Tutorial Outline

Section I – Understanding Data
  • How to use data
  • Understanding variation
  • Requirements for success
  • Common risks and pitfalls

Section II – Data Analysis Dynamics
  • Learning from our experiences
  • Useful tips for making measurement work
  • Thread together methods, tools, processes
Tutorial Outline

Section III – Case Study

Summary

Addenda
- Additional vignettes
- Tool tips
Tutorial Focus

Tools, tips, and techniques your organization can use for analyzing software data and taking action

Specifically we will focus on
- day-to-day practices
- activities that lead to breakthroughs
- why the problem, not management, should drive your measurement program

Remember:
There is no “cookie-cutter” approach to doing good measurement, but there are some best practices.
Section I: Understanding Data

Data can help you
- Identify root causes of variability, off-target performance
- Better predict plans and commitments
- Make better decisions and take action
- Monitor activities to keep projects on cost, schedule

Data is the means to an end, not the end itself.
Process Performance Data

Data allows you to access/analyze process performance.

*Process performance* is behavior that can be described or measured using attributes of
- process operation or execution
- resultant products or services

Process performance measures answer the question: “How is the process performing with respect to quality, quantity, effort (cost) and time?”

All process behavior is variable.
Getting at the Cause of Variation

Shewhart divides variation into two types:

- **Common Cause Variation**
  - variation in process performance due to normal or inherent interaction among process components (people, machines, material, environment, and methods).

- **Assignable Cause (Special Cause) Variation**
  - variation in process performance due to events that are not part of the normal process.
  - represents sudden or persistent abnormal changes to one or more of the process components.
Understanding Variation

Everything is a process.
All processes have inherent variability.
Data is used to understand variation and to drive decisions to improve the processes.

(Spread due to common cause variation will re-establish itself.)
In Other Words…

**Process Off Target**

- Target
- Defects

- LSL
- USL

**Excessive Variation**

- Target
- Defects

- LSL
- USL

**Center Process**

**Reduce Spread**
Separating signal from noise requires rigorous analysis procedures.

This allows quantitatively based inferences to be drawn to guide decisions and actions.
Data Analysis Studies

Remember what you are trying to accomplish. There are two approaches to data analysis to consider:

- **Enumerative**
  - aim is descriptive
  - determines “How many?” - not - “Why so many?”

- **Analytic**
  - aim is to predict or improve product attributes and/or the behavior of the process in the future
Enumerative Studies

An enumerative study answers questions such as:

- How many defects were found inspecting product code?
- How many problem reports have customers filed?
- What percent of staff have been trained in object-oriented design methods?
- How large were the last five products we delivered?
- What were the average sizes of our code-inspection teams last year?
- How many staff hours were spent on software rework last month?
Analytic Studies

Software engineering examples of analytical studies include:

- measuring software product attributes for the purpose of making changes to future products
- evaluating defect discovery profiles to identify focal areas for process improvement
- predicting schedules, costs, or operational reliability
- evaluating/comparing software tools, technologies, or methods—for the purpose of selecting among them for future use
- stabilizing and improving software processes or to assess process capability
Enumerative vs. Analytic

Undertake an enumerative study if: action is to be taken on the subject based on data that is already collected.

Undertake an analytic study if: action is to be taken on the process that produced the data.

Analytic studies utilize statistical process control tools to draw inferences about future process performance.
Basic Data Analysis Paradigm

Problem and goal statement (Y):
- maximum latent defects released
- minimum mean time between failure in the field
- time to market improvement (as function of test time, defect density)

Define

Measure

Analyze

Act

Control

- Problem & goal statements
- Define boundaries
- Process maps
- “Management by Fact”

- Discovery: paretos, histograms, distributions, c&e
- Understanding: root cause, critical factors
- Improvement: adjust critical factors, redesign
- Performance: on target, with desired variation

\[ Y = f(\text{defect profile, yield}) \]
\[ = f(\text{review rate, method, complexity}) \]
Tips for Good Measures

Measures used to characterize products or processes
- relate closely to the issue under study
- have high information content
- pass a reality and validity test
- permit easy and economical collection of data
- permit consistently collected, well-defined data
- show measurable variation as a set
- have diagnostic value

[Wheeler 92]
Tips for Better Data Analysis

Verified: accuracy of format, type, range, completeness, and type

Valid and Reliable: clear, consistent definitions

Accurate and Precise: precise counting method

Based on operational definitions, you should know
  • What does this measure mean?
  • What are the rules for assigning values?
  • What is the data recording procedure?
Tips for Operational Definitions

Three criteria for creating operational definitions

- Communication - will others know precisely what was measured, how it was measured, and what was included or excluded?
- Repeatability - could others, armed with the definition, repeat the measurements and get essentially the same results?
- Traceability - are the origins of the data identified in terms of time, source, sequence, activity, product, status, environment, tools used, and collector.

[Deming]
Tips for Operational Definitions

Operational definitions also help pinpoint training needs for data collection.

The cost of data collection also bears on
- When the data will be collected
- Where the data will be collected
- Who will collect the data
Tips for Better Data Analysis

Why should we care about the data details?

Validity - apples to apples comparisons

Reliability - understand the impact of variation

Accuracy - knowing that there is a signal

Precision - level of certainty for responding to the signal
Tips for Analyzing Data

Critical inputs
- Knowledge of product or process being measured
- Driven by business/ technical issues or goals
- Quality of measurement data

Critical aspects of the analysis process
- Acknowledgement of and accounting for variation
- Appropriate use of analysis tools and techniques
- Resources and references (people, books)
Take the Data Deeper

To reduce variation pursue three investigative directions:

- Identify the assignable causes of instability and take steps to prevent the causes from recurring.

- If the process is stable but not capable (not meeting organizational or customer needs), then identify, design, and implement necessary changes that will make the process capable.

- Continually improve the process, so that variability is reduced and quality, cost, or cycle time are improved.
Tips for Finding and Correcting Assignable Causes

No formula or transformation algorithm is applicable. Just like debugging software – it requires good detective work.

- thorough knowledge of the process
- sufficient contextual data
- re-check assumptions, interpretations, and data accuracy
- pick up on clues provided by behavior patterns
- suspect everything
- relate chart signals to process events and activities
- check process compliance
Methods to Change the Process

Improving a stable process requires making changes to common cause entities and variables. Selecting the right change involves examination of:

- process decomposition and evaluation
- technology change
- cause and effect relationships
- products and by-products from other processes
- business strategies and management policies

These factors may well be the drivers for changing the process!
Tips for Changing the Process

Agree on process performance issues.
  • What needs improvement, why, and how much?

Select process performance variables, target means, and variability.

Determine required changes to common cause entities and variables.

Select pilot process.

Execute and measure the changed process.

Compare new process performance data to historical baseline.

Make conclusions and recommendations.
Common Data Risks and Pitfalls

Analysis misses the “big picture”

Charts are colorful, but meaningless

Data set lacks robustness

No baseline for comparing current performance

Infrequent comprehensive rechecks of the data

Comparing or predicting process results without ensuring stability of processes
## A Process Improvement Toolkit

<table>
<thead>
<tr>
<th>Define</th>
<th>Measure</th>
<th>Analyze</th>
<th>Improve</th>
<th>Control</th>
</tr>
</thead>
</table>
Section II: From Data to Decisions

This concludes our introduction to understanding data and getting the most use out of your analyses.

In Section II: Data Analysis Dynamics we will
- share our experiences
- provide useful tips for how to make measurement work
- thread together methods, tools, processes
- provide a path for action
Getting Started

- Identify the goals
- Black box process view
- Is the data right?
- Do I have the right data?

Decision point:
- If the data is not perfect, do I move forward or obtain better data?
Initial Evaluation
• What should the data look like?
• What does the data look like?
• Can I characterize the process and problem?

Decision point:
• Can I address my goals right now?
• Or is additional analysis necessary? at the same or deeper level of detail?
• Can I move forward?
Analysis Dynamics

Moving Forward
- Further evaluation
- Decompose the data
- Decompose the process

Decision point:
- Do I take action?
- What action do I take?

Repeat until
- root cause found
- at target with desired variation

typical stumbling point
Identify the Goals

Goals should be continuously generated.

Without data, goals are stated at a conceptual level.

By quantifying performance
  • problems are characterized
  • true customer specifications are understood
  • quantitative goals statements can be made

Typical problems
  • goals do not exist or have not been explicitly stated
  • goals at different levels are disconnected
Identify the Goals

Relevant tools and methods

- Voice of the Client
- Quality Function Deployment
- Management by Fact
- 4 Whats
- SMART goals
- FAST diagrams (Function Analysis Systems Technique)
Identify the Goals: Example

Why?

Customer Satisfaction

Success Indicators, Management Indicators

Deliver high quality product

How?

Track/chart field defects

Analysis Indicators, Progress Indicators

Track/chart cost & schedule deviation

Analysis Indicators, Progress Indicators

Plot, plot, plot:
- trends
- distributions
- control charts (c-charts)
- scatter plots

other factors

Plot, plot, plot:
- trends
- distributions
- control charts (x-bar, r; x, mr)
- scatter plots

other factors

SPI Task Plans
What if there are no “Business Goals”?  

Without high-level business goals, data-driven improvement efforts quickly become fragmented.

Articulate business goals by
- Brainstorming with leadership
- Organizing results into strategic, operational goals
  - add in any tactics that emerged during brainstorming
- Performing hierarchical structure check
  - “How?” answered top to bottom
  - “Why?” answered bottom to top

Verify that tactics drive impact and success.
Black Box Process View

What are the key inputs and outputs to your process? What are key in-process variables over which you have control?

Typical problems
• Omitting this step - avoids examination of your assumptions and understanding of the process
• Selecting a view that matches the issue or study level
• Constructing a view that does not match reality

Relevant tools & methods
• Process Mapping
• Mental Model
What is a Process?

- Any set of conditions or causes that work together to produce a given result
- A system of causes which includes people, materials, energy, equipment, and procedures necessary to produce a product or service
Development Process Map

**Design**
- Requirements
  - Estimate
- Concept design

**Code**
- Resources
  - Code Standards
  - LOC counter
  - Interruptions

**Compile**
- Code

**Unit Test**
- Executable Code
  - Test Plan, Technique
  - Operational Profiles

- Detailed Design
- Test cases
- Complexity
- Data: Design Review
  - Defects, Fix time, Defect Injection Phase, Phase duration

- Code
  - Data: Defects, Fix time, Defect Injection Phase, Phase duration

- Executable Code
  - Data: Defects, Fix time, Defect Injection Phase, Phase duration

- Functional Code
  - Data: Defects, Fix time, Defect Injection Phase, Phase duration

- Inspection
- Rework
- Critical Inputs: Noise
- Standard Procedure: Control Knobs
Is the Data Right?

Understand the data source and the reliability of the process that created it.

Typical problems
- wrong data
- missing data
- accuracy
- veracity
- credibility
- skewed

Data transformations
- ratios of bad data still equal bad data
- increasing the number of decimal places does not improve the data
## Is the data right? - Example

### Inspection Data Set 1

<table>
<thead>
<tr>
<th># of People</th>
<th>Preparation Effort</th>
<th>Size (SLOC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3.7</td>
<td>2070</td>
</tr>
<tr>
<td>6</td>
<td>21.0</td>
<td>555</td>
</tr>
<tr>
<td>6</td>
<td>5.1</td>
<td>102</td>
</tr>
<tr>
<td>8</td>
<td>18.0</td>
<td>260</td>
</tr>
<tr>
<td>6</td>
<td>12.0</td>
<td>101</td>
</tr>
<tr>
<td>8</td>
<td>22.1</td>
<td>165</td>
</tr>
<tr>
<td>6</td>
<td>11.8</td>
<td>1764</td>
</tr>
<tr>
<td>8</td>
<td>9.2</td>
<td>348</td>
</tr>
<tr>
<td>5</td>
<td>7.3</td>
<td>76</td>
</tr>
<tr>
<td>8</td>
<td>16.5</td>
<td>1575</td>
</tr>
<tr>
<td>5</td>
<td>12.5</td>
<td>2441</td>
</tr>
<tr>
<td>6</td>
<td>18.3</td>
<td>126</td>
</tr>
<tr>
<td>5</td>
<td>6.5</td>
<td>88</td>
</tr>
<tr>
<td>6</td>
<td>7.1</td>
<td>383</td>
</tr>
<tr>
<td>8</td>
<td>10.2</td>
<td>111</td>
</tr>
<tr>
<td>8</td>
<td>11.5</td>
<td>192</td>
</tr>
<tr>
<td>6</td>
<td>5.2</td>
<td>212</td>
</tr>
<tr>
<td>7</td>
<td>9.3</td>
<td>401</td>
</tr>
<tr>
<td>7</td>
<td>8.8</td>
<td>815</td>
</tr>
<tr>
<td>5</td>
<td>31.0</td>
<td>551</td>
</tr>
<tr>
<td>5</td>
<td>4.9</td>
<td>429</td>
</tr>
<tr>
<td>8</td>
<td>12.7</td>
<td>883</td>
</tr>
<tr>
<td>9</td>
<td>30.3</td>
<td>1017</td>
</tr>
<tr>
<td>8</td>
<td>26.4</td>
<td>2116</td>
</tr>
</tbody>
</table>

### Inspection Data Set 2

<table>
<thead>
<tr>
<th># of People</th>
<th>Preparation Effort</th>
<th>Size (SLOC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>2.0</td>
<td>350</td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
<td>210</td>
</tr>
<tr>
<td>3</td>
<td>2.0</td>
<td>333</td>
</tr>
<tr>
<td>3</td>
<td>2.0</td>
<td>430</td>
</tr>
<tr>
<td>3</td>
<td>2.0</td>
<td>400</td>
</tr>
<tr>
<td>1</td>
<td>2.5</td>
<td>400</td>
</tr>
<tr>
<td>4</td>
<td>3.0</td>
<td>440</td>
</tr>
<tr>
<td>3</td>
<td>2.5</td>
<td>450</td>
</tr>
<tr>
<td>3</td>
<td>3.5</td>
<td>440</td>
</tr>
<tr>
<td>3</td>
<td>3.0</td>
<td>255</td>
</tr>
<tr>
<td>3</td>
<td>2.8</td>
<td>470</td>
</tr>
<tr>
<td>4</td>
<td>2.8</td>
<td>500</td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
<td>253</td>
</tr>
<tr>
<td>2</td>
<td>0.7</td>
<td>78</td>
</tr>
<tr>
<td>4</td>
<td>7.0</td>
<td>900</td>
</tr>
<tr>
<td>3</td>
<td>3.5</td>
<td>400</td>
</tr>
<tr>
<td>3</td>
<td>4.8</td>
<td>1014</td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
<td>120</td>
</tr>
<tr>
<td>5</td>
<td>15.0</td>
<td>1495</td>
</tr>
<tr>
<td>4</td>
<td>4.0</td>
<td>200</td>
</tr>
<tr>
<td>4</td>
<td>4.0</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>4.5</td>
<td>200</td>
</tr>
<tr>
<td>4</td>
<td>4.0</td>
<td>200</td>
</tr>
</tbody>
</table>

Which set of data appears to be more credible? Why?

© 2003 by Carnegie Mellon University
Do I Have the Right Data?

Analyses can get off on the wrong track if the data is misunderstood, or implicit assumptions are made about it.

Analyst must ask questions:
- “Do I have measurements of all the significant and relevant factors?”
- “Does this data represent what I think it does?”

Typical examples
- total SLOC count in place of new/changed SLOC count
- date recorded is often not the same as date observed
- use of averages based on unstable processes (as in normalization)
Do I Have the Right Data? 2

Frequently the answers to these questions can not be answered by a simple “eyeball” test, then an initial evaluation must be made using various tools and methods.

Relevant tools & methods
- Process Mapping
- Goal-Driven Measurement templates
- Operational definitions
- Initial evaluation/exploration assessment using statistical tools
Initial Evaluation / Exploration

What should the data look like?
- first principles or relationships
- mental model of process (refer to that black box)
- what do we expect

What does the data look like?
- Magnitude, range, and frequency
- look at absolute and percentages
- the shape of the curve
Initial Evaluation / Exploration 2

Relevant tools & methods
- descriptive statistics
- run charts or SPC charts
- time series
- boxplots
- correlation plots – first scan of relationships
Is this the right data?
- unexpected high inspection rate
- unusually large SLOC per inspection
- How many inspectors contributed to the prep-hr effort?

<table>
<thead>
<tr>
<th>Review ID</th>
<th>Defects</th>
<th>SLOC</th>
<th>SLOC/Rev</th>
<th>Prep</th>
<th>Defect/KSLOC</th>
<th>Defects/hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>9</td>
<td>9,800</td>
<td>933.3</td>
<td>10.5</td>
<td>0.918</td>
<td>0.857</td>
</tr>
<tr>
<td>32</td>
<td>5</td>
<td>16,091</td>
<td>804.6</td>
<td>20</td>
<td>0.311</td>
<td>0.250</td>
</tr>
<tr>
<td>34</td>
<td>45</td>
<td>73,344</td>
<td>2,716.4</td>
<td>27</td>
<td>0.613</td>
<td>1.667</td>
</tr>
<tr>
<td>36</td>
<td>45</td>
<td>32,352</td>
<td>808.8</td>
<td>40</td>
<td>1.390</td>
<td>1.125</td>
</tr>
<tr>
<td>37</td>
<td>12</td>
<td>51,525</td>
<td>5,725.0</td>
<td>9</td>
<td>0.233</td>
<td>1.333</td>
</tr>
<tr>
<td>41</td>
<td>13</td>
<td>98,207</td>
<td>4,214.9</td>
<td>23.3</td>
<td>0.132</td>
<td>0.558</td>
</tr>
<tr>
<td>43</td>
<td>19</td>
<td>16,091</td>
<td>707.3</td>
<td>22.75</td>
<td>1.180</td>
<td>0.835</td>
</tr>
<tr>
<td>44</td>
<td>13</td>
<td>204,216</td>
<td>8,168.6</td>
<td>25</td>
<td>0.064</td>
<td>0.520</td>
</tr>
<tr>
<td>45</td>
<td>14</td>
<td>80,775</td>
<td>4,895.5</td>
<td>16.5</td>
<td>0.173</td>
<td>0.848</td>
</tr>
<tr>
<td>47</td>
<td>2</td>
<td>72,747</td>
<td>5,914.4</td>
<td>12.3</td>
<td>0.027</td>
<td>0.163</td>
</tr>
<tr>
<td>48</td>
<td>14</td>
<td>10,901</td>
<td>681.3</td>
<td>16</td>
<td>1.284</td>
<td>0.875</td>
</tr>
<tr>
<td>50</td>
<td>11</td>
<td>11,468</td>
<td>1,146.8</td>
<td>10</td>
<td>0.959</td>
<td>1.100</td>
</tr>
<tr>
<td>52</td>
<td>31</td>
<td>16,909</td>
<td>573.2</td>
<td>29.5</td>
<td>1.833</td>
<td>1.051</td>
</tr>
<tr>
<td>53</td>
<td>17</td>
<td>28,538</td>
<td>1,902.5</td>
<td>15</td>
<td>0.596</td>
<td>1.133</td>
</tr>
<tr>
<td>57</td>
<td>22</td>
<td>18,136</td>
<td>824.4</td>
<td>22</td>
<td>1.213</td>
<td>1.000</td>
</tr>
</tbody>
</table>
Exploration Example 2

Little to no correlation between SLOC size and inspection effort

$R = 0.04549$

$R^2 = 0.00207$
Evaluation Example

Given there is no correlation between review time and the amount of SLOC reviewed,

What questions can be raised about the
- SLOC count?
- review time?
- number of defect?
- defect density?
- defects discovered per review hour?
Can I Move Forward?

Does the initial evaluation/exploration of data support the critical assumptions?

What are your assumptions?
- are they explicitly articulated?
- for process, for data?

What are the risks you are taking if you move forward with the assumptions you have made?

Is the variability or presence of process issues so significant that they overshadow data issues?
Moving Forward

Moving forward is often a judgment call
- can proceed with further data and process analysis in parallel with improving data
  - it’s a tradeoff and a matter of balancing risks
- else get the “right” data before proceeding

Types of actions
- removing assignable causes
- reducing common cause variation
- testing hypotheses
- further decomposing data and process
Moving Forward

This is the “heart” of the analysis

- Explore, establish/confirm cause-effect relationships
- Plot trends over time
- Look for and identify the “drivers” or dominant factors
- Gauge the variation of the variables
- Find assignable causes
- Determine stability and capability of processes
- Decompose to find root cause

Relevant tools & methods

- The “Basic Tools”
Moving Forward- Basic Tools

Fundamental data plotting and diagramming tools
- Cause & Effect Diagram
- Histogram
- Scatter Plot
- Run Chart
- Box and Whisker Plots
- Pareto Chart
- Control chart

The list varies with source. Alternatives include
- Bar charts
- Flow Charts
- Descriptive Statistics (mean, median and so on)
- Check Sheets
Moving Forward—
Establish Relationships

Review Hours vs New/Changed SLOC

\[ R = 0.83569 \]
\[ R^2 = 0.69838 \]

Review Hours vs Total SLOC

\[ R = 0.19244 \]
\[ R^2 = 0.03703 \]
Moving Forward—Identify Dominant Factors

Profile of Defects Found in Product XYZ

- **Syntax Error**: 45 defects (100%)
- **Ambiguous Requirements**: 15 defects (33.3%)
- **Interface Error**: 10 defects (22.2%)
- **Missing Function**: 5 defects (11.1%)
- **Memory**: 2 defects (4.4%)

Cumulative Percentage:
- 0% - 0 defects
- 25% - 5 defects
- 50% - 15 defects
- 75% - 30 defects
- 100% - 45 defects
Moving Forward -
Determine Extent of Variability

Basic Histogram shows distribution, spread.

Look for multimodal distributions. They point to multiple processes.

Number of Days

Number of defects

Time to fix a defect found after development
Moving Forward-
Determine Extent of Variability

Add control limits to reflect process capability
Moving Forward -
Determine Extent of Variability

Add specification limits:
Process Capability vs. Capable Process

Voice of the customer

Voice of the Process

Product Service Staff-Hours

LSL = 30
Target = 40
USL = 50

LCL = 36.08
CL = 45.06
UCL = 54.04
Moving Forward-
Find Assignable Causes

Problem Repair-
Wait time
• Issue: Delays in repairing software test sets
• Control chart indicates process unpredictable
• Pattern suggests mixture of cause systems
Moving Forward-Finding Assignable Causes

Problem Repair- Wait time

Histogram indicates data includes possible mixture of cause systems
- One process for problems up to 150 wait days
- A second process involving more than 150 wait days
Moving Forward-
Find Assignable Causes

Problem repair Wait time < 150 days

Problem Closure Sequence

One process with 67-day average wait time
- Near stable
- Investigate cause system for driving factors
  - nature of defect
  - staffing
  - equipment
  - test set type

LCL = 0
CL = 67.29
UCL = 161.3
Another process with average wait time of 246 days.
Moving Forward-
Find Assignable Causes

Problem Repair-Wait time
  - Determined that there were two processes in operation
  
  - Since both were (near) stable, necessary to examine cause systems for components that may be the driving contributors to wide variation and make appropriate changes to each process

  - Activities undertaken:
    - Classification of problems (defects) reported and found
    - Classification of test sets
    - Evaluation of test equipment availability
    - Availability of necessary skills
Decomposition

Decomposition is separating the process into its component parts or data by one or more of its attributes

- Makes sources of variation visible
- Provides opportunity for process improvement

This approach is useful
- when process is stable and process change is needed to reduce variation
- for highlighting unusual data attributes that may be the source of variation
Decompose Data

- Defect data decomposed by year
- May also decompose by project type, organizational slices, and so on

- Means comparison test determines if data groupings are statistically different. These groups are not different.
- Values and sample size are accounted for in the test.
## Decompose Process Data

Twenty one components from same product, same team
- approximately same size
- approximately same complexity

Defects found in design inspection are:

<table>
<thead>
<tr>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defects</td>
<td>12</td>
<td>16</td>
<td>18</td>
<td>32</td>
<td>22</td>
<td>16</td>
<td>23</td>
<td>35</td>
<td>15</td>
<td>27</td>
<td>16</td>
<td>25</td>
<td>20</td>
<td>26</td>
<td>20</td>
<td>23</td>
<td>23</td>
<td>36</td>
<td>22</td>
<td>27</td>
<td>17</td>
<td>471</td>
</tr>
<tr>
<td>Defect Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>20</td>
<td>4</td>
<td>11</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>7</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Interface</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>16</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Timing</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Algorithm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>14</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Checking</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>12</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Assignment</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Build/Pkg.</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Document</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>14</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

© 2003 by Carnegie Mellon University
Decompose Process Data 2

Apparent stable process behavior

- But, defect rate too high and too much variation
- Explore examination of defects by type
Decompose Process Data

Establish process stability by defect type

X’s mark assignable causes by defect type

Elimination of assignable causes will reduce variation
Potential Process Improvement

Before Improvement

After Improvement

Control chart on right reflects potential improvement if all assignable causes removed.
Repeat until…..

Root cause(s) found

The process is at target, with desired variability

Other process performance data has not suffered
  • I.e. the process has not been suboptimized

Relevant tools & methods
  • Management by Fact
  • 5 Whys
  • Dashboard
# Number-Crunching Tools

<table>
<thead>
<tr>
<th>Analysis done in….</th>
<th>Comment</th>
</tr>
</thead>
</table>
| Spreadsheet (Excel)         | • Most people have a copy  
                              | • OK for some basic charts  
                              | • Nice for presentations  
                              | • Otherwise quite limited |
| Excel Addin                 | • Many new add-ins available  
                              | • Enables a wider variety of charts                                 |
| Standalone SPC Package      | • May be better suited for charts which an organization is routinely monitoring than for exploration |
| Statistical Package         | • Higher learning curve than others  
                              | • Best for those doing data-driven improvement as large part of their workload |
Section III: Case Study

This concludes our introduction to analysis dynamics.

In Section III we will showcase these dynamics through a case study.

Context:

- organization project portfolio includes both new development and maintenance
- project size and complexity varies significantly
- project schedules vary from <1 month to >18 months
Case Study Overview

This case study features the following:
- pursuit of customer satisfaction
  - via proxies of defects and effort & schedule variance
- initial data evaluation and exploration
- initial data and process decomposition
- separation of goals into “monitor” and “improvement”
- first iteration of root cause analysis for improvement goals

Along the way, we will use this stop sign
- to pause and generalize,
- to ask probing questions,
- to extend the topic
Getting Started

- Identify the goals
- Black box process view
- Is the data right?
- Do I have the right data?

Decision point:
- If the data is not perfect, do I move forward or obtain better data?

Sound bytes

“We didn’t stumble here—there were goals from the beginning—but it took time to clarify them, to make them quantitative, and to separate monitoring from improvement.”

“We had a lot of missing data. We conducted “data archaeology” as much as possible to backfill the data set. Learnings were used to improve the automation of data collection.”

“Our data wasn’t perfect, but no matter how we sliced it, there were clear improvements to pursue.”
Analysis Dynamics 2

Initial Evaluation
- What _should_ the data look like?
- What _does_ the data look like?
- Can I characterize the process and problem?

Decision point:
- Can I address my goals right now?
- Or is additional analysis necessary? at the same or deeper level of detail?
- Can I move forward

Sound bytes

- “We were able to identify many of the “data rightness” issues without exploring the data. But, in some cases, it was necessary to dive into the data to identify the issues.”

- “For earned value data, we found the process to be consistently “out of spec,” yet the external customers seemed satisfied. Reconciling the ‘voices’ of the process, external customers and internal management is part of the process.”
Moving Forward
• Further evaluation
• Decompose the data
• Decompose the process

Decision point:
• Do I take action?
• What action do I take?

Repeat until
• root cause found
• at target with desired variation

Sound bytes
“Initial iterations of decomposition will be shown. Because of risks associated with imperfect data, each conclusion needs to be carefully weighed against the need for additional verifying data.”
Business Objectives

Goals from the beginning of effort

Customer Satisfaction

Deliver high quality product

Track/chart field defects

Plot, plot, plot:
- trends
- distributions
- control charts (c-charts)
- scatter plots

Success Indicators, Management Indicators

• other factors
• survey or interview data

Project: What are leading in-process indicators of success? Where are improvements needed?

Track/chart cost & schedule deviation

Analysis Indicators, Progress Indicators

Analysis Indicators, Progress Indicators

SPI Task Plans

other factors

Plot, plot, plot:
- trends
- distributions
- control charts (x-bar, r; x, mr)
- scatter plots
Customer Data

• What data are readily available data?
  - post-project surveys
• Data archeology
  - What has been communicated via emails, phone calls
• Is the data “perfect”? NO
  - few responses
  - qualitative responses
• New data collection needed:
  - updated, routine customer survey

By the way, is data ever perfect? Can you afford to wait for perfect data?
Customer Data - Sample

Qualitative comments, all positive:
  • Pleasure to work with!
  • Outstanding in all aspects!!
  • If this team had been on this project from the start a lot of things may have gone smoother.
  • Really good to work with. Have been working with them 2-3 years now. They do a good job and we get along well.

Quantitative comments
  • Finished testing without having to create any additional builds.
  • We were able to save three flights.
Defect Data

• What data are readily available data?
  - peer review inspection data
• Data archeology
  - field defects and confirmation of in-process defects
• Is the data “perfect”? NO
  - missing data
  - defect data skewed toward low priority defects
  - variations in operational definitions
  - feedback loops at group level, not org level
• New data collection needed:
  - confirmed operational definitions
  - improved automation of data collection process
# Field Defect Data Baseline

Organizational goal: 0 field defects

## Field defects

<table>
<thead>
<tr>
<th>Field Defects</th>
<th>FY 01</th>
<th>FY 02</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

## In-process defect detection

- # of defects vs. development life cycle

When your “count for the year” is 4, how useful are control charts?

And, if your counts are higher?

Leading in-process indicators are what you should consider for control charting.
Earned Value Data

Readily available data
- monthly process effort, cost, schedule
- compared to specification
  - with text entry for out of spec causes

Data “archaeology”:
- completed project data
  - final vs. original with differences categorized

Is the data “perfect”? NO
- losing track of replanning impact on performance
- monthly data uses non-homogeneous sample
- sparse data – some parts of organization better represented
- not sure if “extreme” outliers can be excluded
## Completed Project Data Baseline

<table>
<thead>
<tr>
<th></th>
<th>% effort variance</th>
<th>% sched variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>average</td>
<td>-66.1%</td>
<td>-15.0%</td>
</tr>
<tr>
<td>standard deviation</td>
<td>415.9%</td>
<td>38.3%</td>
</tr>
<tr>
<td>median</td>
<td>0.9%</td>
<td>-8.1%</td>
</tr>
<tr>
<td>min to max</td>
<td>-2689.9% to 50.1%</td>
<td>-99.8% to 128.0%</td>
</tr>
<tr>
<td>n</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>capability notes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(spec = +/- 20%)</td>
<td>45.2%</td>
<td>40.4%</td>
</tr>
</tbody>
</table>

This represents (initial plan – final actual)
- negative numbers are overruns
- schedule is in terms of calendar days

It is the **total cumulative variance**
- customer-requested/approved changes are included
- one way or another, this is what the customer sees
### Completed Project Data - Decomposed

**Contribution to total variance, by internal/external categories**

<table>
<thead>
<tr>
<th>internal/external categories</th>
<th>median contribution toward total effort (cost) variance</th>
<th># of projects reporting</th>
<th>median contribution toward total schedule variance</th>
<th># of projects reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>internal project</td>
<td>-30.83%</td>
<td>7</td>
<td>-34.32%</td>
<td>4</td>
</tr>
<tr>
<td>internal organization, outside project</td>
<td>-1.25%</td>
<td>5</td>
<td>-73.77%</td>
<td>3</td>
</tr>
<tr>
<td>external, reqt</td>
<td>-22.48%</td>
<td>10</td>
<td>-20.20%</td>
<td>10</td>
</tr>
<tr>
<td>external, sched</td>
<td>0.00%</td>
<td>15</td>
<td>-98.36%</td>
<td>17</td>
</tr>
</tbody>
</table>

“Internal” and “external” taxonomy selected based on “sphere of influence and control”

Risk: while “internal causes” seem to be a significant opportunity, a small number of projects reported such causes.
Explore, Evaluate (Plot, Plot, Plot)

<table>
<thead>
<tr>
<th>% effort variance</th>
<th>% sched variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>avg</td>
<td>-2%</td>
</tr>
<tr>
<td>std dev</td>
<td>-33%</td>
</tr>
<tr>
<td>median</td>
<td>2%</td>
</tr>
<tr>
<td>min to max</td>
<td>-95% to 50%</td>
</tr>
<tr>
<td>capability notes</td>
<td>43.8%</td>
</tr>
<tr>
<td>(spec = +/- 20%)</td>
<td>outside spec</td>
</tr>
</tbody>
</table>

When flyers are removed
- Averages closer to target, spread narrowed
- Medians minimally affected
- Still nearly as many outside specs
- Small “second peak” more visible

What are guidelines for removing flyers?
- Average vs. median

STOP
Explore, Evaluate (Plot, Plot, Plot)²

Schedule Variance Distribution to Time Series

Time series plot shows
• where in time the contributions to overall high variability occur
• possible change in variability over time
• where in time the points of the possible “second population” occur

Why not a control chart?
Explore, Evaluate (Plot, Plot, Plot) 3

Schedule Variance Time Series to Control Chart

Control charts also show
• possible second “population”
• wide variability

But,
• process may just not be stat. control
  (if 2 populations, assumption violated)
• wide limits have limited practical value
  (use for off-line analysis only at this stage)
• control charts geared for monitoring sustainment not improvement
In-Process Cost/Schedule Data Baseline

Organizational goal (specification): ±20%

In process effort/cost data
- all life cycle phases, all projects, Oct – June (770+ pts)

<table>
<thead>
<tr>
<th></th>
<th>all data</th>
<th>extreme values excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean +/- 3 standard deviations</td>
<td>-32 +/- 3*423 or -1301 to 1237</td>
<td>-2 +/- 3*25 or -77 to 73</td>
</tr>
<tr>
<td>schedule capability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>spec = +/- 20%</td>
<td>18% of values outside spec</td>
<td>17% of values outside spec</td>
</tr>
</tbody>
</table>

In process schedule data
- all life cycle phases, all projects, Oct – June (770+ pts)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>mean +/- 3 standard deviations</td>
<td>-7.2654498 +/- 19.23 or -64.96 to 50.43</td>
<td></td>
</tr>
<tr>
<td>capability notes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>spec = +/- 20%</td>
<td>17% of values outside spec</td>
<td></td>
</tr>
</tbody>
</table>
In-Process Schedule Variance Boxplot

Data reported monthly for all projects, cycle phases

Conclusion: need to address variability

Why a boxplot and not an SPC chart?
Are There Group Differences?

Schedule Variance, all projects, Oct 01 to Jun 02

Boxes influenced by quantity of data, and numbers themselves

Are there statistically significant group to group differences: NO
Are There Project Differences?

Schedule Variance, all projects Oct 01 to Jun 02

Each box represents the timeline of an individual project.

Are there statistically significant project to project differences: YES, in some cases (Tukey-Kramer test not shown).

Conclusion: Non-homogeneous sample (data from all points along “project timeline”) was a major contributor to the “significant differences” and to the overall variability.
Improving Sampling & Analysis

Overall rollup:
- group the data by project milestones

Within project:
- identify different control limits for each development phase
- compare each project’s phase against the history of similar projects in that same phase
- robust sample for limit calculations is critical

![Project Cost Index](chart)

- wider limits for projects in planning phase
- narrower limits for projects in execution phase
Our Improvement Focus

Two performance improvement priorities, for two different portions of the organization
  • effort variation reduction
  • schedule variation reduction

Additionally, a specific improvement effort to efficiently gather more complete, more consistent data
  • needed to more fully understand the magnitude of variability
  • needed to set exact (SMART) improvement goals (Specific, Measurable, Agreed upon, Realistic, Timely)
Can We Address the Goals?

This is a decision point in the analysis dynamics.

Do we have enough understanding of our data and process? **NO**

Key questions at this stage
- What are the root sources of the variability?
- How does the in-process variability provide an early view of the end-of-project result?
Data and Process Decomposition

Brainstormed root causes of variance

Decomposed process into 4 main subprocesses
  • mapped cause codes to process
  • identified cause codes that are resolved in-process

Data archaeology
  • evaluated cause codes using historical data

risks of data archaeology vs. starting anew
Cause Codes

Transformed original brainstorm list
- initial experiential assessment of frequency, impact of each cause code
- refined “operational definitions” and regrouped brainstorm list
- tagged causes to historical data
- refined again

Final list included such things as
- Missed requirements
- Underestimated task
- Over commitment of personnel
- Skills mismatch
- Tools unavailable
- EV Method problem
- Planned work not performed
- External
- Other

Direct Cause vs. Root Cause

Causes resolved in-process vs. causes that affect final performance
Four High-Level Processes that Influence Final Performance

<table>
<thead>
<tr>
<th>Project Management</th>
<th>Organizational Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Workload Proposal</td>
<td>- Workload Agreements</td>
</tr>
<tr>
<td>- Planning</td>
<td>- Resource Allocation</td>
</tr>
<tr>
<td>- Requirements Management</td>
<td>- Funding</td>
</tr>
<tr>
<td>- Configuration Management</td>
<td>- Training</td>
</tr>
<tr>
<td>- Decision Analysis and Resolution</td>
<td></td>
</tr>
<tr>
<td>- Training</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project Monitoring and Control</th>
<th>Technical Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Measurement</td>
<td>- Design</td>
</tr>
<tr>
<td>- Quality Assurance</td>
<td>- Implement</td>
</tr>
<tr>
<td>- Peer Review</td>
<td>- Formal Test</td>
</tr>
<tr>
<td></td>
<td>- Release</td>
</tr>
</tbody>
</table>

Cause Codes were mapped to these processes
Prioritizing the Causes

- External
- Underestimated Tasks
- EV Method
- Tools
- Sphere of Influence

 Algorithms and Assumptions
  - frequency & impact of occurrences – and which occurrences?

 Cause Codes
  - Which are resolved in process?

 Sphere of Influence
  - internal vs. external
  - degree of “process understanding”
  - degree of “process control”

- Pie Chart vs. Pareto?
- Does everyone understand where the data came from?
- Are the algorithms and assumptions valid?
- What are the risks?
Data Treatments

<table>
<thead>
<tr>
<th>Project</th>
<th>Month</th>
<th>Cause Code</th>
<th>Variance</th>
<th>Repeat?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td>A</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cause Code data may be summarized by frequency (f), impact (i), or f x i.

Usage of the latter resembles methods used to evaluate, mitigate risk.

Risk Mitigation Analogy

<table>
<thead>
<tr>
<th>Risk Mitigation Analogy</th>
<th>frequency</th>
<th>impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>L</td>
<td></td>
</tr>
</tbody>
</table>

Might also use median
## Co-Optimizing Across the Organization – Internal Causes

<table>
<thead>
<tr>
<th>Impact # (from Pareto)</th>
<th>Schedule</th>
<th>Effort</th>
<th>Organization Slice 1</th>
<th>Organization Slice 1 Effort</th>
<th>Organization Slice 2</th>
<th>Organization Slice 2 Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Under estimated Task</td>
<td>Tools</td>
<td>Under estimated Task</td>
<td>Under estimated Task</td>
<td>Tools</td>
<td>Tools</td>
</tr>
<tr>
<td>2</td>
<td>Tools</td>
<td>Assets not available</td>
<td>EV Problems</td>
<td>Under planned rework</td>
<td>Skills mismatch</td>
<td>Under estimated Task</td>
</tr>
<tr>
<td>3</td>
<td>EV Problems</td>
<td>Under planned rework</td>
<td>Missed requirements</td>
<td>Missed requirements</td>
<td>Under estimated Task</td>
<td>Missed requirements</td>
</tr>
<tr>
<td>4</td>
<td>Missed requirements</td>
<td>Planned work not performed</td>
<td>Under planned rework</td>
<td>EV Problems</td>
<td>Missed Requirements</td>
<td>Unexpected departure of personnel</td>
</tr>
<tr>
<td>5</td>
<td>Skills Mismatch</td>
<td>Under estimated task</td>
<td>Asset availability</td>
<td>Planned work not performed</td>
<td>Unexpected departure</td>
<td>EV Problems</td>
</tr>
</tbody>
</table>
In-process data as leading indicator

<table>
<thead>
<tr>
<th>internal/external categories</th>
<th>median contribution toward total effort (cost) variance</th>
<th># of projects reporting</th>
<th>median contribution toward total schedule variance</th>
<th># of projects reporting</th>
<th>In-process data</th>
</tr>
</thead>
<tbody>
<tr>
<td>internal project</td>
<td>-30.83%</td>
<td>7</td>
<td>-34.32%</td>
<td>4</td>
<td>freq impact f x i</td>
</tr>
<tr>
<td>internal organization, outside project</td>
<td>-1.25%</td>
<td>5</td>
<td>-73.77%</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>external, reqt</td>
<td>-22.48%</td>
<td>10</td>
<td>-20.20%</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>external, sched</td>
<td>0.00%</td>
<td>15</td>
<td>-98.36%</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

Join the views of completed project performance and in-process performance.

Since “cause categories” differ between the data sets, the first iteration is not trivial.
SMART Schedule Variance Goal

Reduce the total variance by decreasing the variance of the top 3 internal causes by 50% in 1 year

Reduce the impact of external causes by 50%

Indicators:
- Trend for each cause independently
- Trend for total variance

Will focus on these causes give us bottom line results?
Schedule Variance Root Cause

Cause Code: Underestimated tasks

Process: Project Management

Subprocesses: Planning
- Establish requirements
- Define project process
- Perform detailed planning

Requirements Management

As subprocesses are explored, process mapping techniques may be used with (or based on) ETVX diagrams
Schedule Variance Root Cause 2

Root Causes of Common Cause Variation
- Inexperience in Estimation process
- Flawed resource allocation.
- Inexperience in product (system) for estimator
- Requirements not understood

Root causes of Special Cause Variation
- Too much multitasking
- Budget issues

A list of possible countermeasures was developed

Pros/Cons of doing this retrospectively vs. real time

What is needed before executing the countermeasures?
Could the “special causes” also be “common causes”?
Putting it all Together

Dashboard to monitor “the whole picture”
- customer satisfaction
- defects
- effort and schedule variance

Management by Fact* to monitor improvement efforts
- effort variance reduction
- schedule variance reduction
- measurement quality improvement

Reference process documentation and project management principles in use.

*Tooltip for Management by Fact (MBF) in the Addendum
Notional Management by Fact (MBF)

Reduce the total schedule variance by decreasing the variance of the top 3 internal causes by 50% in 1 year.

<table>
<thead>
<tr>
<th>Total variance w/ mean comparison</th>
<th>Variance for top 3 causes:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Underestimated Tasks</td>
</tr>
<tr>
<td></td>
<td>• EV Method Problem</td>
</tr>
<tr>
<td></td>
<td>• Missed Requirements</td>
</tr>
</tbody>
</table>

Prioritization & Root Cause
- Inexperience
- Resource Allocation
- Requirements not understood
- 

Counter Measures
First: Gather realtime data and verify “data archaeology”
Then:
  - 
  - 

Impact, Capability
In total, these countermeasures will remove 15% of typical variance.
(as possible, list impact of each countermeasure)

Still needed: Relate in process and completed project data
Notional Dashboard

**Earned Value Data**
In-process data:
- monthly schedule index, cost index by project milestones

**Completed projects data:**
- control chart
- % outside spec
- contribution of internal causes to completed project variance

**Defect Data:** Tally of Field Defects
Note: In-process profiles to be shown on “group level” dashboards

Other possible inclusions:
- Engineering process procedural adherence (as a leading indicator for EV, defect and measurement quality performance)

**Customer Satisfaction**

**Return on Investment**

“return” = variance reduction translated into $$

**Measurement Quality**
Completeness
Accuracy
Procedural Adherence

© 2003 by Carnegie Mellon University
Version 1.0
Organization Specific Process

1. Select Business Goal (Customer Satisfaction)
   - Business Objective
     - Specs
     - Performance Thresholds
   - Identified Thresholds

2. Gather Data
   - Establish capability, models, etc.

3. Analyze Data
   - • Project Performance
   - • Measures Quality
   - • SPI Implementation

4. Prioritize Issues
   - Start subprocess selection
   - • Snapshot (1st Iteration Baseline)
   - • Issues (Validity of data, Quality of Data, Variance (performance))
   - Draft Improvement Goal (SMART) or Identify focus area

5. Identify Possible Causes (Brainstorm)
6. Identify Potential Solutions
7. Develop Action Plan
8. Implement Improvement

Improvements
1st Iteration Final Goal

Goal Refinement

1st Iteration Final Goal

No “Issues”
Case Study Summary

- Goal: Customer satisfaction via effort, schedule, field defects
- Black Box Process: not explicitly dealt with until root cause
- Right Data:
  - in-process data available
  - needed to “data mine” for completed data
  - some “new data needs” identified
- Data is Right
  - multiple iterations to correct some data (is this in slides?)
- Explore/Evaluate
  - key to determining need for “data archaeology”
  - put field defects into “monitor” mode
  - focus on improving effort, schedule variability (or change specs)
  - focus on improving measurement quality
  - focus on improving sampling schemes

goals get SMARTer, more quantitative

iterative, the “dynamics” overlap

SMARTer, more quantitative

Case Study Summary 2

- Explore/Evaluate continued
  - extent of variability characterized
  - some decomposition conducted to distinguish overall variability vs. multiple populations
- Data & Process Decomposition
  - Sub processes of interest selected based on pareto analysis of “cause codes
- Root Cause Analysis:
  - many direct causes identified
  - separating common and special causes of variability
  - we’re getting there….

decomposition starts in “initial exploration”
© 2003 by Carnegie Mellon University

Case Study Summary - Tools Used

Define
- Benchmark Baseline
- Contract/Charter
- Kano Model
- Voice of the Customer
- Voice of the Business
- Quality Function Deployment
- Process Flow Map
- Project Management
- “Management by Fact”

Measure
- Defect Metrics
- Data Collection Methods
- Sampling Techniques
- Measurement Sys. Evaluation
- Quality of Data

Analyze
- 7 Basic Tools
- Cause & Effect Diagrams, Matrix
- Failure Modes & Effects Analysis
- Statistical Inference
- Reliability Analysis
- Root Cause Analysis
- 4 Whats
- 5 Whys
- Hypothesis Test
- ANOVA

Improve
- Design of Experiments
- Modeling
- Tolerancing
- Robust Design
- Systems Thinking
- Decision & Risk Analysis

Control
- Statistical Controls:
  - Control Charts
  - Time Series methods
- Non-Statistical Controls:
  - Procedural adherence
  - Performance Mgmt
  - Preventive activities

- control charts for limited analysis NOT as control mech.

adapted technique for impact evaluation

bold = tool used
Summary – Key Points

Show me the data! Follow the data!

Couple data analysis with your knowledge of the process.

If your number-crunching is not adding value, then STOP!
  • Have a goal: a monitoring goal, an improvement goal

This isn’t that hard.
  • Slow down, think about your process and proceed methodically

But it isn’t that easy either. (If it were, we’d all be out of a job).
  • Don’t be afraid to explore your data, to pursue your ideas. Use your goals and your data as your guides.

You can get yourself into a chicken-and-egg argument with data.
  • Sometimes, you need to just dive in with what you have.
Contact Information

Bill Florac  
Software Engineering Institute  
Software Engineering Measurement and Analysis  
Email: waf@sei.cmu.edu  
434-978-7780

Jeannine Siviy  
Software Engineering Institute  
Measurement & Analysis Initiative  
Email: jmsiviy@sei.cmu.edu  
412-268-7994

Contact us for a copy of the slides.  
Or, leave a business card with Jeannine or Bill.  
Also, they will be posted on the SEMA web pages  
http://www.sei.cmu.edu/sema
References

Note: URL's subject to change without notice


Additional Reading

References on statistics and analytical tools (URL’s subject to change without notice)

General Statistics and Tools
The Memory Jogger, Goal/QPC, http://www.goalqpc.com

Statistical Process Control
AT&T / Western Electric Co., *Statistical Quality Control Handbook*, Delmar Printing Company

Bayesian Modeling:
Addenda

Additional vignettes

Tool tips
Example of an Aid for Operational Definitions using Orthogonal Classification

<table>
<thead>
<tr>
<th>Problem Status</th>
<th>Include</th>
<th>Exclude</th>
<th>Value Count</th>
<th>Array Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>Recognized</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>Evaluated</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>Resolved</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>Closed</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td>✔️</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Problem Type</th>
<th>Include</th>
<th>Exclude</th>
<th>Value Count</th>
<th>Array Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software defect</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirements defect</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design defect</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Code defect</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational document defect</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test case defect</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other work product defect</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other problems</th>
<th>Include</th>
<th>Exclude</th>
<th>Value Count</th>
<th>Array Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware problem</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating system problem</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User mistake</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operations mistake</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New requirement/enhancement</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Undetermined</th>
<th>Include</th>
<th>Exclude</th>
<th>Value Count</th>
<th>Array Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not repeatable/Cause unknown</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value not identified</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Uniqueness</th>
<th>Include</th>
<th>Exclude</th>
<th>Value Count</th>
<th>Array Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duplicate</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value not identified</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criticality</th>
<th>Include</th>
<th>Exclude</th>
<th>Value Count</th>
<th>Array Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st level (most critical)</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd level</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd level</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th level</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5th level</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value not identified</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Urgency</th>
<th>Include</th>
<th>Exclude</th>
<th>Value Count</th>
<th>Array Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st (most urgent)</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value not identified</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Compliance Issues

May be basis for assignable causes

<table>
<thead>
<tr>
<th>Compliance Issues</th>
<th>Things to Examine When Seeking Reasons for Noncompliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adherence to the process</td>
<td>awareness and understanding of the process</td>
</tr>
<tr>
<td></td>
<td>existence of explicit standards</td>
</tr>
<tr>
<td></td>
<td>adequate and effective training</td>
</tr>
<tr>
<td></td>
<td>appropriate and adequate tools</td>
</tr>
<tr>
<td></td>
<td>conflicting or excessively aggressive goals or schedules</td>
</tr>
<tr>
<td>Fitness and use of people, tools, technology</td>
<td>availability of qualified people, tools, and technology</td>
</tr>
<tr>
<td>and procedures</td>
<td>experience</td>
</tr>
<tr>
<td></td>
<td>education</td>
</tr>
<tr>
<td></td>
<td>training</td>
</tr>
<tr>
<td></td>
<td>assimilation</td>
</tr>
<tr>
<td>Fitness and use of support systems</td>
<td>availability</td>
</tr>
<tr>
<td></td>
<td>capacity</td>
</tr>
<tr>
<td></td>
<td>responsiveness</td>
</tr>
<tr>
<td></td>
<td>reliability</td>
</tr>
<tr>
<td>Organizational factors</td>
<td>lack of management support</td>
</tr>
<tr>
<td></td>
<td>personnel turnover</td>
</tr>
<tr>
<td></td>
<td>organizational changes</td>
</tr>
<tr>
<td></td>
<td>relocation</td>
</tr>
<tr>
<td></td>
<td>downsizing</td>
</tr>
<tr>
<td></td>
<td>disruptive personnel</td>
</tr>
<tr>
<td></td>
<td>morale problems</td>
</tr>
</tbody>
</table>
Assignable causes due to:

- Erroneous and Missing Data
- Multiple Cause Systems (six components each with own development team)
Inspection Package Review Rate for Component A

Re-analyzed data

- Data errors eliminated
- Consider single major cause system at a time
- Control chart for one component
- Several assignable causes apparent
Investigation resulted in removal of separate cause systems included in inspection packages:

- data tables
- lists
- arrays
- different review process
Component A Revision

Process Instability: Apparent shift of process performance after #15

Leads to investigation of changes in process cause systems
Cause-and-Effect Relationships

Inspection review rate with increase in SLOC

Y = 14.68315 + 0.22702 x

CORRELATION:
- LINEAR: 0.77
- EXPONENTIAL (2): 0.86
- EXPONENTIAL (3): 0.86
Component A Review Rate

Distribution of review rates by SLOC size

Amount of SLOC in review package is key driver of review time spent
Component A Review Rate

Replot data using two charts:
- Rates for Inspection <60 SLOC
- Rates for Inspection >60 SLOC

Indicates two processes in operation depending on size of Inspection package

Establish Trial Limits for each subprocess
Component A Review Rate

Additional observations identify more assignable causes.
Investigation determines that assignable cause observations from re-inspection process.
Component A Review Rate

Component A: Package Size < 60 SLOC

Component A: Package Size > 60 SLOC

All re-inspection data identified and removed from control chart since they represent a different process (different cause system)
Component A Review Rate

Component A: Package Size < 60 SLOC

Component A: Package Size > 60 SLOC

Charts plotted with remaining data (single cause system)

Additional data points reinforce trial limits hypothesis
Component A Review Rate

Analysis summary:
• Inspection process consists of several (3) undocumented subprocesses
• Review rate appears to be stable within two categories (< and > 60 SLOC)
• Inspection packages of 60 SLOC or more reviewed about 6X faster than those with <60 SLOC

Key questions requiring more study:
• Why difference in review rates?
• Is there a difference in effectiveness (rate of escaped defects)?
• Do other components behave similarly?
• How do rates compare from release to release?
Tool Tips Part 1: The Basic Tools

Overview (description, procedure, tips, examples) for
- run charts
- spc charts
- boxplots
  - including pareto boxes
- scatter plots
- histograms, distributions and capability
  - twist: rayleigh, weibull distributions
- bar charts
- pareto charts
- cause&effect diagram
  - including cause & effect matrix
Tooltip: 7 Basic Tools

Description

- Fundamental data plotting and diagramming tools
  - Cause & Effect Diagram
  - Histogram
  - Scatter Plot
  - Run Chart
  - Flow Chart
  - Brainstorming
  - Pareto Chart

- The list varies with source. Alternatives include
  - Statistical Process Control Charts
  - Descriptive Statistics (mean, median and so on)
  - Check Sheets
7 Basic Tools: Usage

Plot trends over time

Examine relationships among measures

Explore cause-effect relationships

Prioritize issues

Determine stability and capability of processes
7 Basic Tools: Chart Examples

Pareto Chart

Run Chart

Mean Time To Repair

Defects Removed By Type

Product

Time (minutes)

Removed in test
Injected in Design

© 2003 by Carnegie Mellon University
Version 1.0
7 Basic Tools: Chart Examples

Scatter Plot

Histogram
7 Basic Tools: Cause & Effect

[Westfall]
7 Basic Tools: Chart Variations

Box & Whisker Plot for assessment data
7 Basic Tools: Chart Variations

Boxplot variations:
- cost and schedule variance over time to show organizational average and also variability
- prioritized features for a new process technology rollout: a combination “pareto-boxplot”
Tool Tip: Run Charts

Description
  • Time series plot that can be used to examine data quickly and informally for trends or other patterns that occur over time.

Tips
  • Run charts are not control charts - don’t over-interpret them.
  • If observations are not all similarly spaced in time, there may be more than one process influencing what appears to be a single run.
Run Charts: Example

Assumptions
- ordered by time
- single underlying process
- consistent operational definitions
Tool Tip: Statistical Process Control (SPC) Charts

Description
• run chart with statistical limits

Usage
• let you know what your processes can do, so that you can set achievable goals.
• provide the evidence of stability that justifies predicting process performance.
• separate signal from noise, so that you can recognize a process change when it occurs.
• distinguishes common cause variation from special cause variation
• point you to fixable problems and to potential process improvements
Control Chart Basics

Control Limits → Determined by Process Performance Measurements (Voice of the process)

Specification Limits → Set by customer, engineer, etc. (Voice of the customer)

Specification Limits

Upper Control Limit (UCL)

Mean or Center Line (CL)

Lower Control Limit (LCL)

Event Time or Sequence

CL + 3σ

CL - 3σ

Limits
SPC: Tips

Reacting to Common Cause Variation as if it were Special Cause Variation cannot improve the process and will result in increased variability.

Check your data distributions!
- Defect counts are never negative and may not be normally distributed.

Set specification limits based on statistics, engineering knowledge and risk of escaping defects.

Implement charts “in the field” only when you have corrective action guidelines. Otherwise, work the charts offline.

Always look at the average (or individual) and range charts!
SPC: Example

Number of Unresolved Problem Reports

- LCL = 8.49
- CL = 20.04
- UCL = 31.6

Moving Range

- LCL = 4.35
- CL = 14.2
- UCL = 14.2

Week of System Test
SPC: Rules for Detecting Process Instabilities

TEST 1:
Single point outside of zone C

TEST 2:
2 out of three beyond zone B

TEST 3:
4 out of 5 signals in zone B

TEST 4:
8 successive points on same side of centerline

Individuals

Subgroup No.

Zone A
Zone B
Zone C

LCL
CL
UCL

© 2003 by Carnegie Mellon University
Version 1.0
SPC: Anomalous Patterns

Rapid Shift in Level

Unstable Mixture

Stratification

Trends

Cycles Pattern

Bunching or Grouping
Tooltip: Scatter Plots

Description
- Display empirically observed relationships between two measures.

Usage
- A pattern in the plotted points may suggest that the two measures are associated.
- When the conditions warrant, scatter diagrams are natural precursors to regression analyses.
- Scatter diagrams are rarely used as the only means of characterizing the relationship between two measures.
- Does not predict cause and effect relationships
Scatter Plot: Example with Line

Inspection Effort versus Inspected Sloc

Y = 2.08112 + 0.00435 x

R = 0.45031
R-Squared = 0.20278

R = Correlation Coefficient

R-Squared = Fraction of variability explained by the model
Tooltip: Histograms

Description:
- Display the empirically observed distribution for values of a measure.
- Show the frequency of each value and the range of values observed.

Usage:
- Inappropriate unless the measure can be treated as a continuous scale.
Histograms - Examples

- Look for multimodal distributions
- May point to multiple processes

- Time to fix a defect found after development

- Number of defects

- Product-Service Staff Hours

- Number of Days

- Number of defects

- Product-Service Staff Hours

- Number of Days
Tooltip: Bar Charts

Description

Usage
- Similar in many ways to histograms
- Do not require that the measure be treated as a continuous variable.
- Bar charts are much more frequently used than histograms.
Bar Charts: A Word of Caution

Because they are so flexible, it is easy to get carried away with bar charts.

Defect Counts by Project and Type

- Syntax Error
- Ambiguous Requirements
- Interface Error
- Missing Function
- Memory
Tooltip: Pareto Charts

Description:
- Special form of a bar chart that ranks categories of data in terms of their amounts, frequency of occurrence, or economic consequences.

Usage:
- Ranking of problems, causes, or actions, etc., must be orthogonal
- Interpretation based on the “80/20 rule”

If the 80/20 rule does not apply
- Consider counting a different attribute, while maintaining the same stratification.
- Consider re-stratifying - use a different classification scheme.
- Consider a different attribute of the process under study.
Pareto Charts: Example

Profile of Defects Found in Product XYZ

Number of Defects

Syntax Error  Ambiguous Requirements  Interface Error  Missing Function  Memory

Cumulative Percentage

0%  25%  50%  75%  100%

Number of Defects

Syntax Error  Ambiguous Requirements  Interface Error  Missing Function  Memory

Cumulative Percentage

0%  25%  50%  75%  100%
Tooltip: Cause & Effect Diagrams

Description
*Also called “Fishbone” or “Ishikawa” diagrams*

Usage
- Allow you to probe for, map, and prioritize a set of factors that are thought to affect a particular process, problem, or outcome.
- Help elicit and organize information from people who work within a process and know what might be causing it to perform the way it does.
Cause & Effect Diagram: Tips

You can spend a lot of time discussing what the principal causes should be (the main branches) if you are not careful.

- May need to work on the categorization of causes in advance
- May want to just use generic cause categories like; Materials, Equipment, Operators, Procedures and Environment.
It takes too long to process our software change requests

**Collection**
- Problem reports not logged in properly
- Information missing from problem reports
- Cannot replicate problem

**Evaluation**
- Change control board meets only once a week
- Changes decisions not released in a timely manner
- Cannot isolate software artifact(s) containing the problem
- Cannot determine what needs to be done to fix the problem

**Resolution**
- Takes time to make changes
- Must reconfigure baselines
- Delays in approving changes

**Closure**
- Delays in shipping changes and releases
- Delays enroute
Basic Tools: Cause & Effect

[Westfall]
Tool Tip: Cause & Effect Matrix

Description
- method to determine possible causes of variation in the process and to feed future experimental designs

Purpose
- to organize problem-solving efforts when there are multiple responses involved
- to prioritize the number of factors to study
- to build team consensus about what is to be studied
Cause & Effect Matrix: Usage

When to use:
- team is overwhelmed with the number of variables affecting process
- not possible to experiment with all of the variables – need to narrow down the list
- team is struggling with which factors may have the biggest impact
- it is not clear how each factor impacts customer requirements

Feeds other tools:
- Failure Mode and Effects Analysis
- Data collection plans
- Experimentation
- Control plans

[Hexsab 02]
Cause & Effect Matrix: Terms

**Process:** The combination of people, equipment, materials, methods and environment that produce output (product or service). It is a repeatable sequence of activities with measurable inputs and outputs.

**Parameter:** A measurable characteristic of a product or process.

**Process Parameter:** A measurable characteristic of a process that may impact product performance but may not be measured on the product. (The “x.”)

**End-Product Parameter:** A parameter that characterizes the product at the finished product stage. (The “Big Y.”)

**In-Process Product Parameter:** A parameter that characterizes the product prior to the finished product stage. It is measured on the product upstream and is the result of a process step. (The “little y.”)

**Input Variable:** An output from other processes. (Neither x’s or y’s.)
Cause & Effect Matrix: Procedure

Identify the y’s from process map.

Rate the y’s on a scale from 1-10.
  • Involve the “customers” to determine the ratings.
  • Ratings are relative.

List the process steps and all of the x’s from the process map.

Rate the relationship of each x to each y on a 0, 1, 3, 9 scale.
  0 = No relationship between x and y
  1 = Remote relationship between x and y
  3 = Moderate relationship between x and y
  9 = Strong relationship between x and y

For each x
  • Multiply each relationship rating by the corresponding y rating
  • Sum the products

Use the summations to rank and select x’s for future experiments or focused efforts

[Hexsab 02]
Cause & Effect Matrix: Format

<table>
<thead>
<tr>
<th>Process steps</th>
<th>X's</th>
<th>X relationship to Y</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Y's:

Y ratings:

[Hexsab 02]
Tool Tips Part 2: Beyond Basics

Overview (description, procedure, tips, examples) for
- capability
- voice of the customer
- management by fact
- process mapping
Tooltip: Process Capability

Description
• When a process is in statistical control with respect to a given set of attributes, we have a valid basis for predicting, within limits, how the process will perform in the future.

Usage
• Addresses predictable performance of a process under statistical control.
• For a process to be capable, it must meet two criteria:
  - The process must be brought into a state of statistical control for a period of time sufficient to detect any unusual behavior.
  - The capability of the process must meet or exceed the specifications that have to be satisfied to meet business or customer requirements.
Histogram Reflecting Process Capability

Voice of the Process

LCL = 36.08
CL = 45.06
UCL = 54.04

Product Service Staff-Hours

Frequency Count

© 2003 by Carnegie Mellon University

Version 1.0
Process Capability vs. Capable Process

- Voice of the Process
- Voice of the customer

Frequency Count

<table>
<thead>
<tr>
<th>Product Service Staff-Hours</th>
<th>LCL = 36.08</th>
<th>CL = 45.06</th>
<th>UCL = 54.04</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSL = 30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target = 40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USL = 50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

© 2003 by Carnegie Mellon University
Tool Tip: Voice of the Client (VOC)

Description

- a method to describe the stated and unstated needs or requirements of the customer
- can captured in a variety of ways: direct discussion or interviews, surveys, focus groups, customer specifications, observation, warranty data, field reports, complaint logs, etc.
VOC: Usage

Feeds Quality Function Deployment (QFD)

Risks
- anecdotal, not quantitative
- difficult to get “the right answer”
- humans are PERFECT FILTERS!
- it is very easy to induce bias in VOC

Tips
- use existing information with care – it may be biased or too narrowly focused
- always use more than one source
- customer visits allow direct discussion and observation
- customer visits allow immediate follow-up questions and unexpected lines of inquiry
VOC Interviews: Procedure 1

- Define the customer
- Select customers to interview
  - Always interview more than one
- Plan interview
  - Develop a checklist/guideline
  - Teams of 3: “Moderator,” “Scribe,” “Observer”
- Conduct interviews
  - Customer statements & observations need to be recorded VERBATIM
  - Keep asking “why”
VOC Interviews: Procedure 2

Create VOC table.
- Interpret verbatim statements into new meanings.
- Document source of VOC or re-worked VOC.
  - “I” if internally changed or generated (by team)
  - “E” if externally generated (by customer) or not changed by team
- Classify each statement as:
  - a real need feeds QFD
  - a technical solution
  - a feature requirement feeds QFD
  - not a true need (e.g., cost issue, complaint, technology, hopes dreams, etc.)
- Quantify, Analyze, Prioritize
**VOC: Example Table**

New process initiative under consideration
- interview statements recorded verbatim and classified
- column added for keyword sorting

Further development
- “interpreted” comments about the organization’s true goals, the overlap of initiatives (and so on)
- evaluation for common themes
- additional data collection may be needed

<table>
<thead>
<tr>
<th>Customer comment</th>
<th>Interpreted, reworded</th>
<th>I/E</th>
<th>perception, experience, context</th>
<th>barrier</th>
<th>root issue?</th>
<th>results, success</th>
<th>need</th>
<th>solutions</th>
<th>Keyword for sorting</th>
</tr>
</thead>
<tbody>
<tr>
<td>We are already at maturity level x, so why do more?</td>
<td></td>
<td>E</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>competing initiatives</td>
</tr>
</tbody>
</table>
## VOC: Analysis

<table>
<thead>
<tr>
<th>Prioritization Method</th>
<th>Customer Time</th>
<th>Preparation Complexity</th>
<th>Analysis Complexity</th>
<th>Quality of Resulting Prioritization</th>
<th>Number of customers needed</th>
<th>Number of Needs to Prioritize</th>
<th>Recommend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of Response</td>
<td>short</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>large</td>
<td>large</td>
<td>NO</td>
</tr>
<tr>
<td>Constant Sum</td>
<td>medium</td>
<td>medium</td>
<td>medium</td>
<td>medium</td>
<td>small</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Rating</td>
<td>short</td>
<td>low</td>
<td>low</td>
<td>medium</td>
<td>medium</td>
<td>med-large</td>
<td>Yes</td>
</tr>
<tr>
<td>Simple Ranking</td>
<td>medium</td>
<td>low</td>
<td>low</td>
<td>medium</td>
<td>medium</td>
<td>small-med</td>
<td>Yes</td>
</tr>
<tr>
<td>Q-Sort</td>
<td>short</td>
<td>low</td>
<td>low</td>
<td>medium</td>
<td>medium</td>
<td>large</td>
<td>Yes</td>
</tr>
<tr>
<td>Paired Comparison</td>
<td>long</td>
<td>medium</td>
<td>high</td>
<td>high</td>
<td>large</td>
<td>small</td>
<td>Yes</td>
</tr>
<tr>
<td>Regression</td>
<td>short</td>
<td>medium</td>
<td>high</td>
<td>high</td>
<td>large</td>
<td>small-med</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Tool Tip: Management by Fact (MBF)

Description
• a concise summary of quantified problem statement, performance history, prioritized root causes and corresponding countermeasures for the purpose of data-driven project and process management

Management by Fact
• uses the facts
• eliminates bias
• tightly couples resources and effort to problem-solving
MBF: Procedure

Identify and select problem
• use “4 Whats” to help quantify the problem statement
• quantify gap between actual and desired performance

Determine root cause
• separate beliefs from facts
• use “7 Basic Tools”
• use “5 Whys”

Generate potential solutions and select action plan
• Must be measurable/sustainable
• Specific/assignable ownership
• Understand expected results from each action

Implement solutions and evaluate
• Compare data before and after solution
• Document actuals and side effects
• Compare with desired benchmark
**MBF: 4 Whats**

Customer satisfaction scores are too low.
- What is too low?

Compared to best-in-class benchmark of 81%, we are at 63%.
- What is the impact of this gap?
  - It represents lost revenue and earnings potential?
- What is the correlation between customer satisfaction and revenue?
  - Each percent of customer satisfaction translates to 0.25 percent of market share which equals $100M US revenue.
  - What is the lost potential?

**Final problem statement:**

Customer satisfaction is 18% lower than best-in-class benchmark, which corresponds to a potential lost revenue of $1.8B US.
The marble in the Jefferson Memorial was deteriorating. Why? The deterioration was due to frequent cleanings with detergent. Why? The detergent was used to clean bird droppings from local sparrows. Why? The sparrows were attracted by spiders. Why? The spiders were attracted by midges. Why? The midges were attracted by the lights.

Solution: Delay turning on the lights until later at dusk.
MBF: Format

FACTUAL STATEMENT OF PROBLEM, PERFORMANCE TRENDS & OBJECTIVES

Graph of performance over time

Graph of supportive or more detailed information

Prioritization & Root Cause
List of gaps in performance and true root cause

Counter Measures & Activities
List of specific actions, who has ownership and due date

Impact, Capability
List of expected benefits and impact of each countermeasure
## MBF: Example

### Problem Statement

Customers A, B, and C, representing x% of market share, are facing budget/cost constraints and require a 10% cost reduction in our product line XYZ in order to continue doing business with us. Baseline data shows that 33% of software development time is spent detecting and correcting defects.

### Prioritization & Root Cause

| Large Quantity of Syntax & Similar defects that are repaired in &lt;10 minutes on avg | Goal is 50% reduction in time, relative to historical data |
| "Big Hitter" (&gt;10 minutes) defects involve a variety of errors that escape to testing. Design-injected and Test-removed errors fall into this category | Goal is 25% reduction in time, relative to historical data |

### Counter Measures & Activities

<table>
<thead>
<tr>
<th>Counter Measures &amp; Activities</th>
<th>Who</th>
<th>When</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarify type definitions</td>
<td>jms</td>
<td>4/30/2001</td>
</tr>
<tr>
<td>Improve subcategory data collection</td>
<td>jms</td>
<td>4/30/2001</td>
</tr>
<tr>
<td>Build a cause &amp; effect diagram to be used for next round of analysis, improvement planning</td>
<td>jms</td>
<td>4/30/2001</td>
</tr>
<tr>
<td>Increase correction efficiency by seeking all occurrences of a defect upon the detection of the first occurrence</td>
<td>jms</td>
<td>4/30/2001</td>
</tr>
<tr>
<td>Increase and log (new) usage of off-line programs to test small pieces of functionality</td>
<td>jms</td>
<td>4/30/2001</td>
</tr>
<tr>
<td>Create &amp; Use a syntax checklist</td>
<td>jms</td>
<td>4/30/2001</td>
</tr>
<tr>
<td>Time breaks: phase completion &amp; every hour</td>
<td>jms</td>
<td>4/30/2001</td>
</tr>
<tr>
<td>Conduct a phase check prior to moving on</td>
<td>jms</td>
<td>4/30/2001</td>
</tr>
<tr>
<td>Increase and log (new) usage of off-line programs to test small pieces of functionality</td>
<td>jms</td>
<td>4/30/2001</td>
</tr>
<tr>
<td>Improve subcategory data collection to use for developing a more directed design review</td>
<td>jms</td>
<td>4/30/2001</td>
</tr>
<tr>
<td>Build a cause &amp; effect diagram to be used for next round of analysis, improvement planning</td>
<td>jms</td>
<td>4/30/2001</td>
</tr>
</tbody>
</table>

### Expected Benefit/Impact

<table>
<thead>
<tr>
<th>Expected Benefit/Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trend of fix time / total time has similar pattern</td>
</tr>
<tr>
<td>About 1/2 of goal. In normalized terms, ~1 LOC/hr increase</td>
</tr>
<tr>
<td>About 1/2 of goal. In normalized terms, ~1 LOC/hr increase.</td>
</tr>
</tbody>
</table>
Tool Tip: Process Mapping

Description
- representation of major activities/tasks, subprocesses, process boundaries, key process inputs, and outputs

**INPUTS**
(Sources of Variation)
- People
- Material
- Equipment
- Policies
- Procedures
- Methods
- Environment
- Information

**PROCESS STEP**
A blending of inputs to achieve the desired outputs

**OUTPUTS**
(Measures of Performance)
- Perform a service
- Produce a Product
- Complete a Task
Mapping: Usage

Feeds other tools
  • Cause and Effects Matrix
  • Failure Modes and Effects Analysis (FMEA)
  • Control Plan Summary
  • Design of Experiments (DOE) planning

Tips for mapping current processes
  • Go to the actual place where the process is performed.
  • Talk to the actual people involved in the process and get the real facts.
  • Observe and chart the actual process.
  • Consider creating “as is” and then “to be” maps.

Reality is invariably different from perception - few processes work the way we think they do!
Process Mapping: Basic Procedure

List inputs and outputs

Identify all steps in the process: value-added and non-value-added

Show key outputs at each step (process and product)

List key inputs and classify process inputs

Add the operating specifications and process targets for the controllable and critical inputs
Process Mapping: Example

Inspection process from earlier illustration

- **Plan**
  - Artifacts to inspect
  - Artifact size
  - Reviewers
  - Data repository

- **Detect Defects**
  - Review Rate
  - Checklists
  - Inspection method, procedure
  - Proficiency
  - Taxonomy interpretations

- **Troubleshoot**
  - What would you list?
  - Defect attributes
  - Proficiency
  - Effort
  - Tools

- **Correct Defects**
  - What would you list?
  - Correction action
  - Config control
  - Effort

- **Defect Log**
- **Record of plan**
- **Direct Cause**
- **Root Cause**
- **Corrective Action**

- **Inspection**
  - Rework

- **Critical Inputs**
  - Noise

- **Standard Procedure**
  - Control Knobs

© 2003 by Carnegie Mellon University

Version 1.0
Process Mapping: Value Map

Identify the process to map
Identify the boundaries
Create input-process-output for the critical processes
Create the process map
Color code each step identifying value
- green = value added
- red = non value added
- yellow = non value added but necessary

- Identify hand-off points, queues, storage, and rework loops in the process
- Quantitatively measure the map (throughput, cycle time, and cost)
- Validate map with process owners
Value Mapping: Change Request

- Request (Need Identified)
- Initial Assessment*
- Assessment Coordination
- Feedback
  - No
  - Yes
  - Validate
- Preliminary Request Accepted?
  - No
  - Yes
- Request Validated?
  - No
  - Yes
  - Provide Additional Guidance
- Additional Guidance Needed?
  - No
  - Yes
  - Select Method/Path
- Right Decision?
  - No
  - Yes
- Forward to Board

© 2003 by Carnegie Mellon University

*Initial Assessment will:
  - Determine Impact Assessment
  - Identify Stakeholder
  - Coordinate with Product/Process Owner
  - Perform Impact Analysis