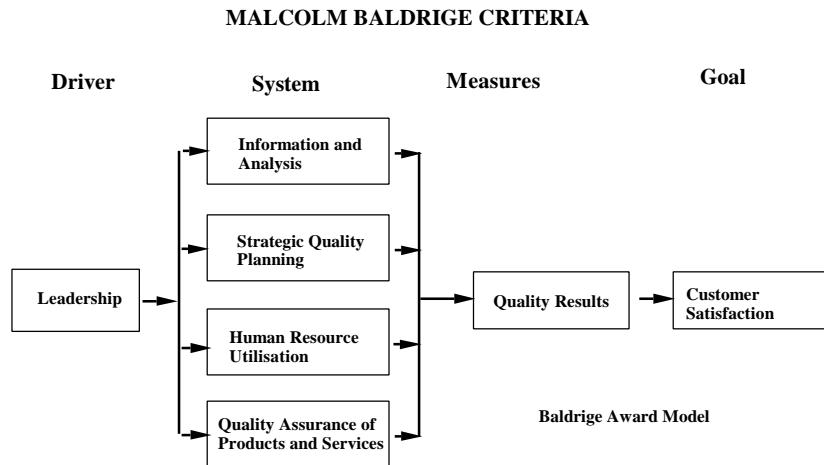
Ford

Florida Power & Light (Deming Prize winner 1989)

Motorola (6 sigma quality, Baldridge Prize winner)

Dupont

# THE ROLE OF STATISTICAL THINKING IN TQM



- Baldrige Award scoring system is based on three elements: Approach, Deployment, and Results

Approach

systematic approach  
notion of process  
use of appropriate tools

Deployment

all processes

Results

measurement  
concepts of variation

## ELEMENTS OF STATISTICAL THINKING

- The four elements of statistical thinking are:
  - notion of process
  - understanding and dealing with variation
  - understanding and appropriate use of statistical tools
  - systematic approach to process improvement

### NOTION OF PROCESS

- Any activity can be portrayed as the central part of a process

INPUTS	ACTIVITY	OUTPUTS TO CUSTOMERS
suppliers machines material methods environment measurement		quality cost responsiveness

- Note that customers and suppliers should be considered part of the process definition (CUSTOMER FOCUS)

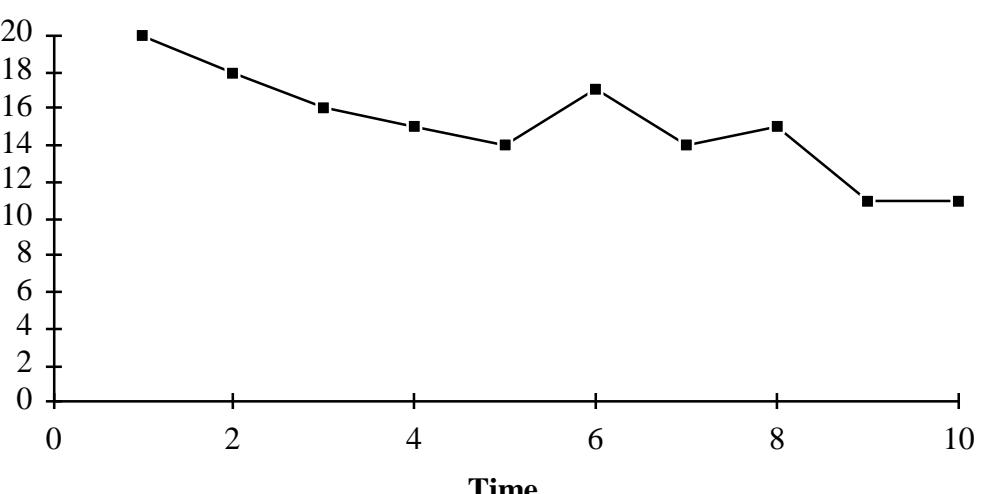
- Tools for describing processes include
  - process flow diagram
  - cause and effect diagram
- Appropriate level of detail in process description is critical
- It is more difficult to think of non-manufacturing work as a process because
  - not tangible
  - usually not well documented (no blueprint)
  - we are not used to doing so
- Immediate consequences of consideration of work as a process are
  - encourages concentration on process, not results (PROCESS FOCUSED)
  - forces customer focus (CUSTOMER DRIVEN)
  - STANDARDIZATION ( best current practice) is possible
  - recognizes role of suppliers and the importance of UP-STREAM QUALITY
  - ideas of INTERNAL and EXTERNAL suppliers and customers
  - process may have many customers and many suppliers
  - process may have many inputs and many outputs

- Most work is an interconnected network of processes
    - the outputs of one are the inputs to others
    - the customers of one process are the suppliers to the next
  - Understanding that work is a network of processes leads to
    - awareness of the dangers of LOCAL OPTIMIZATION
    - recognition of unnecessary COMPLEXITY (steps in which little value is added)
  - Measurement of process inputs and outputs is vital to understanding and improvement
    - measurements should be related to CUSTOMER NEEDS (quality, cost, responsiveness)
    - it may be difficult to find measurement systems for administrative/management processes
- [Ask your customer how a good job is defined!]
- don't get trapped by waiting for the "best" measurement system

# UNDERSTANDING AND DEALING WITH VARIATION

**Fact of life:**      **The outputs of all processes vary.**

**Examples:**

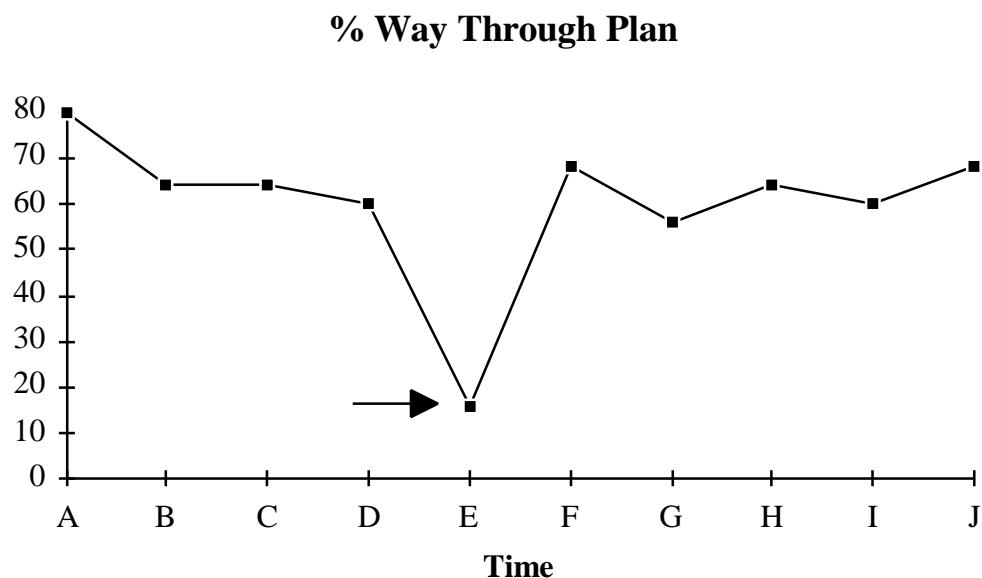
<u>Process</u>	<u>Output</u>																						
<b>Car assembly</b>	<b>number of vehicles per hour</b> <b>number of defects per vehicle</b>																						
<b>Document entry</b>	<b>Documents per minute</b> <b>Errors per 1000 documents</b> <b>Waiting time for storage</b>																						
<b>Defects/vehicle</b>																							
	 <table border="1"><thead><tr><th>Time</th><th>Defects/vehicle</th></tr></thead><tbody><tr><td>1</td><td>20</td></tr><tr><td>2</td><td>18</td></tr><tr><td>3</td><td>16</td></tr><tr><td>4</td><td>15</td></tr><tr><td>5</td><td>14</td></tr><tr><td>6</td><td>17</td></tr><tr><td>7</td><td>14</td></tr><tr><td>8</td><td>15</td></tr><tr><td>9</td><td>11</td></tr><tr><td>10</td><td>11</td></tr></tbody></table>	Time	Defects/vehicle	1	20	2	18	3	16	4	15	5	14	6	17	7	14	8	15	9	11	10	11
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**Note:** Process may have many outputs, each requiring an  
**OPERATIONAL DEFINITION**

**What is needed to understand this picture?**

- Variation

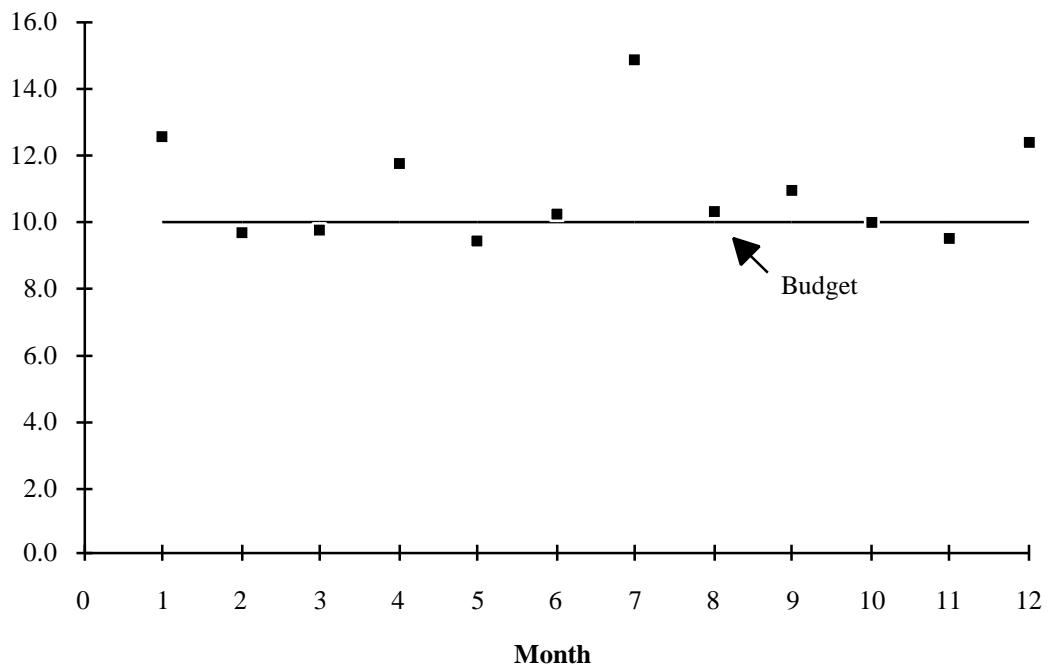
<u>Process</u>	<u>Output</u>
<b>Company-wide implementation of a cost-reduction program</b>	<b>Number of projects per area</b> <b>Cost savings by area</b> <b>% way through plan by area</b>



Why is the arrowed point interesting?

## TWO ASPECTS OF VARIATION

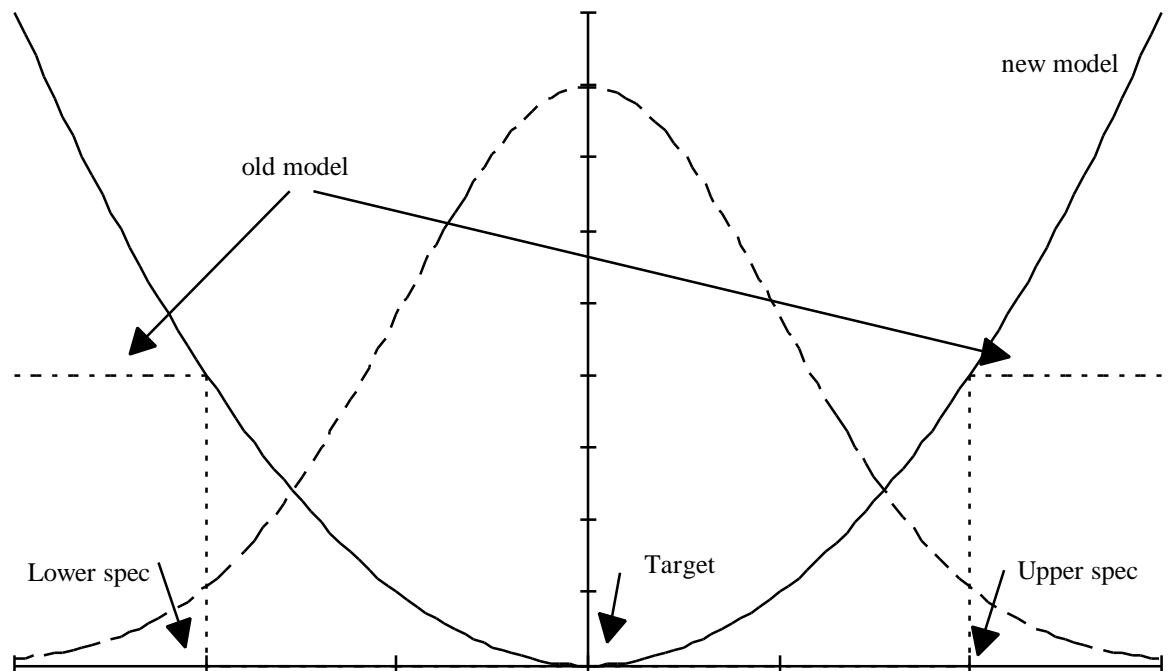
- The output of a process can vary in different aspects
  - from the ideal or target
  - from time to time, person to person, machine to machine etc



- Differing aspects may have differing consequences
  - deviation from target: high long term cost/lost profit/lost capacity, expected returns too low
  - time to time variation: difficulty meeting schedule, higher short term costs

## REDUCTION OF VARIATION IMPLIES IMPROVEMENT

- Reducing variation increases customer satisfaction
- The loss function provides a concept to support the idea that reduction of variation increases value and reduces costs



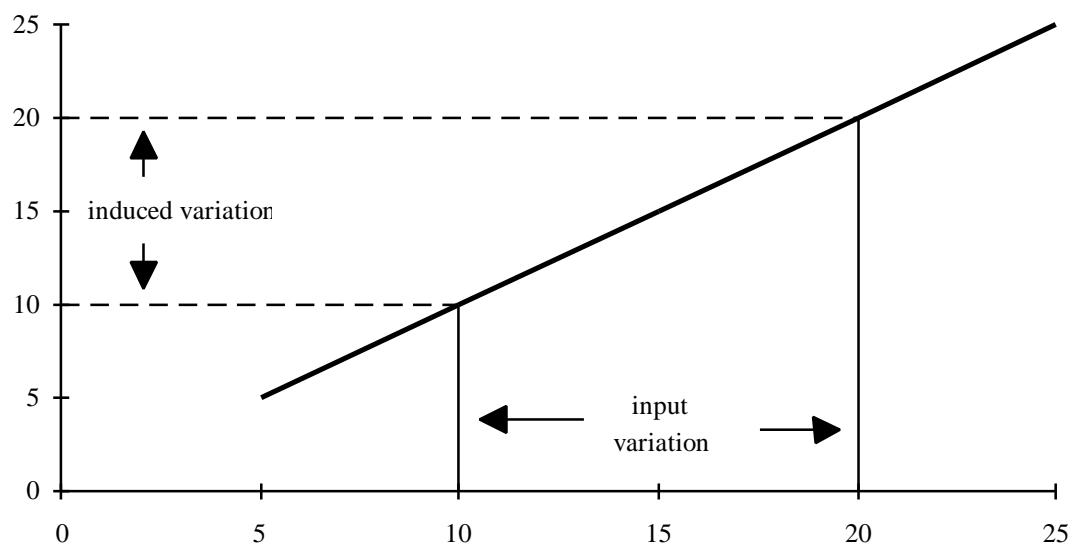
Taguchi proposed a quadratic form for the loss function:

$$L(x) = k(x - m)^2$$

**$L(x)$  is the loss when the quality characteristic is  $x$  units away from the origin,  $m$  is the target value, and  $k$  is the loss coefficient.**

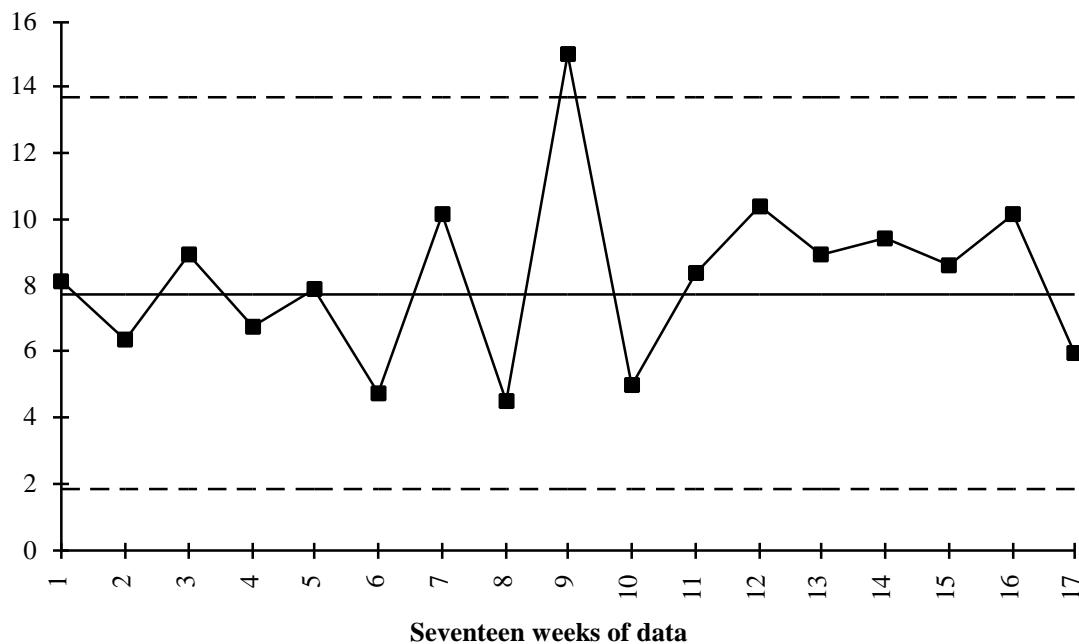
## STRATEGY FOR VARIATION REDUCTION

- The basic strategy is:
  1. Identify significant causes of variation
  2. Deal with the identified causes to remove their effect
- Variation is caused by
  - inputs that change over time cause time to time variation
  - poor process/product design or lack of process control causes deviation from target



# IDENTIFYING CAUSES OF VARIATION

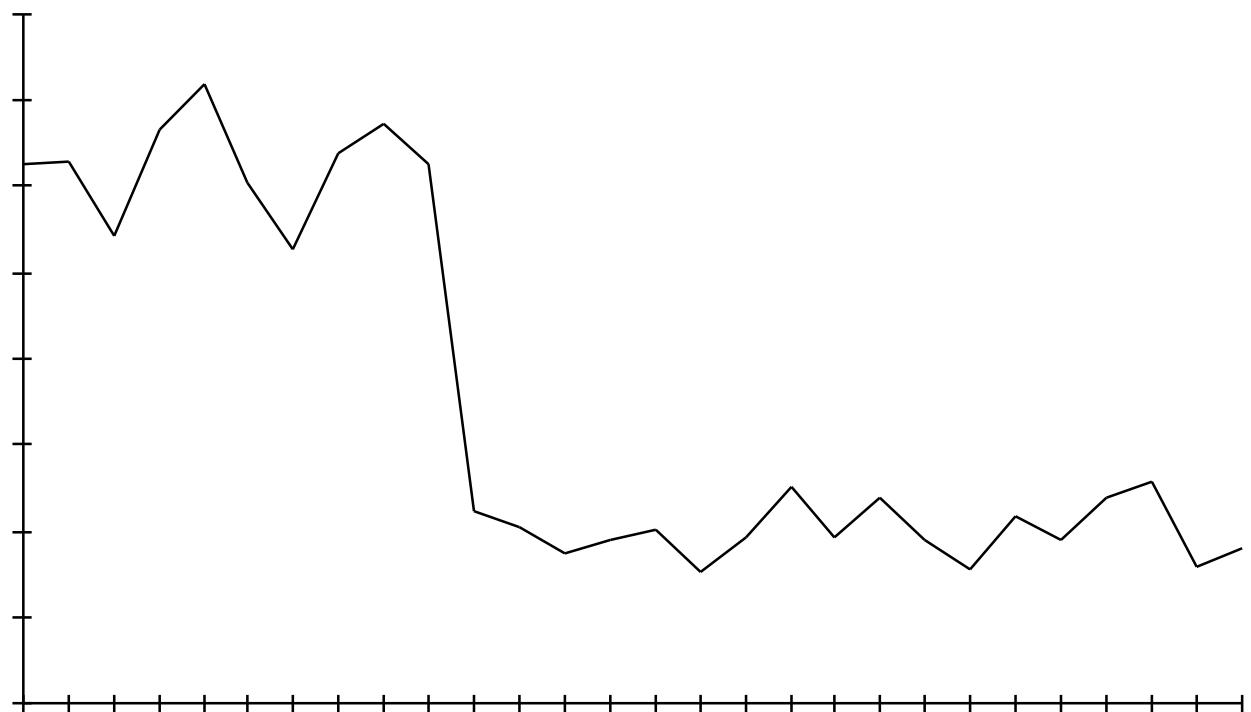
- To identify a cause of variation a process must be studied
  - passive observation
  - active intervention
- A control chart is a passive tool for process monitoring



- Small time-to-time variation on the chart is due to **COMMON CAUSES** of variation
- The chart can indicate that a large sporadic cause of variation is acting (**SPECIAL CAUSE**)
- The chart does not identify the cause; it only indicates that some special cause is acting.

- Simultaneous collection of information on potential causes of variation can provide a valuable supplement to a control chart so that off-line analysis such as stratification, correlation etc can be undertaken
- Active intervention corresponds to an experiment
  - the deliberate change of a factor corresponding to a cause of variation is an experiment
  - experiments can be simple or very complex
  - experiments must be carefully planned so that the causes being studied are not confounded with other process changes such as sporadic causes of variation

higher is worse



Process change

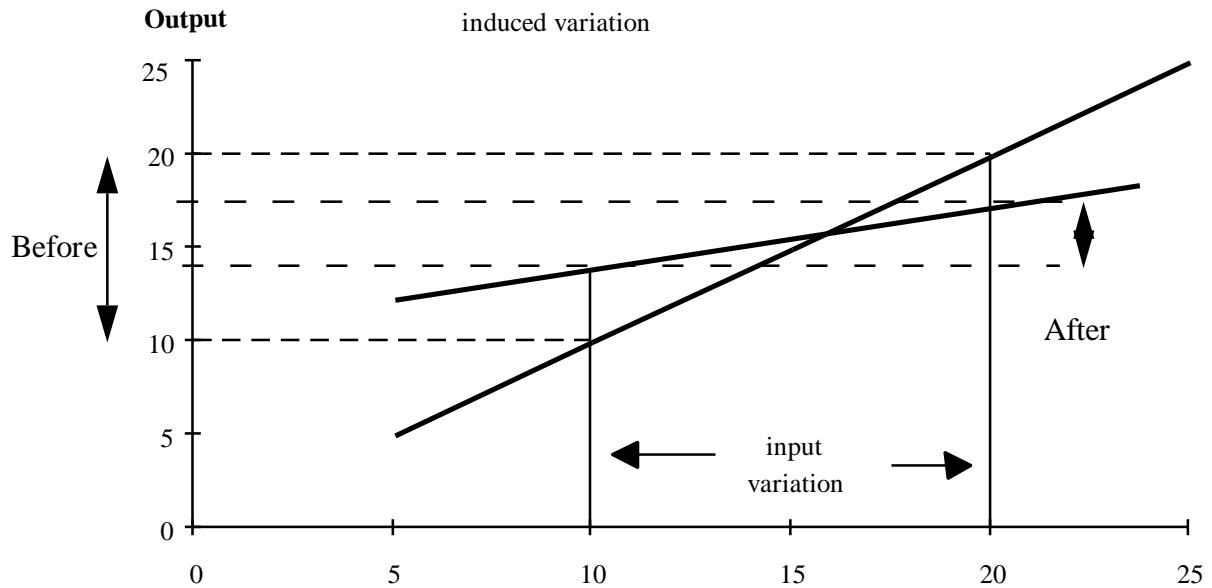
Standardise

## DEALING WITH IDENTIFIED CAUSES OF VARIATION

- Incorrectly assigning responsibility for variation is very common management practice
- Example: Individual performance chart
- Adjusting a process on the basis of common cause variation (tampering) increases overall variation.
- To remove or reduce the effect of an identified cause of variation, some basic tools are:

### Time-to-Time Variation

- standardization
- reduce up-stream variation
- improve process control
- remove complexity (eliminate unnecessary inputs)
- exploit interaction (increase robustness)



## Off Target Variation

- change process design/ process settings

## SUMMARY

- The basic steps in understanding and dealing with variation are:
  - understanding the aspect of the variation (time-to-time vs off target variation - bias)
  - completely identifying and understanding the cause of the variation
  - reducing or eliminating the variation due to the cause by adopting the appropriate strategy

# UNDERSTANDING AND APPROPRIATE USE OF STATISTICAL TOOLS

Statistical Tools are efficient aids to collecting, describing and analysing processes

- Too much emphasis has been given to what the tools are instead of when, where, why, ... they can be used:
  - statistical tools without a Statistical Thinking framework
- Statistical Tools provide:
  - data-based and objective views
  - illustrative descriptions
  - efficiency
  - methods for handling variation
  - methods for generation and organization of ideas
  - facilitation of teamwork/employee involvement
  - improved communication
- Statistical tools are improvements upon
  - opinions/subjectiveness/superstition
  - bad habits/inherited knowledge "That's how we've always done it"
  - poorly planned studies - "seat of the pants", little or poor quality data

- Statistical tools should be used as needed within a process improvement endeavour. Pick the tools that will aid you most at each step.

no one tool works for everything.

make use of the basic tools as much as possible. Turn to more complex tools such as DOE when the simpler tools are not adequate to give the required information.

everyone at all levels and across all departments should make use of the basic tools.

(DOE: Design Of Experiments)

Statistical Tools	Primary Use	Where it Fits
Flow Charts	Process Steps Description	<ul style="list-style-type: none"> <li>Notion of Process</li> </ul>
Check Sheets	Data Collection	<ul style="list-style-type: none"> <li>Variation occurs</li> <li>Identify inputs causing variation</li> </ul>
Cause and Effect Diagrams	Idea generation and organization	<ul style="list-style-type: none"> <li>Process inputs and outputs</li> <li>Identify inputs causing variation</li> </ul>
Pareto Charts	Prioritization	<ul style="list-style-type: none"> <li>Focus efforts</li> </ul>
Histograms	Variation Description	<ul style="list-style-type: none"> <li>Identify inputs causing variation</li> </ul>
Scatter Plots	Relating inputs and outputs	<ul style="list-style-type: none"> <li>Identify inputs causing variation</li> </ul>
Stratification	Find differences from machine to machine, shift to shift, etc.	<ul style="list-style-type: none"> <li>Identify inputs causing variation</li> </ul>
Run Charts/ Control Charts	Variation description over time (people, machines, etc.)	<ul style="list-style-type: none"> <li>Identify inputs causing variation</li> <li>Classifying a cause as special or common</li> <li>avoid tampering</li> </ul>
Capability Ratios	Comparing variation to an expectation (specifications)	<ul style="list-style-type: none"> <li>Reduction of variation implies improvement</li> </ul>
Five Whys	Dig to the root cause of variation of processes	<ul style="list-style-type: none"> <li>Interdependencies</li> <li>identify inputs causing variation</li> </ul>
Linear Regression	Correlating inputs to outputs	<ul style="list-style-type: none"> <li>Identify inputs causing variation</li> </ul>
Designed Experiments	Assess effects of inputs on outputs	<ul style="list-style-type: none"> <li>Identify inputs causing variation</li> <li>Robustness</li> </ul>

## EXERCISE

To assess customer satisfaction with its product ( an office photo-copier), an organization mails a short questionnaire to the customer 4 weeks after delivery. There are 5 questions relating to delivery, service at installation etc. The key question is:

How satisfied are you with our product and service?

The customer chooses one of 5 responses:

- 1: very dissatisfied
- 2: somewhat dissatisfied
- 3: satisfied
- 4: very satisfied
- 5: delighted

The data are collected monthly and the percentage of customers giving a score of 3 or less is charted as shown on the next page. It appears that an improvement has occurred. The company has been making considerable effort to improve the level of satisfaction by changing the delivery and installation process.

1. This study is an experiment. Why?
2. Make a list of at least 5 questions you would need answered before you could decide that the efforts were paying off.

## Customer Satisfaction



## SYSTEMATIC APPROACH TO IMPROVEMENT

A logical systematic step by step approach should be used for all improvement activities

- A systematic approach to improvement
  - enhances employee involvement and teamwork
  - provides an efficient path to effective solutions
  - facilitates communication
  - keeps proper focus
  - ensures planning
  - requires documentation - "technical memory"
  - can be learned and trained
- Many formal approaches exist:
  - Change Process Model
  - Shainin-Juran
  - PDCA (Deming Cycle)
  - Zenger-Miller
  - Kepner-Tregoe
  - Joiner
  - QC Story

- All systems are similar with varying emphasis and level of detail
  - common components are: planning, study, analysis, implementation, evaluation, documentation & teamwork
  - can adapt one to fit another's steps
  - each carries its own language and connotations
- It is important to reduce the variation in the use of different systems within a single organization
  - manufacturing vs non-manufacturing
  - dealing with customers and suppliers
  - Remember the Peters admonition to "follow a guru"!
  - use one coherent system.

## **TYING THE ELEMENTS TOGETHER**

- Statistical Thinking involves defining work as a PROCESS and using knowledge of the CONCEPTS of VARIATION with STATISTICAL TOOLS to SYSTEMATICALLY APPROACH continuous improvement.
- Statistical Thinking is intimately connected to
  - many fundamental principles of good business practice
  - most programs such as work place organization, JIT delivery, SPC etc.

## **KEY IDEAS**

Use the elements of Statistical Thinking to improve every activity.

### 1. Notion of process

- all activity can be described as a process
- processes have inputs, outputs, suppliers, customers
- processes are interdependent
- must measure process effectiveness to improve

### 2. Understanding and dealing with variation

- variation occurs from the ideal and from time to time, person to person etc.
- reduction of variation leads to improvement (cost, quality, ...)
- strategy for variation reduction
  - identify cause using statistical tools
  - deal with identified cause
  - avoid tampering

### 3. Statistical tools

- become knowledgeable about the tools and their uses
- choose the simplest appropriate tool

### 4. Systematic approach to improvement

- use a step-by-step approach to ensure focus, efficiency, consistency, documentation and teamwork
- reduce proliferation of problem solving systems

## QUALITY MANAGEMENT PRINCIPLE      STATISTICAL THINKING ELEMENTS

Avoid local optimization	interconnectedness of processes
Prevention focus	process, identify causes of variation
Company-wide promotion	all activity is a process
Constancy of purpose	variation reduction
Process orientation	notion of process, systematic approach
Reduce variation	understanding and dealing with variation
Deploy Voice of Customer	notion of process, statistical tools
Follow Plan-Do-Check-Act cycle	systematic approach
Standardize	reduce variation
Leadership by example	everyone to use Statistical Thinking
Be customer driven	notion of process
Teamwork	systematic approach
Support for individuals	statistical tools, systematic approach
Continuous Improvement	all

## **IMPROVING THE LEVEL OF STATISTICAL THINKING**

- Two aspects are:
  - using Statistical Thinking to improve your own processes
  - helping others to improve their Statistical Thinking
- The two parts are complementary
  - practising Statistical Thinking serves as role model
  - having others around you use Statistical Thinking increases your understanding and forces appropriate questions
- FOCUS
  - can't apply Statistical Thinking everywhere immediately but more is better
  - pick a process on which to start

## Using Statistical Thinking Yourself

- What processes (work) do you own?
  - personal schedule
  - file maintenance
  - computer usage
  - telephone
  - scheduling/planning/conducting meetings
  - project management
  - appraisal

## **Getting Others To Improve Statistical Thinking**

- Ask appropriate questions
- Concentrate on process not results when conducting reviews

## **Encourage training/education**

- Use language of Statistical Thinking whenever possible (process, customer, variation, problem solving etc)
- Put process improvement as the final item on the agenda in all meetings
  - "how could we have improved this meeting?"
- Include Statistical Thinking in all verbal and written reports
  - write reports in QC story framework if possible (Seven-Step Model)
  - include suggestions on how the process that resulted in the report can be improved

**Every time a process is used, data are produced and you can think about improvements based on customer needs.**

## A LIST OF QUESTIONS

Who are the customers?

How do(could) you measure quality of the output?

What does the process look like?

Are there any obvious improvements?

What are the important inputs that you control?

How could you improve the process by changing these inputs?

What are the important inputs that you do not control?

Can you increase the robustness of the process?

How do you know that an input is a cause of variation?

Is this a special or common cause of variation?

What strategy (plan) do you have to find the major causes of variation?

Is the process stable or not? How do you know?

Have the data been stratified?

How much variation is due to the measurement system?

Who (what) is responsible for the large variation?