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Data Analysis Dynamics

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Sponsored by the U.S. Department of Defense

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:

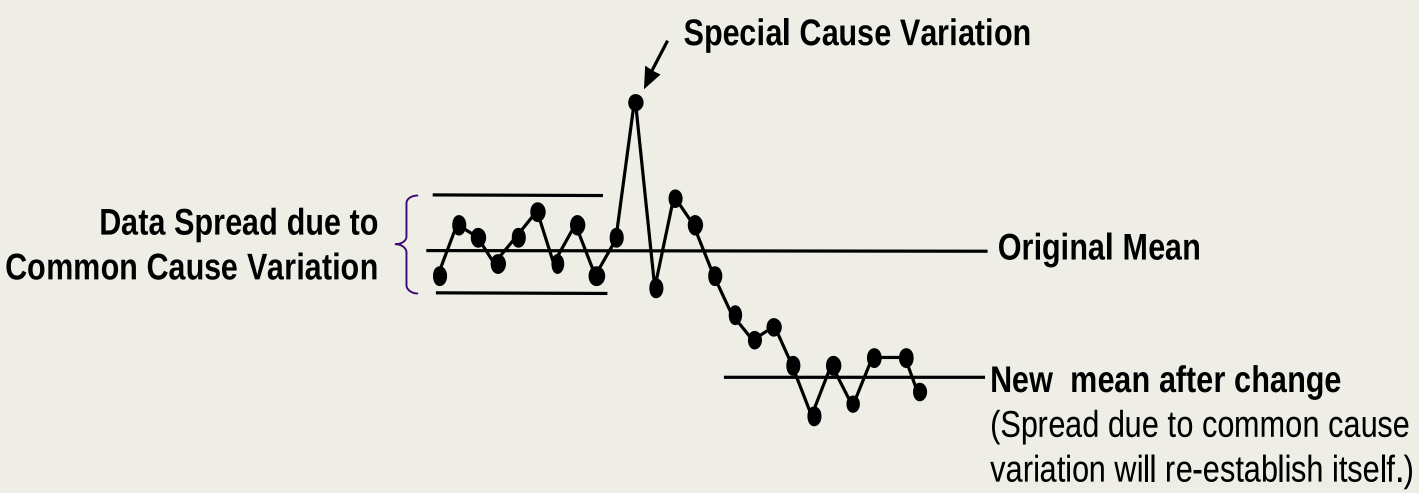
- Common Cause Variation
  - variation in process performance due to normal or inherent interaction among process components (people, machines, material, environment, and methods).
- Assignable Cause (Special Cause) Variation
  - variation in process performance due to events that are not part of the normal process.
  - represents sudden or persistent abnormal changes to one or more of the process components.

Understanding Variation

Everything is a process.

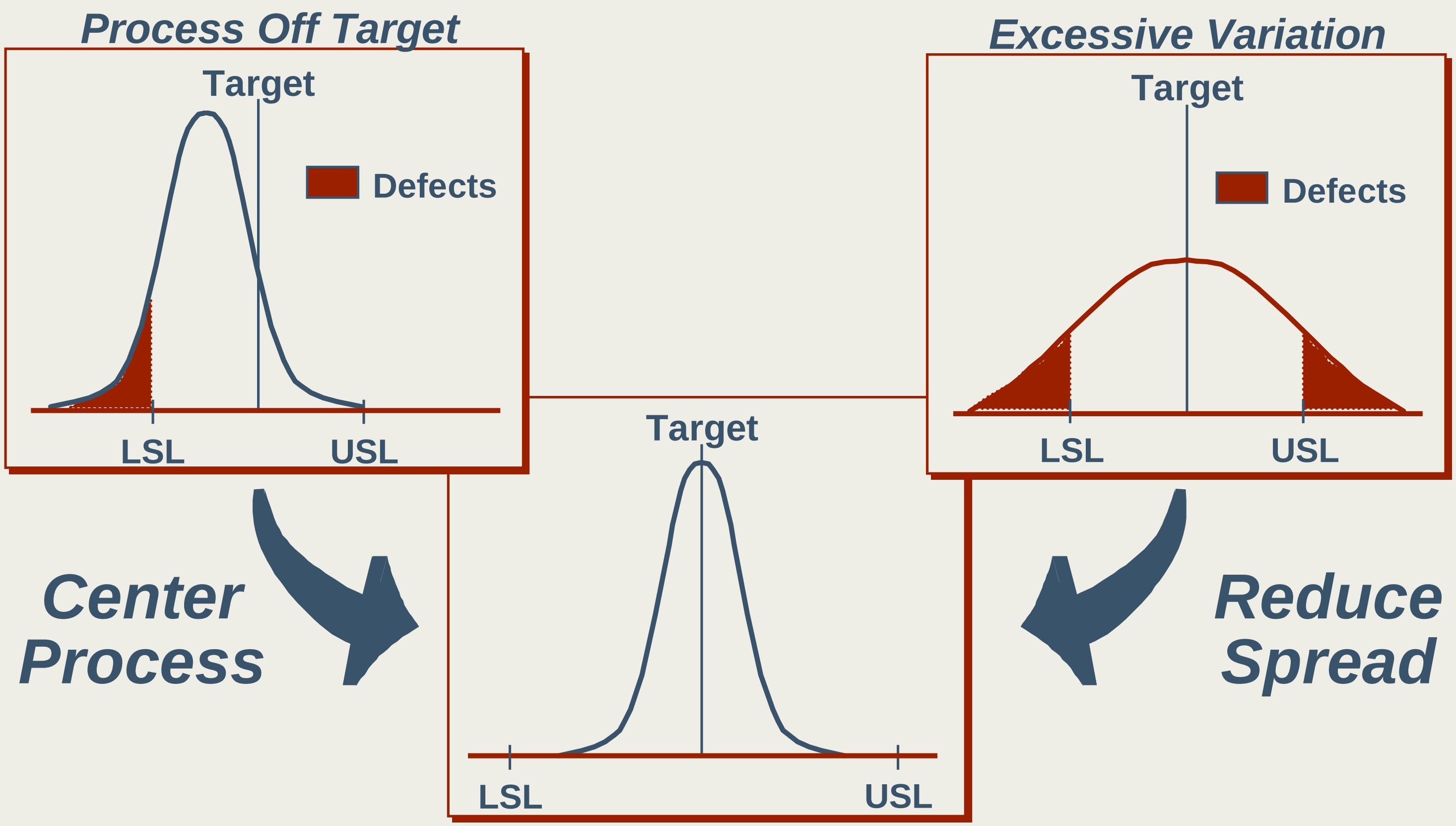
All processes have inherent variability.

Data is used to understand variation and to drive decisions to improve the processes.



[ASQ 00], [ASA 01]

In Other Words…



Measurement Data Requires Analysis and Interpretation

Input | Transformation | Output

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(defect profile, yield)
   = f(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 1

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 2

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

Define	Measure	Analyze	Improve	Control
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”	Defect Metrics Data Collection Methods Sampling Techniques Measurement Sys. Evaluation Quality of Data	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	Design of Experiments Modeling Tolerancing Robust Design Systems Thinking Decision & Risk Analysis	<u>Statistical Controls:</u> • Control Charts • Time Series methods <u>Non-Statistical Controls:</u> • Procedural adherence • Performance Mgmt • Preventive activities

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

Analysis Dynamics 1

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?

typical stumbling point

typical stumbling point

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?

typical stumbling point

typical stumbling point

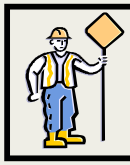
Analysis Dynamics 3

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



typical stumbling point

Identify the Goals 1

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

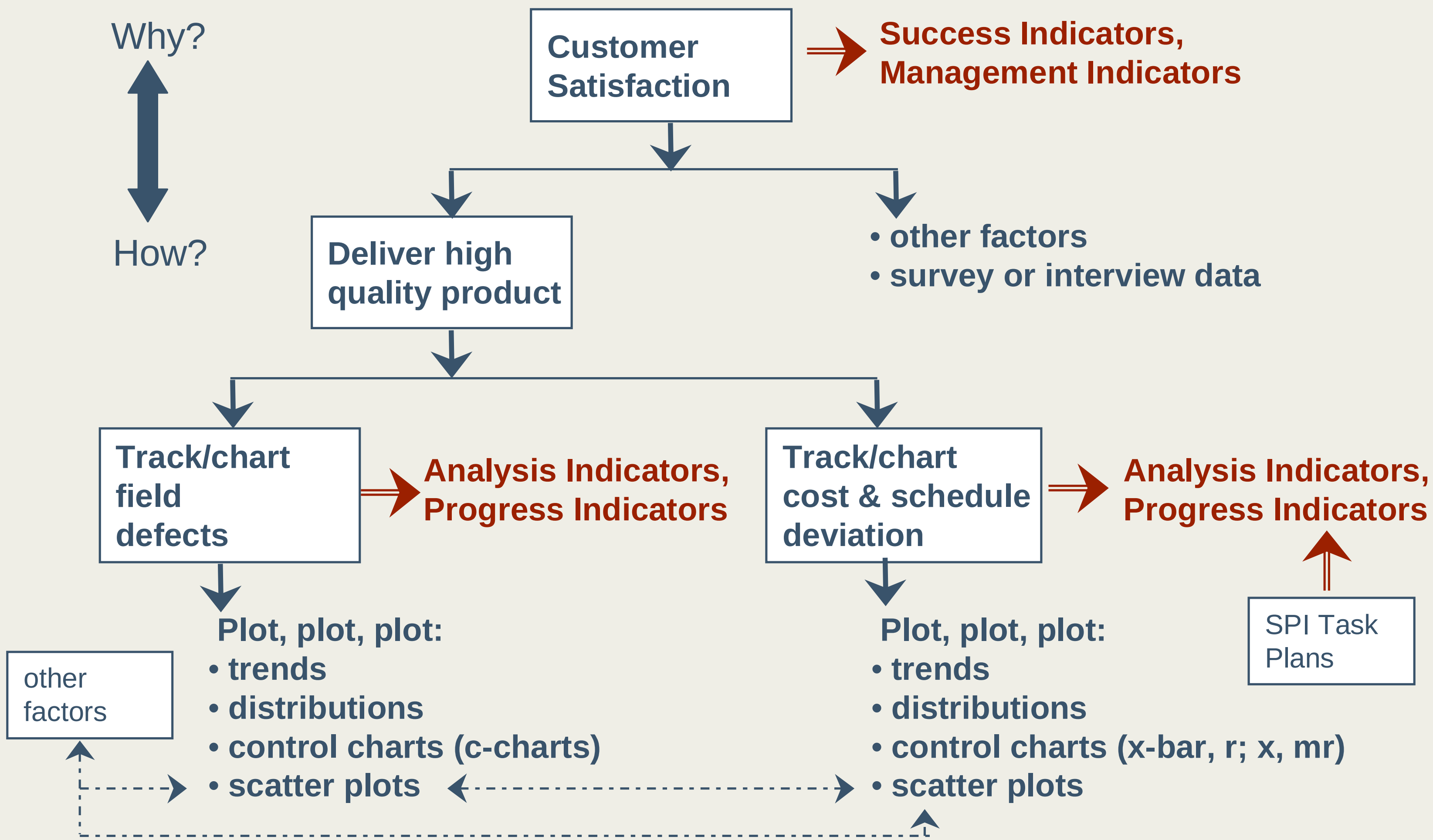
Typical problems
- goals do not exist or have not been explicitly stated
- goals at different levels are disconnected

Identify the Goals $_2$

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



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

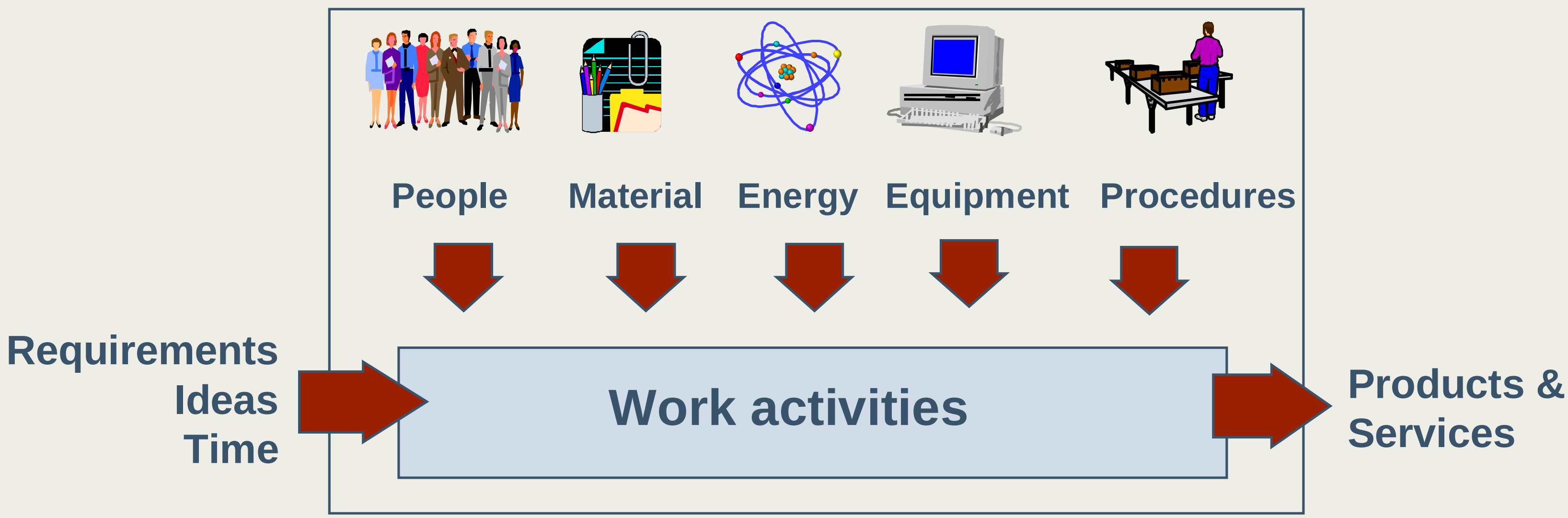
- Omitting this step - avoids examination of your assumptions and understanding of the process
- Selecting a view that matches the issue or study level
- Constructing a view that does not match reality

Relevant tools & methods

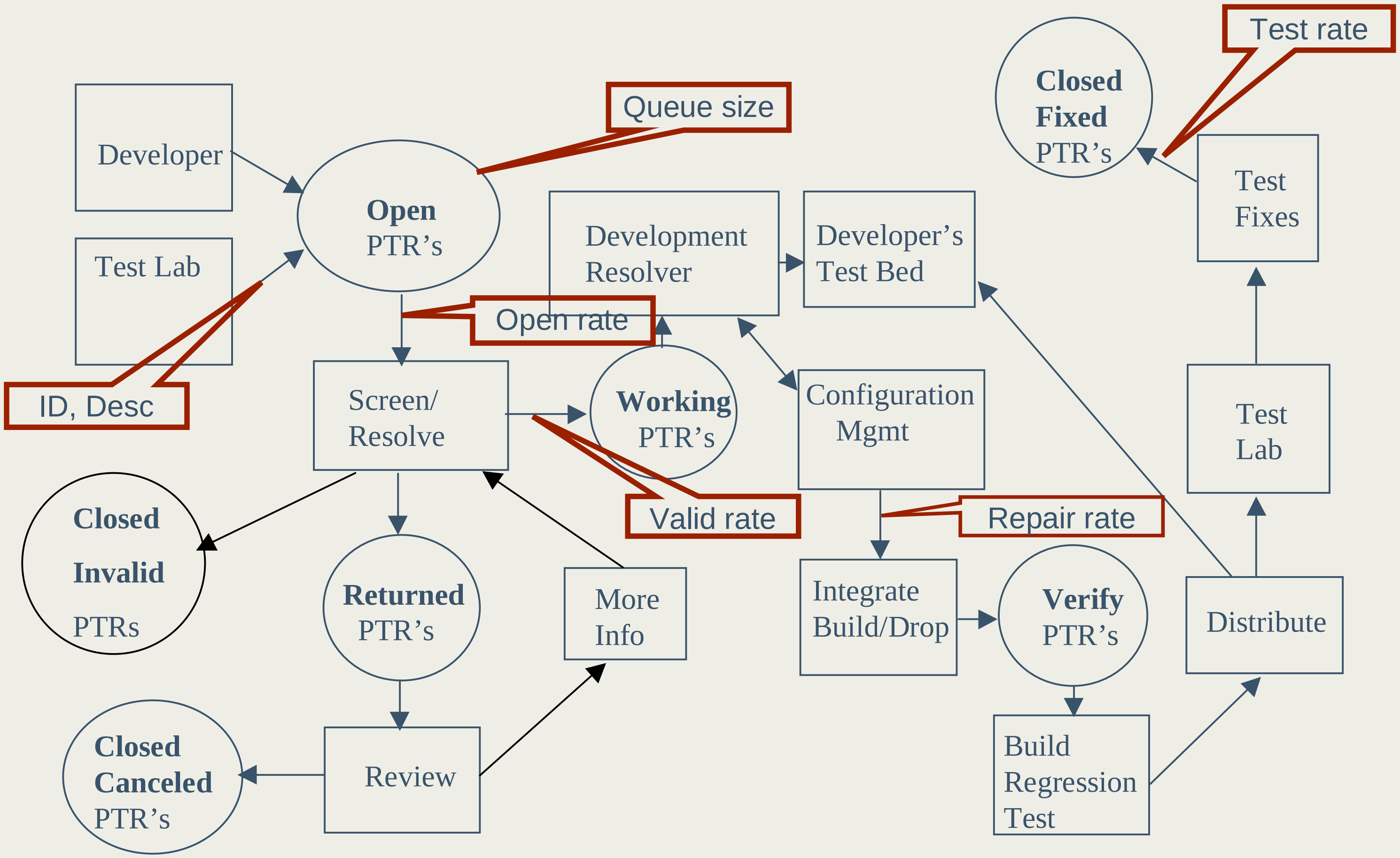
- Process Mapping
- Mental Model

What is a Process?

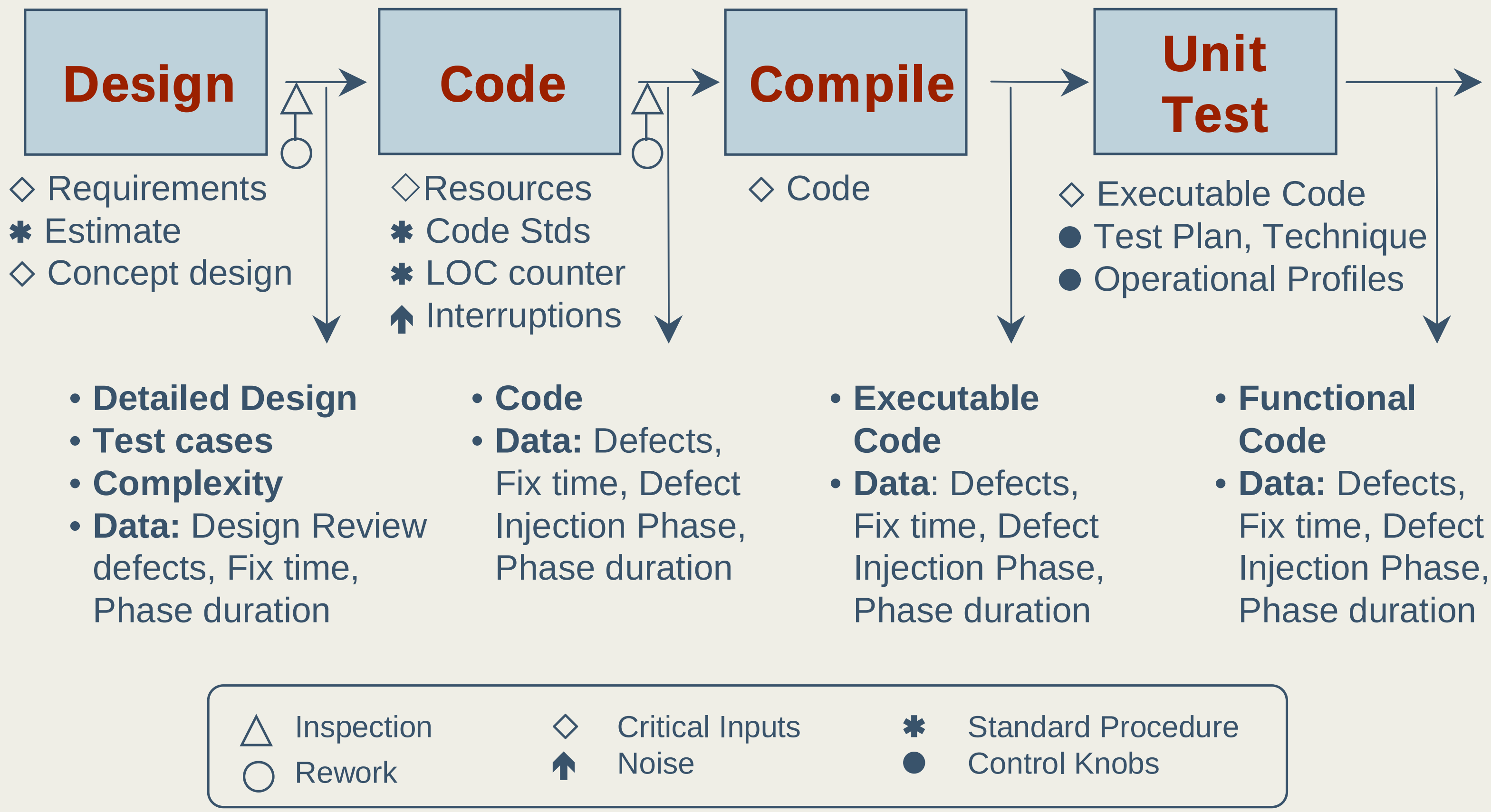
- Any set of conditions or causes that work together to produce a given result
- A system of causes which includes people, materials, energy, equipment, and procedures necessary to produce a product or service



Problem Management Process



Development Process Map



typical stumbling point

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

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Is the data right? - Example

Inspection Data Set 1

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

Inspection Data Set 2

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

Which set of data appears to be more credible?

Why?

typical stumbling point

Do I Have the Right Data? 1

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

typical stumbling point

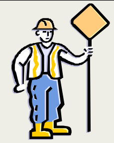
Initial Evaluation / Exploration 1

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



typical stumbling point

Initial Evaluation / Exploration $_2$

Relevant tools & methods

- descriptive statistics
- run charts or SPC charts
- time series
- boxplots
- correlation plots – first scan of relationships

Exploration Example$_1$

Is this the right data?

- unexpected high inspection rate
- unusually large SLOC per inspection
- How many inspectors contributed to the prep-hr effort?

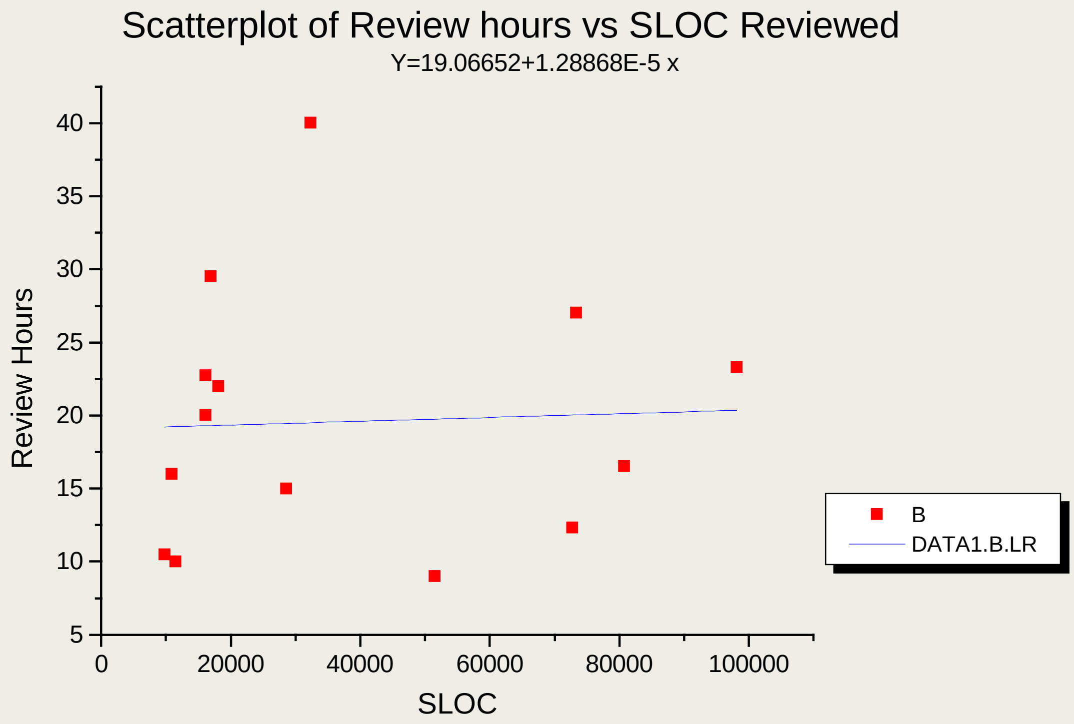
?

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

Exploration Example$_2$

Little to no correlation between SLOC size and inspection effort

R = 0.04549
R^2 = 0.00207

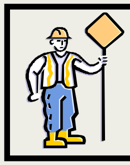


Evaluation Example$_3$

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?



typical stumbling point

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?

typical stumbling point

Moving Forward 1

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 $_2$

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

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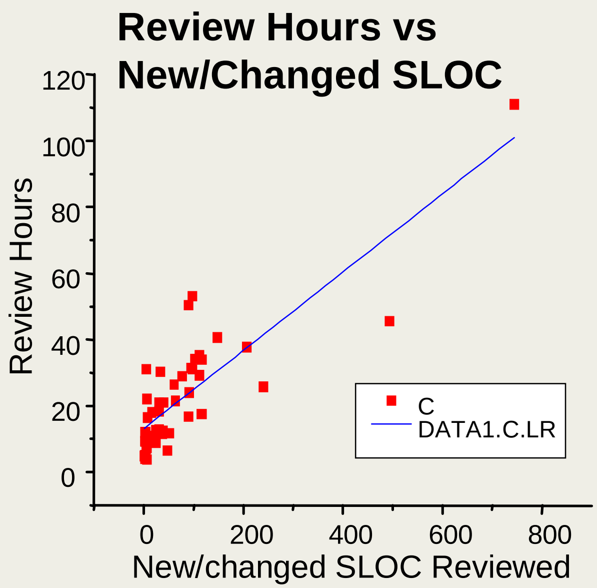
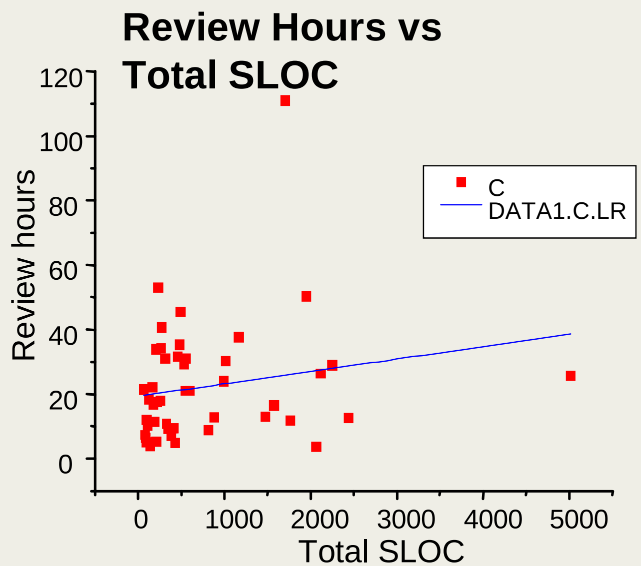
Moving Forward-
Establish Relationships

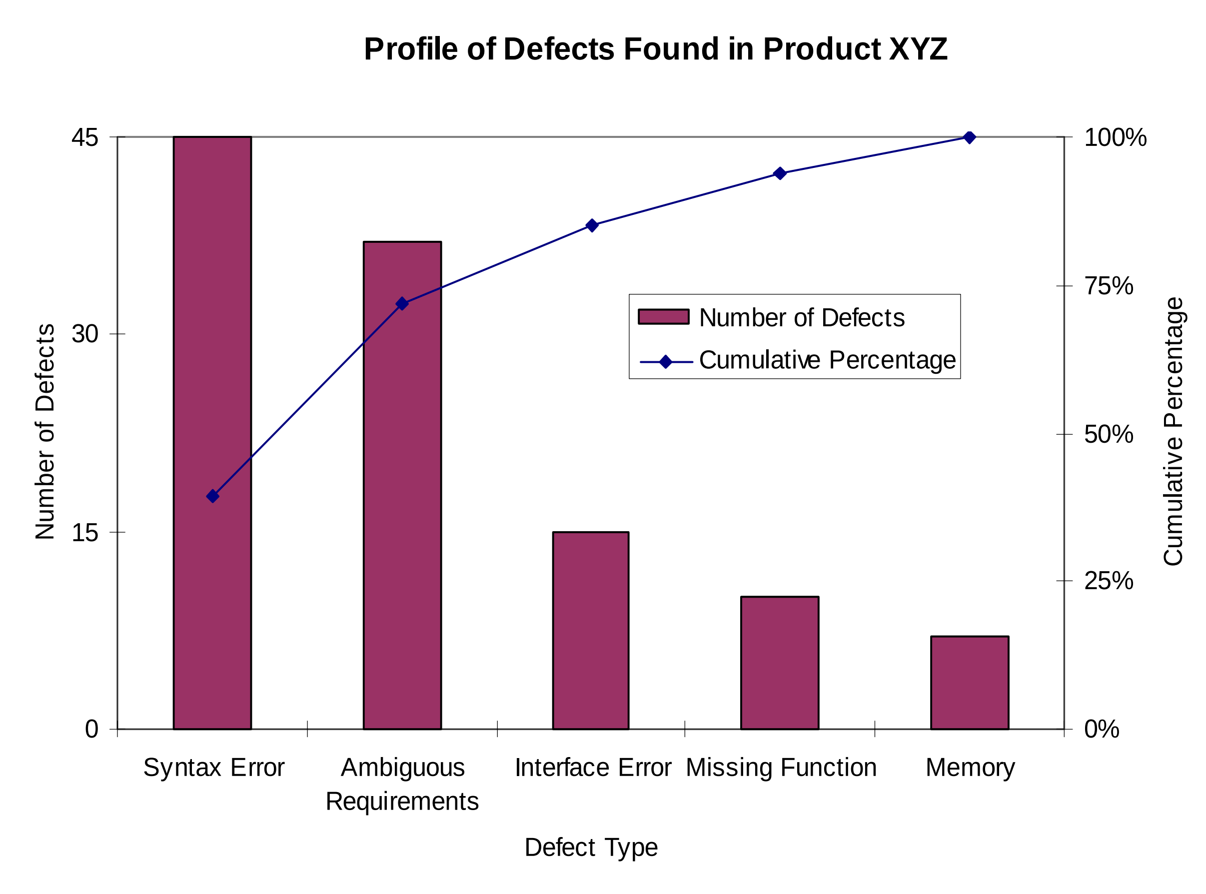




R = 0.83569
R^2 = 0.69838

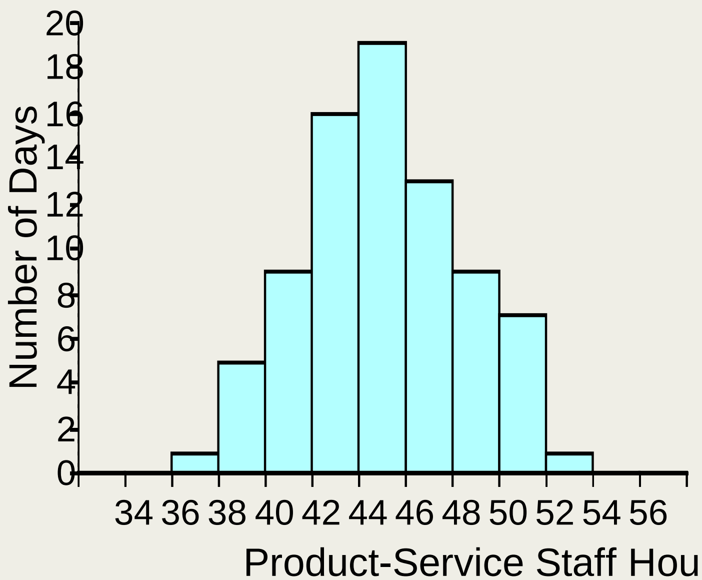
R = 0.19244
R^2 = 0.03703

Moving Forward- Identify Dominant Factors

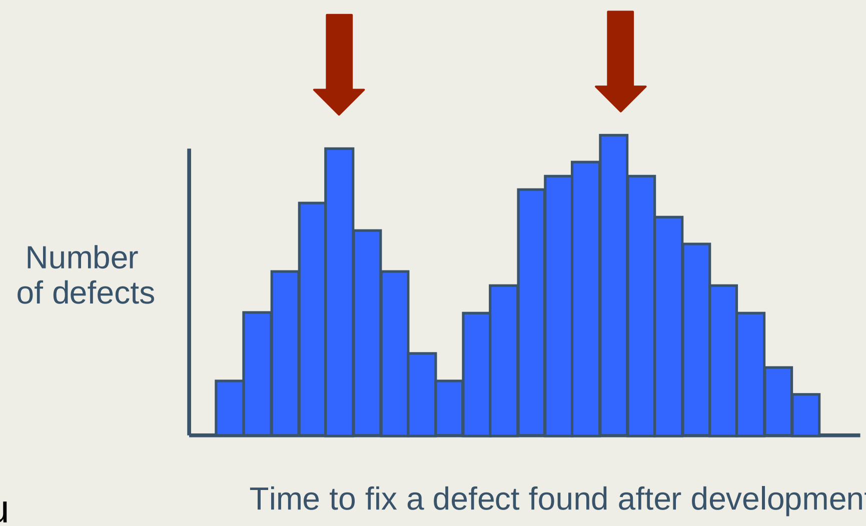


Moving Forward- Determine Extent of Variability 1

Basic Histogram shows distribution, spread.

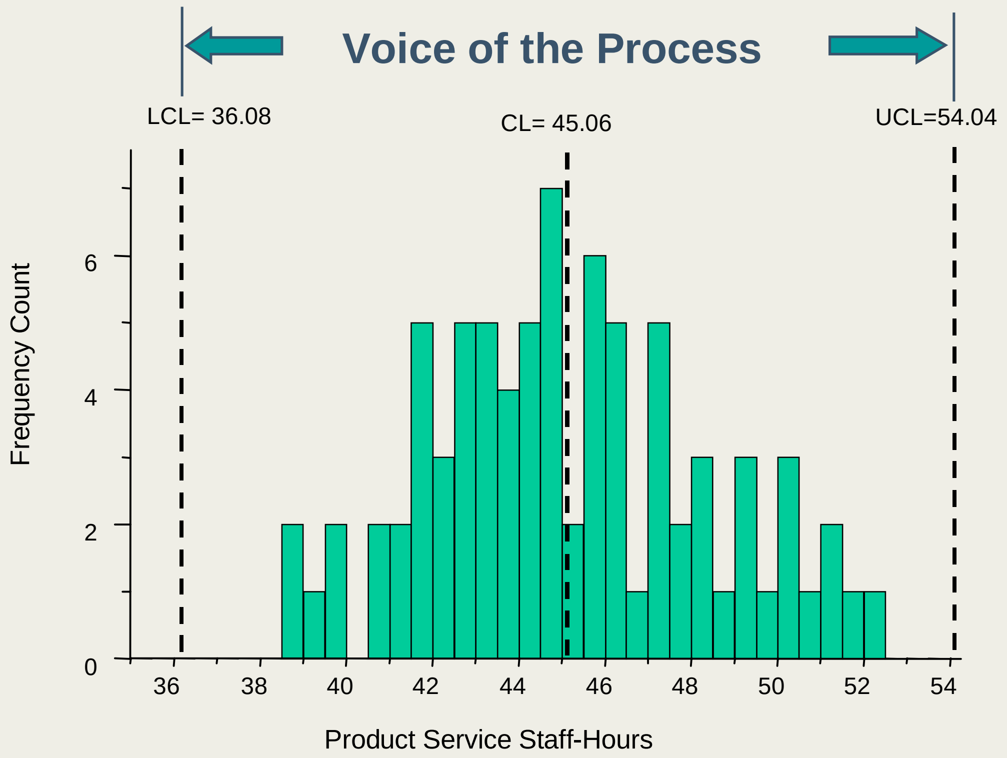


Look for multimodal distributions. They point to multiple processes.



Moving Forward- Determine Extent of Variability 2

Add control limits to reflect process capability



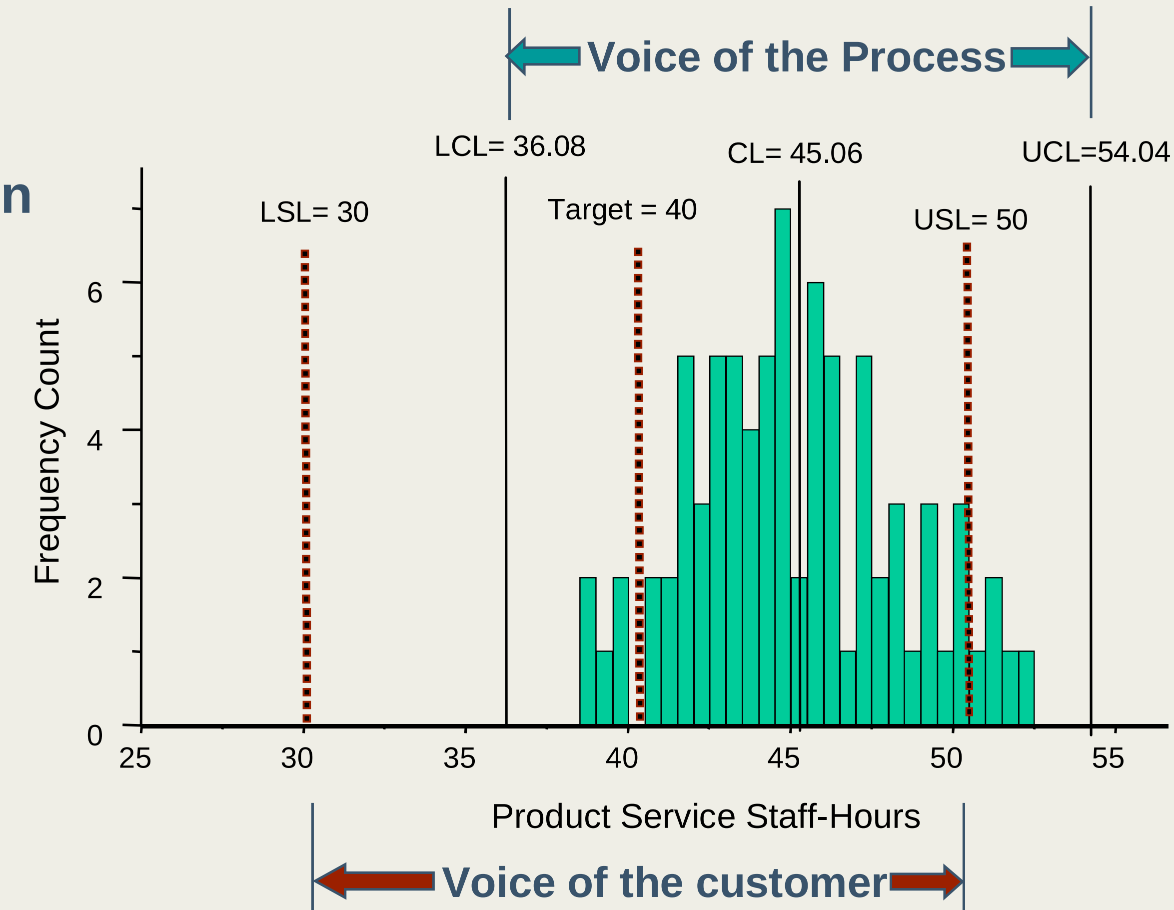
Moving Forward- Determine Extent of Variability 3

Add specification limits:

Process Capability

vs.

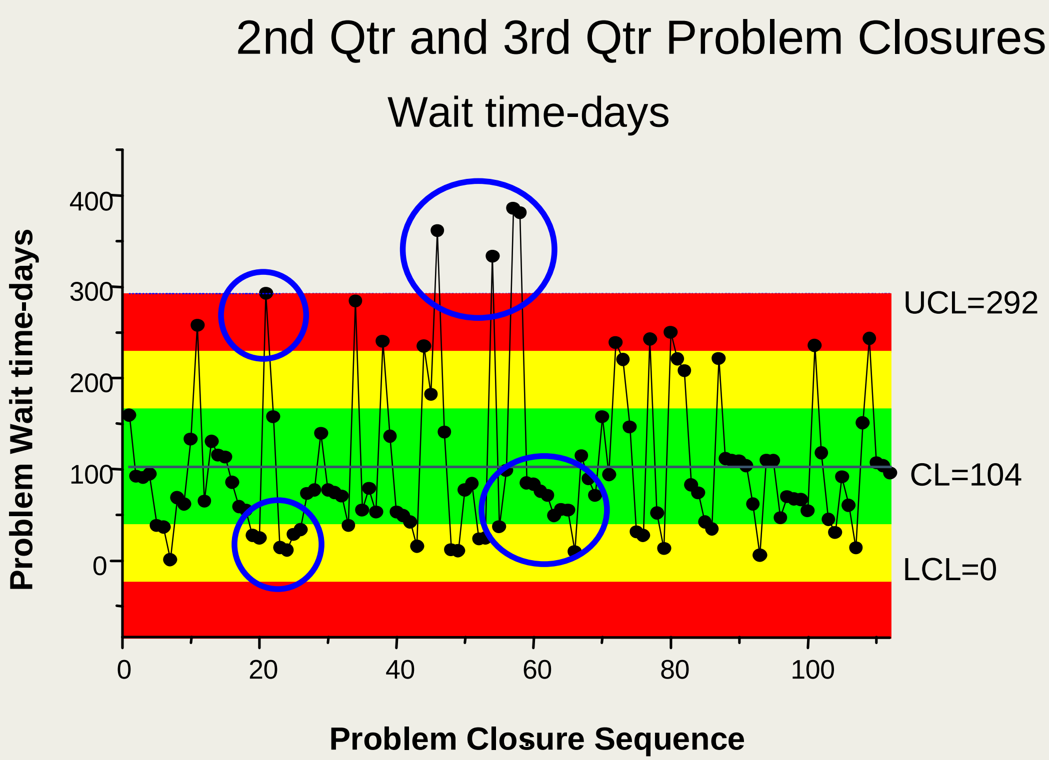
Capable Process



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

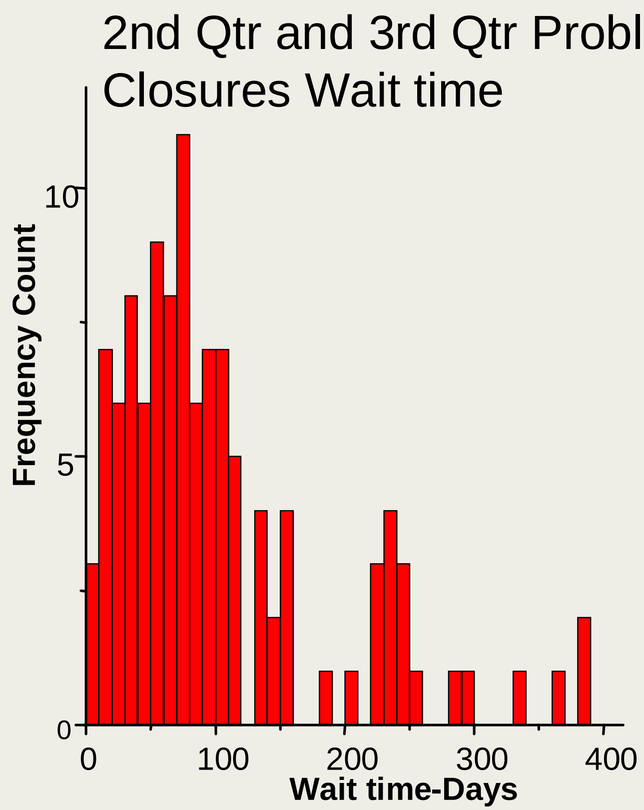


Moving Forward-
Finding Assignable Causes

Problem Repair- Wait time

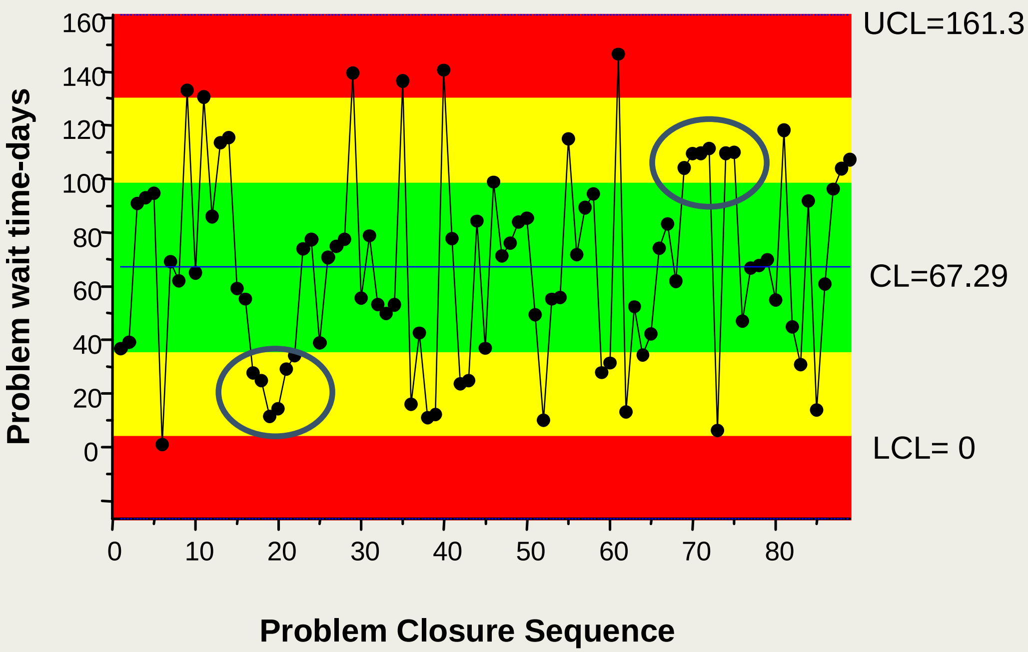
Histogram indicates data includes possible mixture of cause systems

- One process for problems up to 150 wait days
- A second process involving more than 150 wait days



Moving Forward- Find Assignable Causes

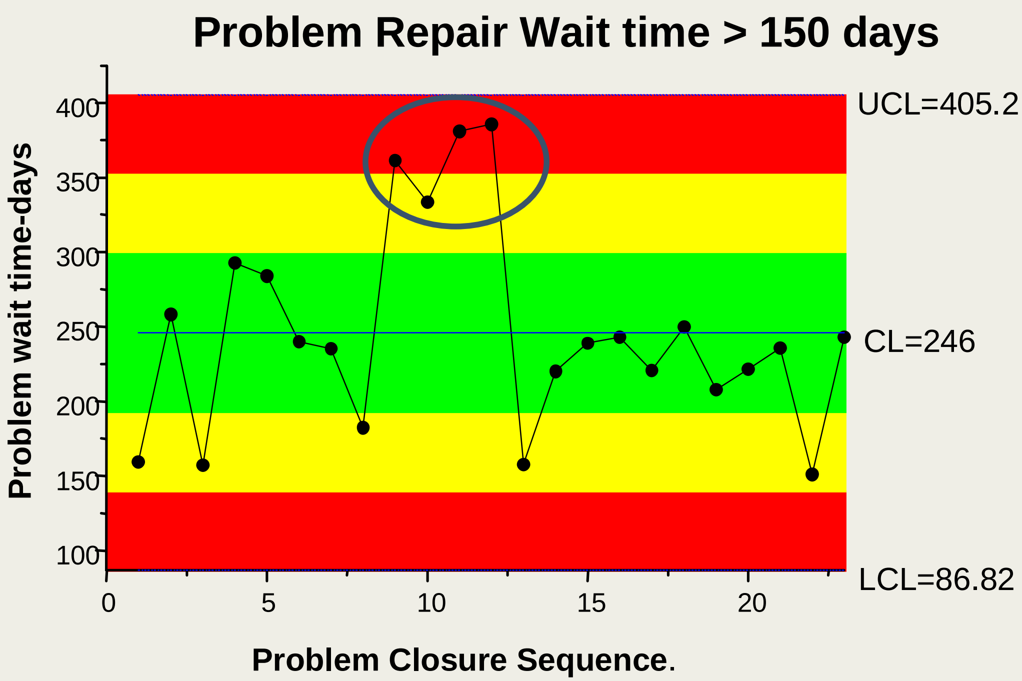
Problem repair Wait time < 150 days



One process with 67-day average wait time

- Near stable
- Investigate cause system for driving factors
  - § nature of defect
  - § staffing
  - § equipment
  - § test set type

Moving Forward-
Find Assignable Causes



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

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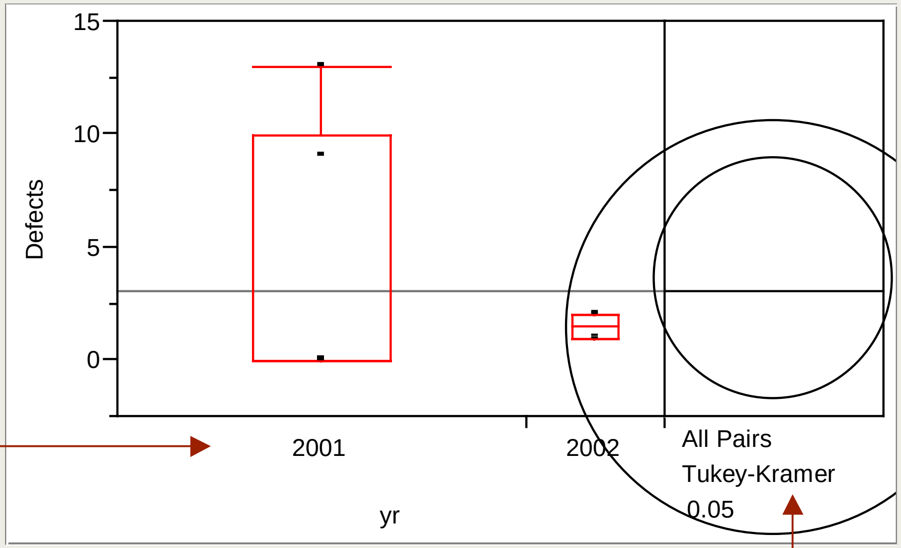
Decompose Data

- 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.

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Decompose Process Data 1

Twenty one components from same product, same team

- approximately same size
- approximately same complexity

Defects found in design inspection are:

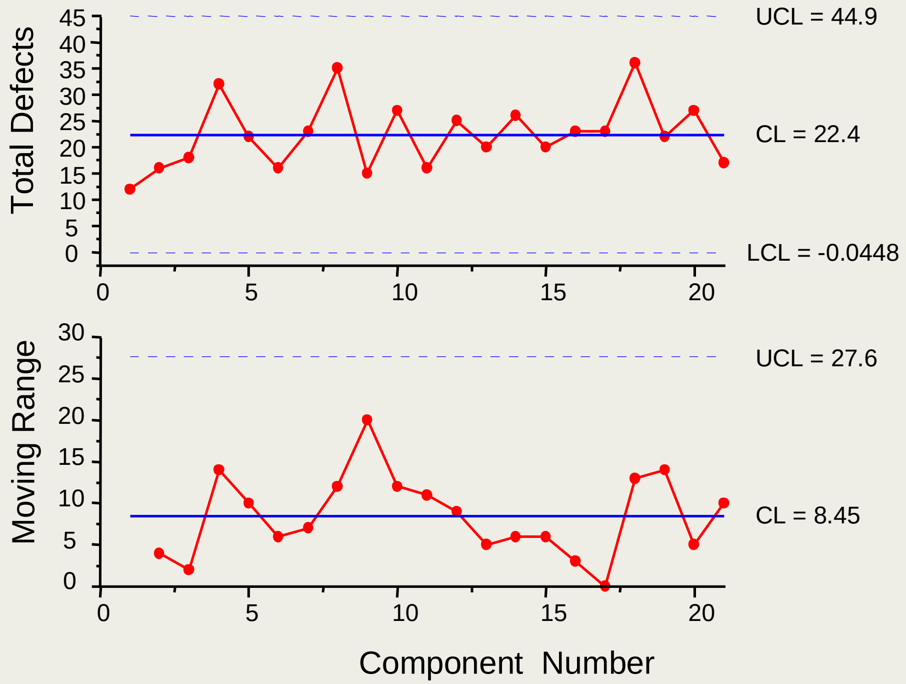
Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	**Totals**
Defects	12	16	18	32	22	16	23	35	15	27	16	25	20	26	20	23	23	36	22	27	17	471
Defect Type	Number of Defects per Type per Component																					
Function	3	5	4	4	4	3	3	20	4	11	2	3	3	5	3	7	4	5	5	15	2	115
Interface	2	2	4	4	3	4	2	3	3	4	2	3	5	3	3	3	2	16	6	2	4	80
Timing	1	1	0	1	1	0	2	1	0	0	2	0	1	1	1	1	1	0	1	0	0	15
Algorithm	0	0	1	14	2	0	0	0	0	0	0	1	5	2	7	6	5	1	2	0	1	47
Checking	1	1	5	1	7	1	1	2	0	1	6	3	1	12	1	0	2	4	3	5	2	59
Assignment	0	2	0	4	1	2	1	3	2	3	2	8	1	0	2	1	2	1	0	1	1	37
Build/Pkg.	3	1	1	2	1	0	0	4	3	6	1	0	2	1	1	1	3	2	2	2	1	37
Document	2	4	3	2	3	6	14	2	3	2	1	7	2	2	2	4	4	7	3	2	6	81

Decompose Process Data 2

Apparent stable process behavior

- But, defect rate too high and too much variation

- Explore examination of defects by type



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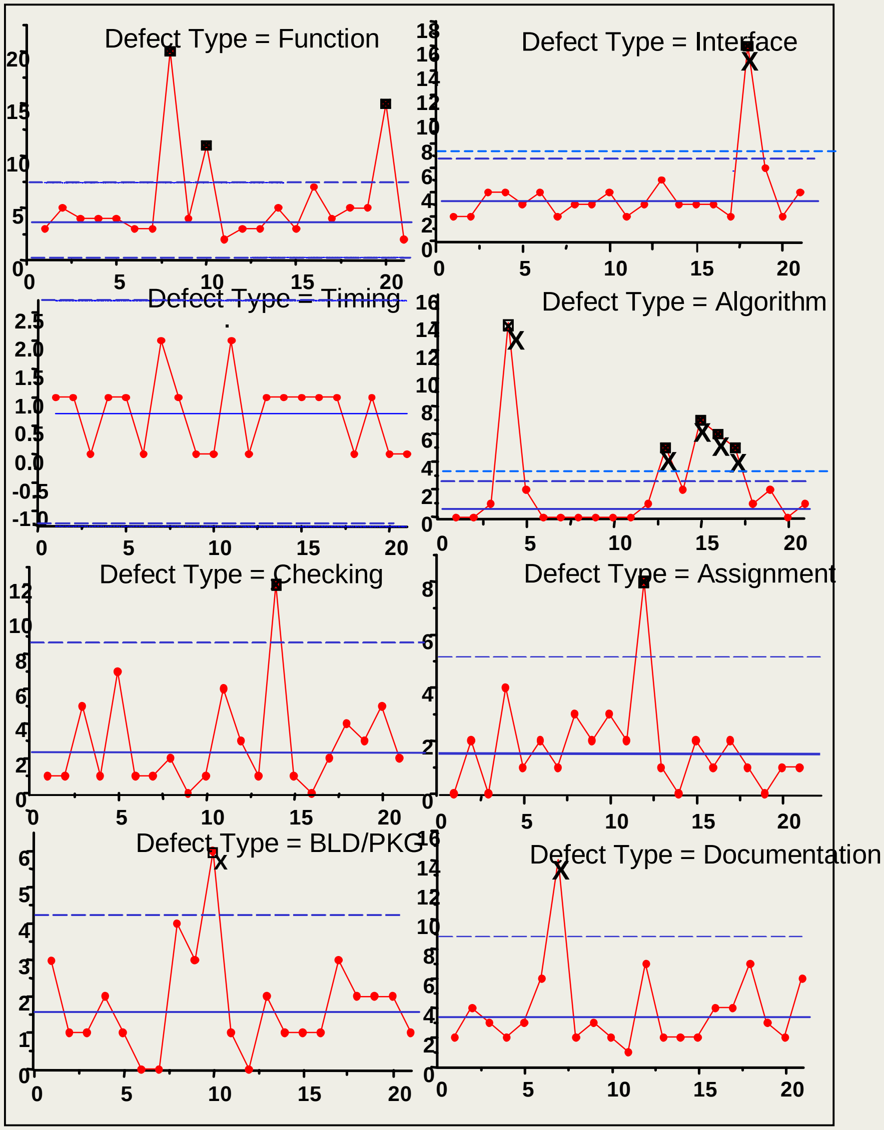
Decompose Process Data $_3$

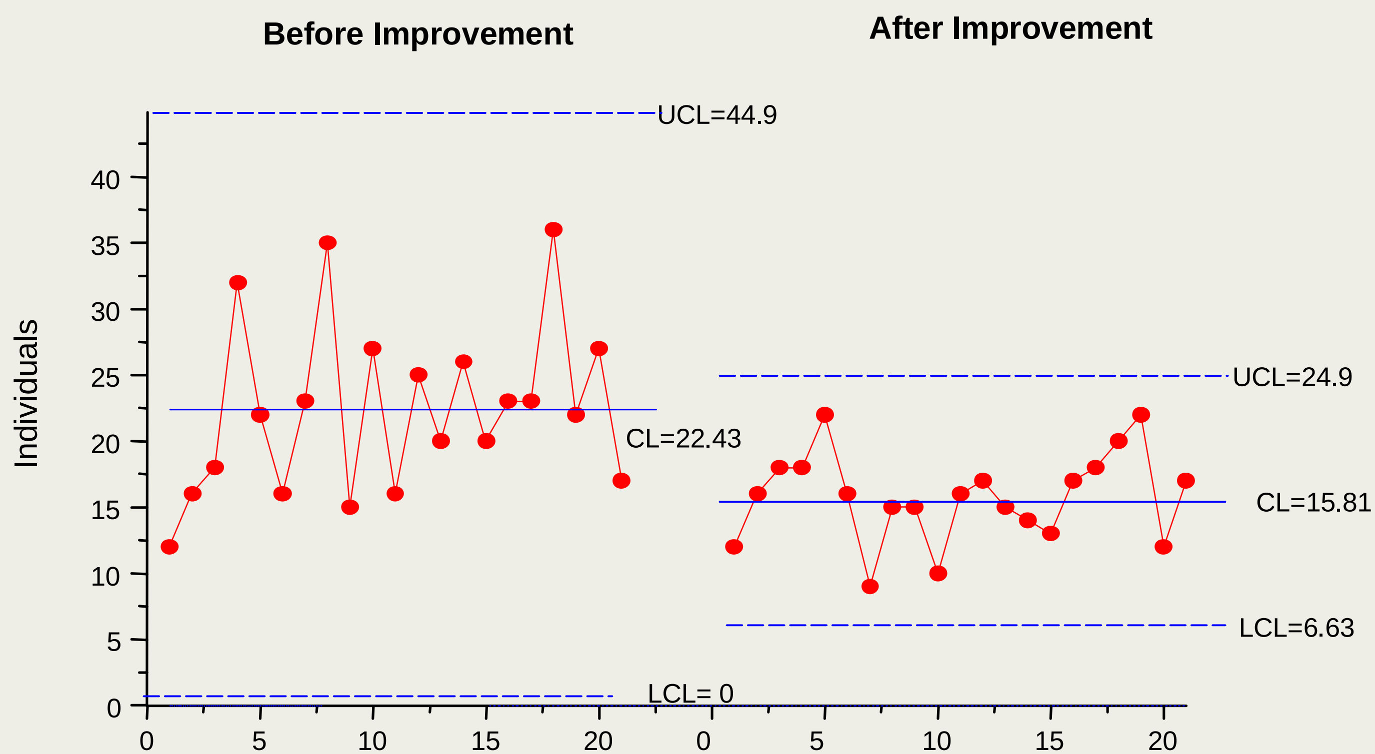
Establish process stability by defect type

X's mark assignable causes by defect type

Elimination of assignable causes will reduce variation



Potential Process 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

Analysis done in….	Comment
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 significantllly
- 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

Analysis Dynamics 1

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 <u>should</u> the data look like?
- What <u>does</u> 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.”

Analysis Dynamics 3

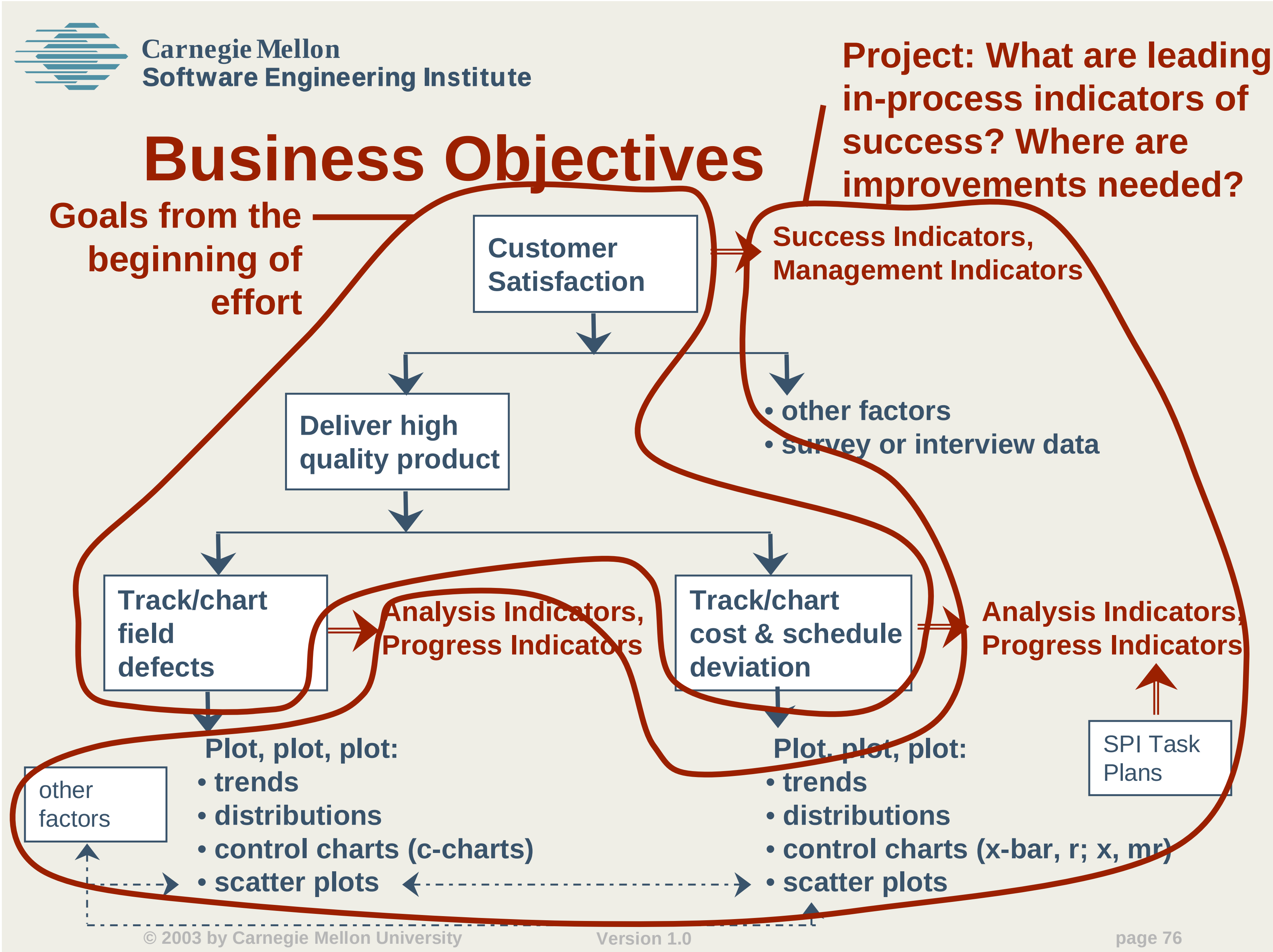
Moving Forward
- Further evaluation
- Decompose the data
- Decompose the process

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."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Business Objectives
Goals from the beginning of effort
Project: What are leading in-process indicators of success? Where are improvements needed?
Customer Satisfaction
Success Indicators, Management Indicators
Deliver high quality product
• other factors
• survey or interview data
Track/chart field defects
Analysis Indicators, Progress Indicators
Track/chart cost & schedule deviation
Analysis Indicators, Progress Indicators
SPI Task Plans
other factors
Plot, plot, plot:
• trends
• distributions
• control charts (c-charts)
• scatter plots
Plot, plot, plot:
• trends
• distributions
• control charts (x-bar, r; x, mr)
• scatter plots
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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

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Field Defect Data Baseline

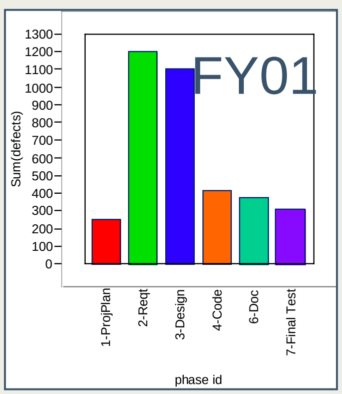
Organizational goal: 0 field defects

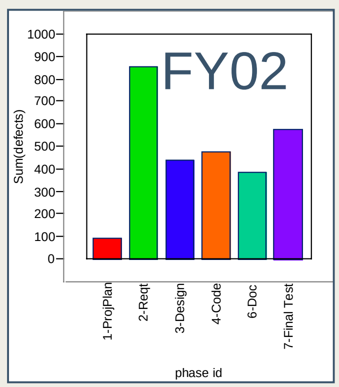
Field defects

	Field Defects
FY 01	4
FY 02	4

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

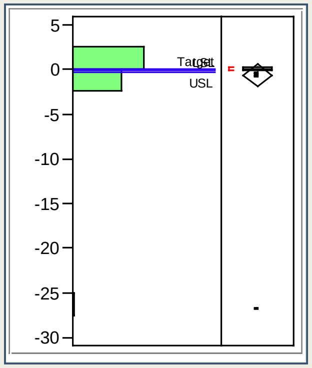
Readily available data
- monthly process effort, cost, schedule
- compared to specification
  - with text entry for out of spec causes

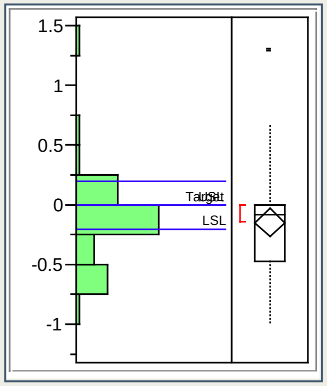
Data “archaeology”:
- completed project data
  - final vs. original with differences categorized

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

	% effort variance	% sched variance
average	-66.1%	-15.0%
standard deviation	415.9%	38.3%
median	0.9%	-8.1%
min to max	-2689.9% to 50.1%	-99.8% to 128.0%
n	42	42
capability notes (spec = +/- 20%)	45.2% outside spec	40.4% outside spec





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

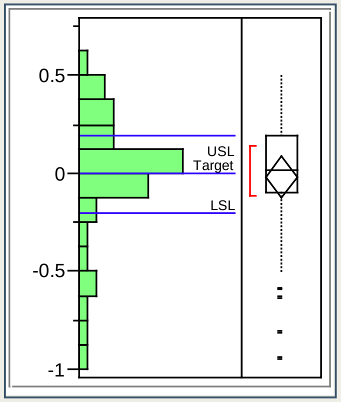
internal/external categories	median contribution toward total effort (cost) variance	# of projects reporting	median contribution toward total schedule variance	# of projects reporting
internal project	-30.83%	7	-34.32%	4
internal organization, outside project	-1.25%	5	-73.77%	3
external, reqt	-22.48%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

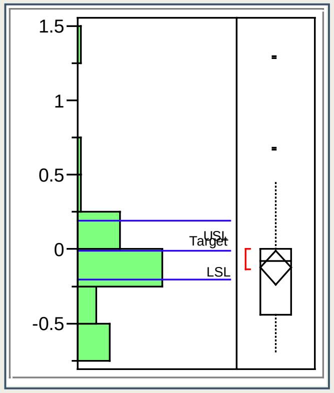
"Internal" and "external" taxonomy selected based on "sphere of influence and control"

Risk: while "internal causes" seem to be a significant opportunity, a small number of projects reported such causes

Explore, Evaluate (Plot, Plot, Plot) 1

	% effort variance	% sched variance
avg	-2%	13%
std dev	33%	36%
median	2%	7%
min to max	-95% to 50%	-128% to 71%
capability notes (spec = +/- 20%)	43.8% outside spec	39% outside spec





When flyers are removed

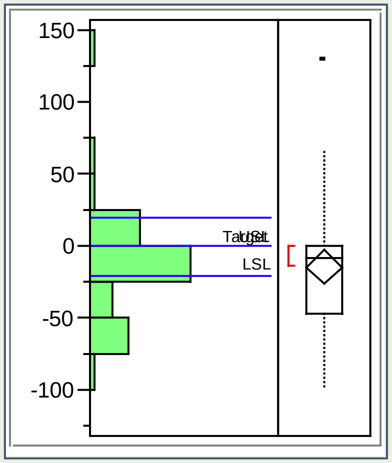
- Averages closer to target, spread narrowed
- Medians minimally affected
- Still nearly as many outside specs
- Small "second peak" more visible

- What are guidelines for removing flyers?

- Average vs. median

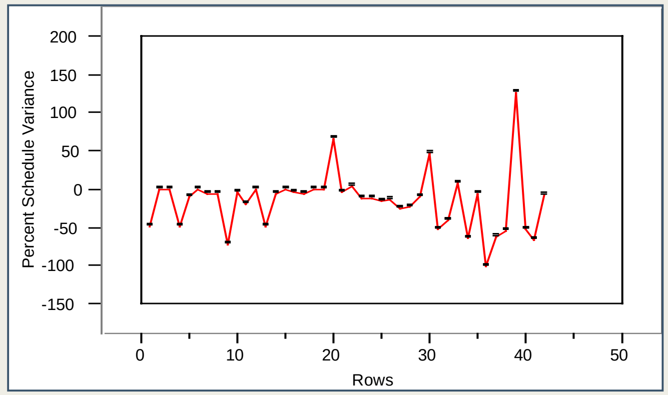
Explore, Evaluate (Plot, Plot, Plot) 2

Schedule Variance Distribution to Time Series



same

data



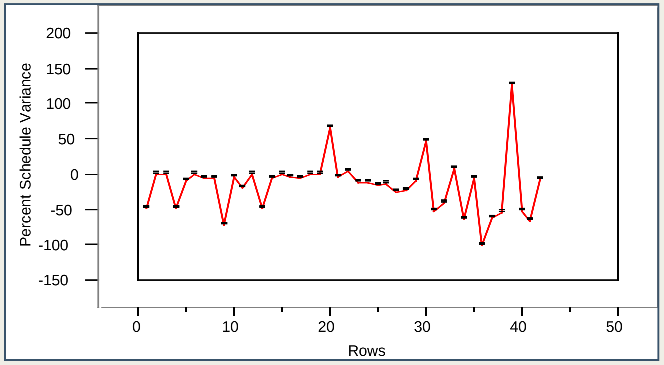
Why not a control chart?

Time series plot shows

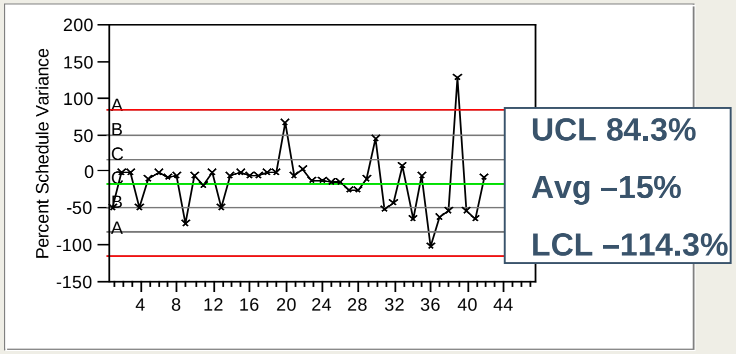
- where in time the contributions to overall high variability occur
- possible change in variability over time
- where in time the points of the possible “second population” occur

Explore, Evaluate (Plot, Plot, Plot) 3

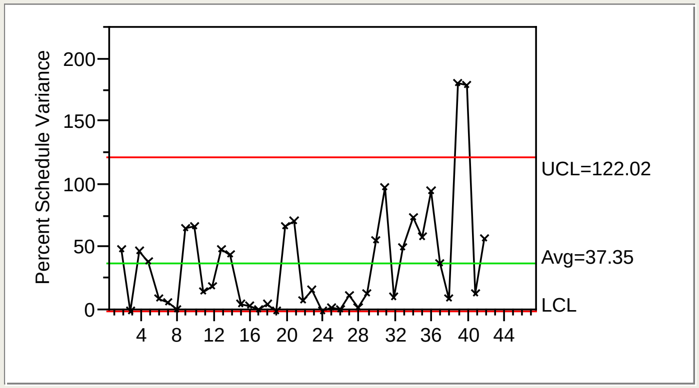
Schedule Variance Time Series to Control Chart



same data



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)

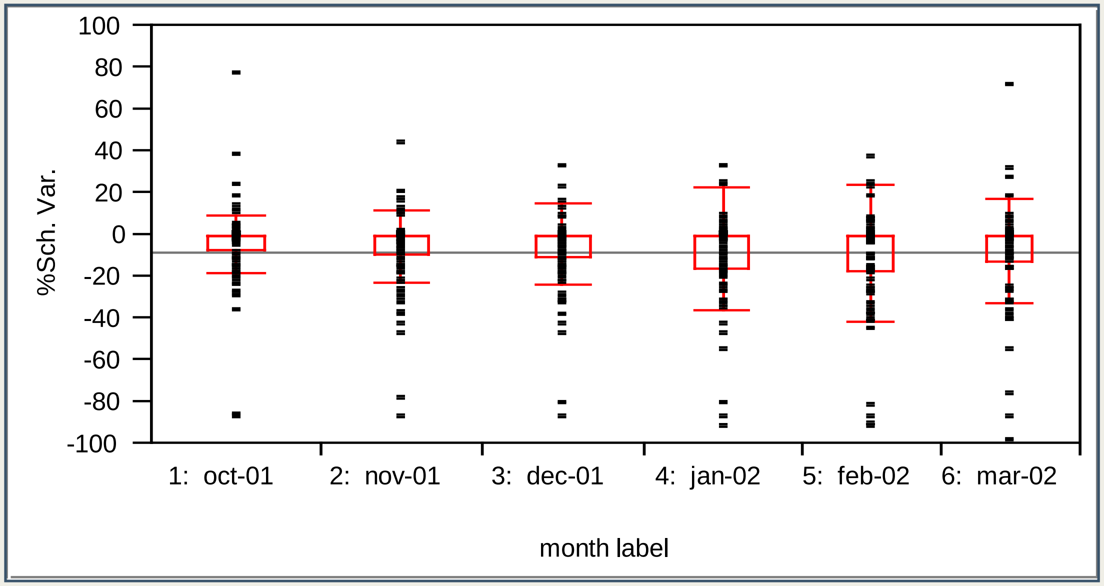
	all data	extreme values excluded
mean +/- 3 standard deviations	-32 +/- 3*423 or -1301 to 1237	-2 +/- 3*25 or -77 to 73
schedule capability spec = +/- 20%	18% of values outside spec	17% of values outside spec

In process schedule data

- all life cycle phases, all projects, Oct – June (770+ pts)

mean +/- 3 standard deviations	-7.2654498 +/- 19.23 or -64.96 to 50.43
capability notes spec = +/- 20%	17% of values outside spec

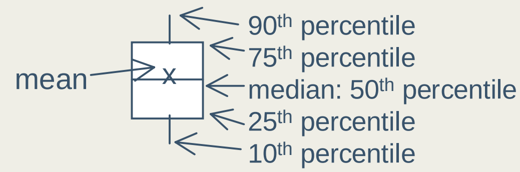
In-Process Schedule Variance Boxplot



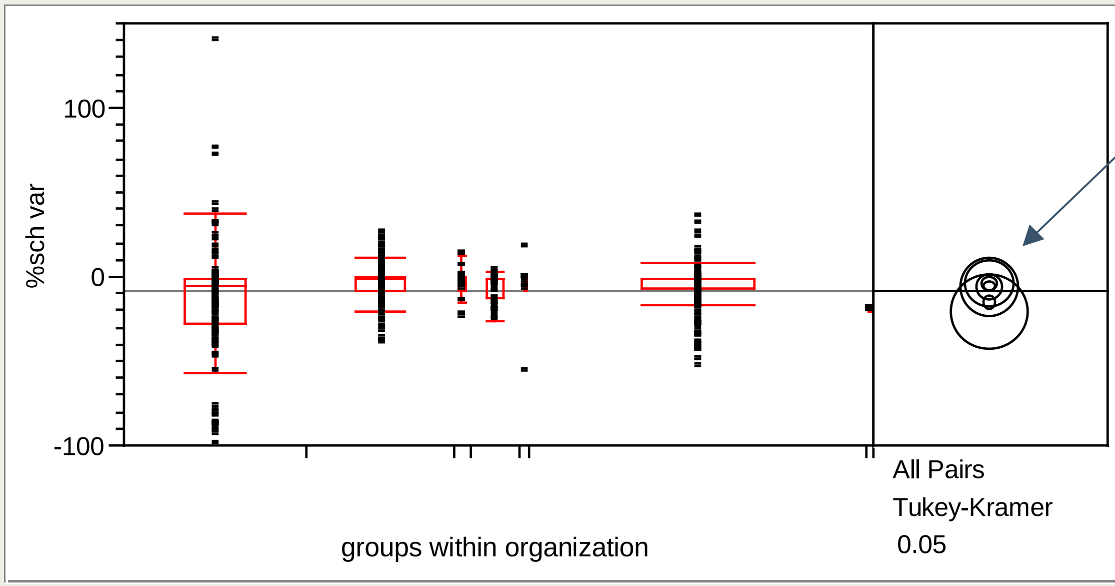
Why a boxplot and not an SPC chart?

Data reported monthly for all projects, cycle phases

Conclusion: need to address variability



Are There Group Differences?



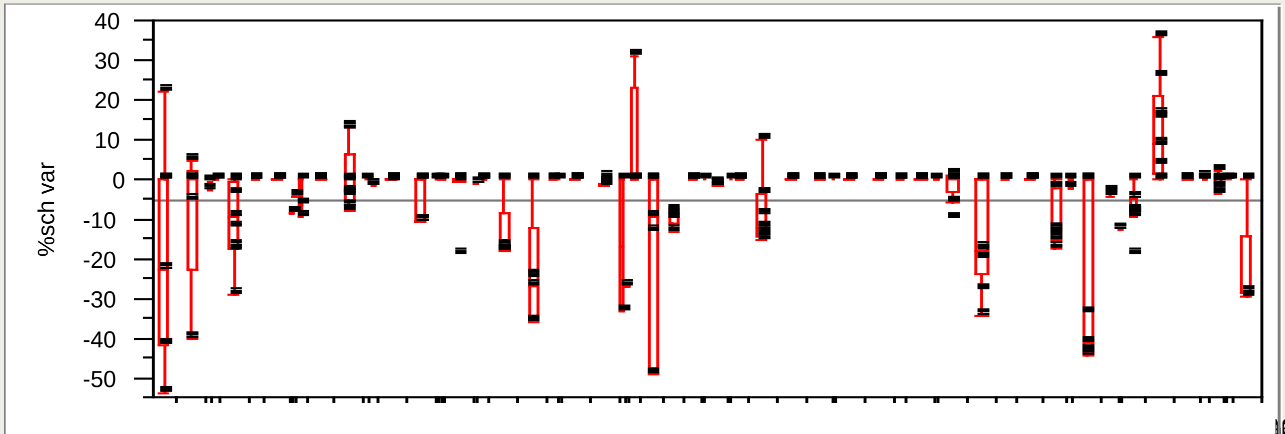
test for significant difference

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

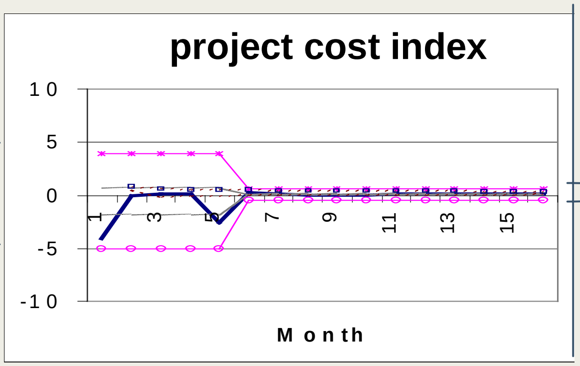
Overall rollup:

- group the data by project milestones

Within project:

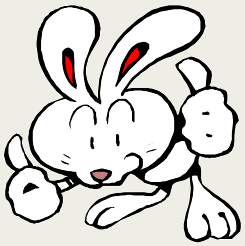
- identify different control limits for each development phase
- compare each project's phase against the history of similar projects in that same phase
- robust sample for limit calculations is critical

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

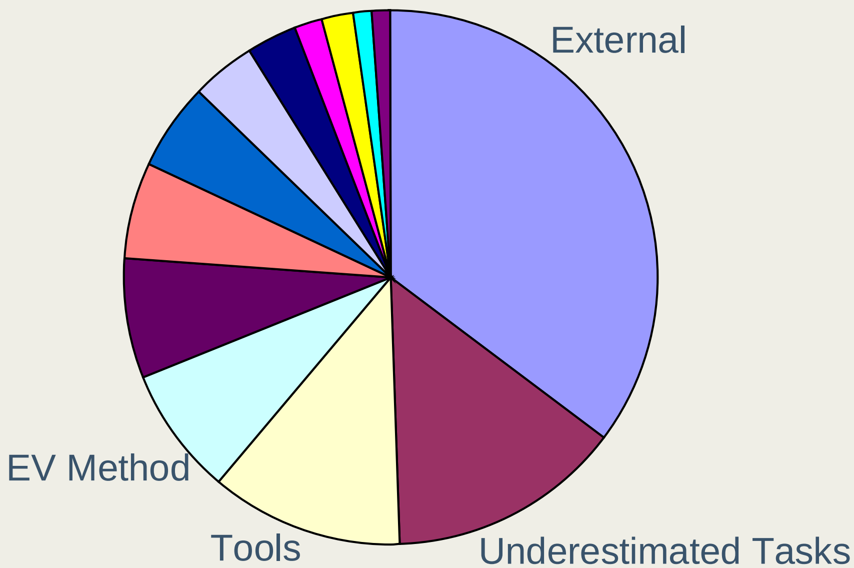
Causes resolved in-process vs. causes that affect final performance

Four High-Level Processes that Influence Final Performance

Project Management	Organizational Management
-Workload Proposal -Planning -Requirements Management -Configuration Management -Decision Analysis and Resolution -Training	-Workload Agreements -Resource Allocation -Funding -Training
Project Monitoring and Control	**Technical Processes**
-Measurement -Quality Assurance -Peer Review	-Design -Implement -Formal Test -Release

Cause Codes were mapped to these processes

Prioritizing the Causes



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

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”

Data Treatments

Project	Month	Cause Code	Variance	Repeat?
A	1	4	4	
A	2	4	3	Y
A	3	5	7	
B	1	2	2	
B	2			
B	3	4	4	
C	1	5	8	
C	2			
C	3			

Cause Code	frequency	impact (average)	frequency x impact (or sum)
2	1	2	2
4	2	4	8
5	2	7.5	15

Might also use median

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	
frequency	impact
H	H
M	M
L	L

Co-Optimizing Across the Organization – Internal Causes

Impact # (from Pareto)	Schedule	Effort	Organization Slice 1 Schedule	Organization Slice 1 Effort	Organization Slice 2 Schedule	Organization Slice 2 Effort
1	Under estimated Task	Tools	Under estimated Task	Under estimated Task	Tools	Tools
2	Tools	Assets not available	EV Problems	Under planned rework	Skills mismatch	Under estimated Task
3	EV Problems	Under planned rework	Missed requirements	Missed requirements	Under estimated Task	Missed requirements
4	Missed requirements	Planned work not performed	Under planned rework	EV Problems	Missed Requirements	Unexpected departure of personnel
5	Skills Mismatch	Under estimated task	Asset availability	Planned work not performed	Unexpected departure	EV Problems

In-process data as leading indicator

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

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 1

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.

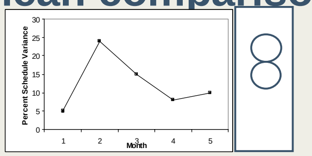
Who uses the dashboards and MBFs?

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

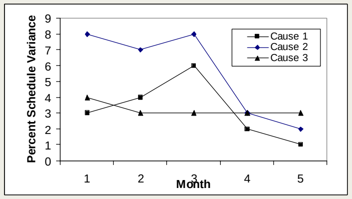
Notional Management by Fact (MBF)

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

Total variance w/ mean comparison



Variance for top 3 causes:
- **Underestimated Tasks**
- **EV Method Problem**
- **Missed Requirements**



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

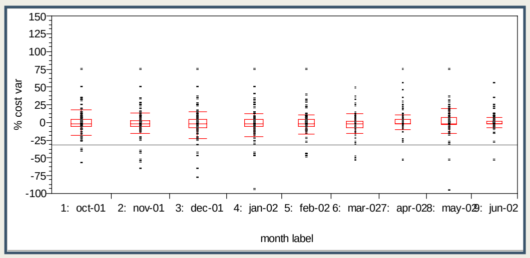
Earned Value Data

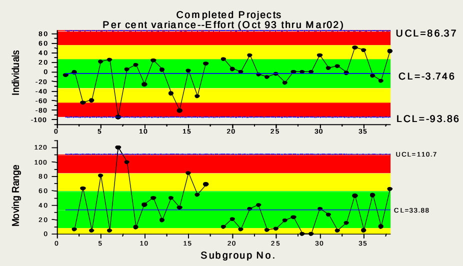
In-process data:

• monthly schedule index, cost index by project milestones

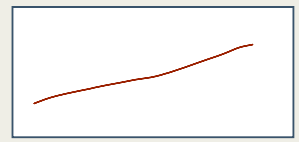
Completed projects data:

• control chart
• % outside spec
• contribution of internal causes to completed project variance

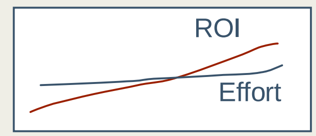




Customer Satisfaction



Return on Investment



"return" = variance reduction translated into $$

Defect Data: Tally of Field Defects

Note: In-process profiles to be shown on "group level" dashboards

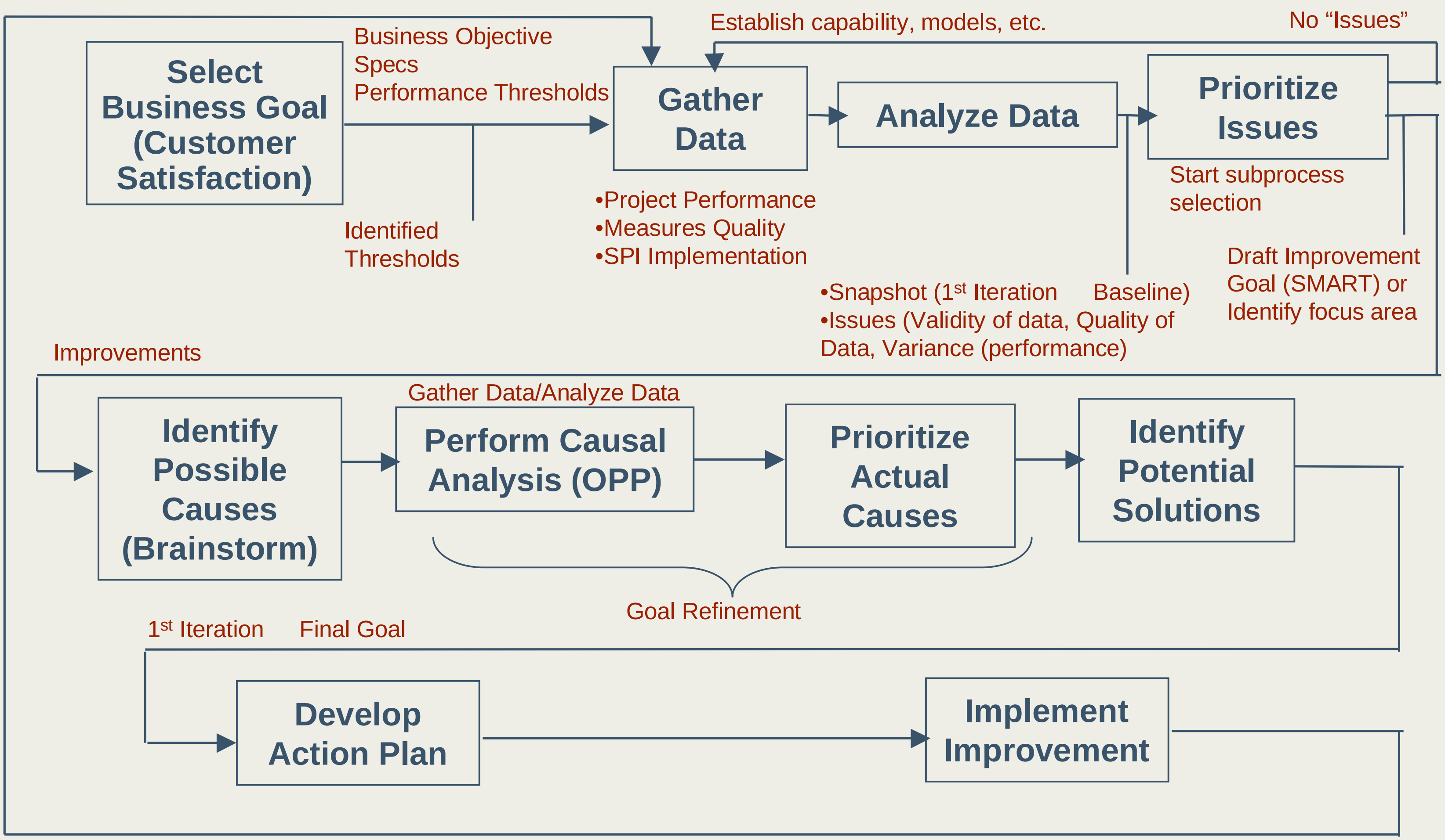
Measurement Quality

Completeness
Accuracy
Procedural Adherence

Other possible inclusions:

• Engineering process procedural adherence (as a leading indicator for EV, defect and measurement quality performance)

Organization Specific Process



Case Study Summary 1

- 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

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”

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Case Study Summary - Tools Used

control charts for limited analysis NOT as control mech.

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

adapted technique for impact evaluation

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

anticipate future use for these improvement efforts

Control

Statistical Controls:

- Control Charts
- Time Series methods

Non-Statistical Controls:

- **Procedural adherence**
- Performance Mgmt
- Preventive activities

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.

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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

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Note: URL's subject to change without notice

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Addenda

Additional vignettes

Tool tips

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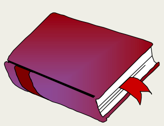
Example of an Aid for Operational Definitions using Orthogonal Classification

Problem Status	**Include**	**Exclude**	**Value Count**	**Array Count**
Open	✓		✓	
Recognized				✓
Evaluated				✓
Resolved				✓
Closed	✓		✓	
Problem Type	**Include**	**Exclude**	**Value Count**	**Array Count**
Software defect				
Requirements defect	✓		✓	
Design defect	✓		✓	
Code defect	✓		✓	
Operational document defect	✓		✓	
Test case defect		✓		
Other work product defect		✓		
Other problems				
Hardware problem		✓		
Operating system problem		✓		
User mistake		✓		
Operations mistake		✓		
New requirement/enhancement		✓		
Undetermined				
Not repeatable/Cause unknown		✓		
Value not identified		✓		
Uniqueness	**Include**	**Exclude**	**Value Count**	**Array Count**
Original	✓			
Duplicate		✓	✓	
Value not identified		✓		
Criticality	**Include**	**Exclude**	**Value Count**	**Array Count**
1st level (most critical)	✓			✓
2nd level	✓			✓
3rd level	✓			✓
4th level	✓			✓
5th level	✓			✓
Value not identified		✓		
Urgency	**Include**	**Exclude**	**Value Count**	**Array Count**
1st (most urgent)	✓			
2nd	✓			
3rd	✓			
4th	✓			
Value not identified		✓		



Reference Page 33

Compliance Issues

May be basis for assignable causes

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

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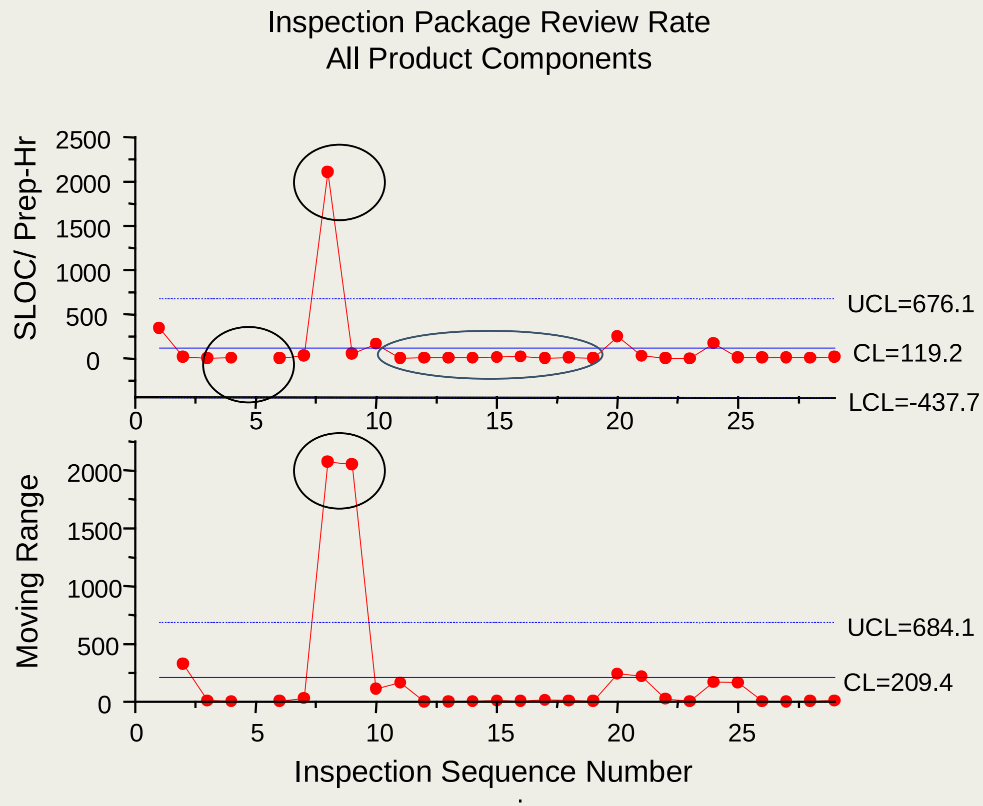
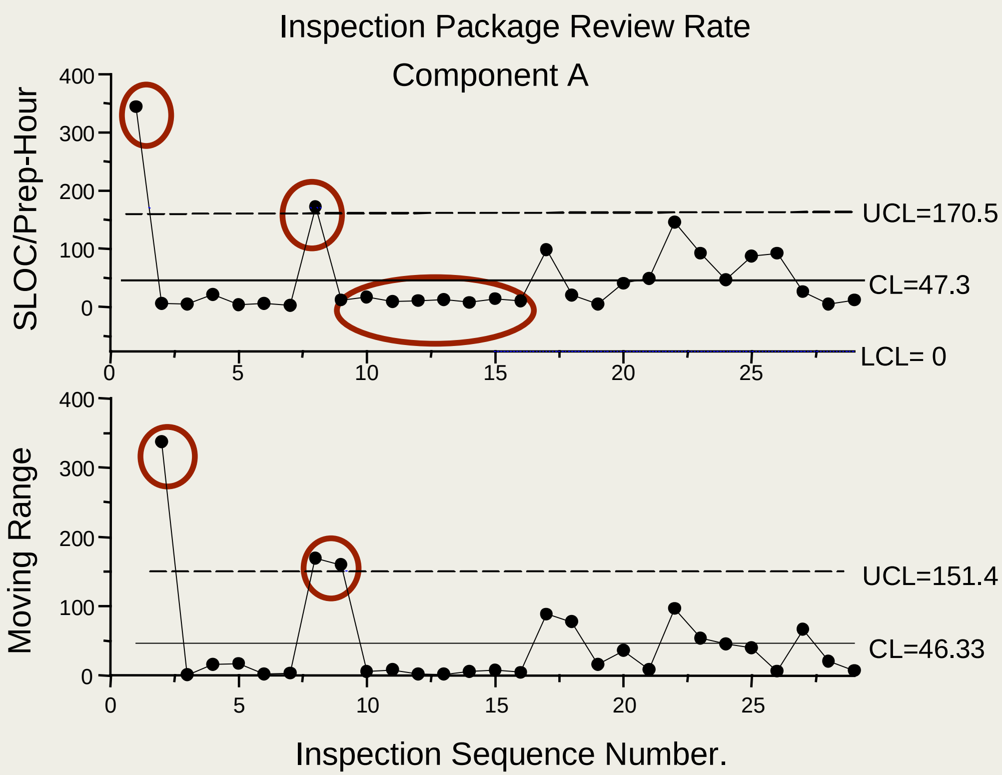
Initial Control Chart of Inspection Package Review Rate (SLOC/Prep-Hr)



Assignable causes due to:

- Erroneous and Missing Data
- Multiple Cause Systems (six components each with own development team)

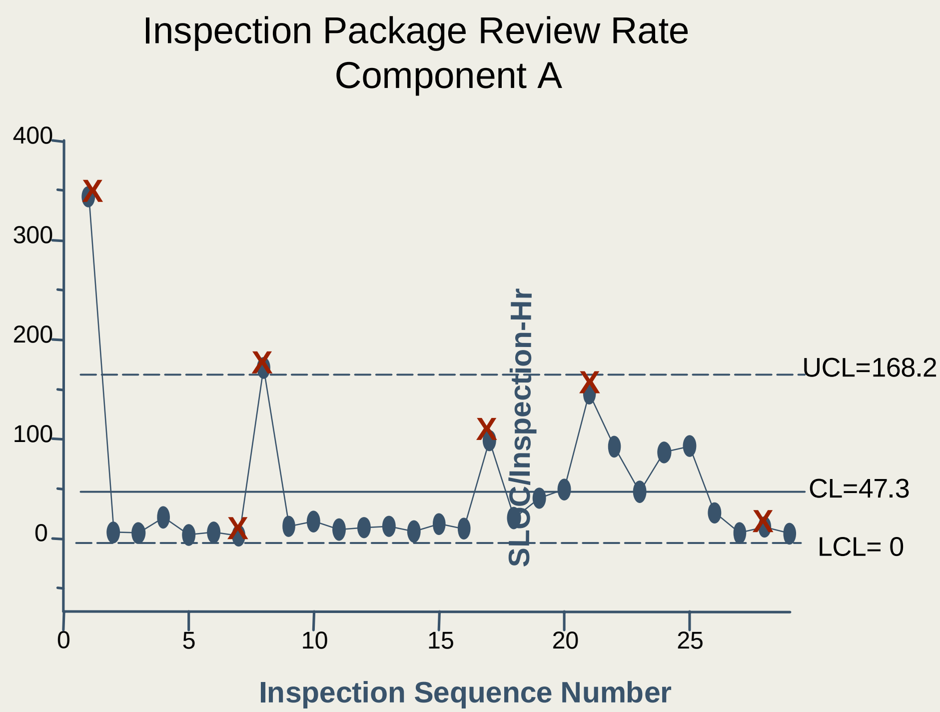
Inspection Package Review Rate for Component A



Re-analyzed data

- Data errors eliminated
- Consider single major cause system at a time
- Control chart for one component
- Several assignable causes apparent

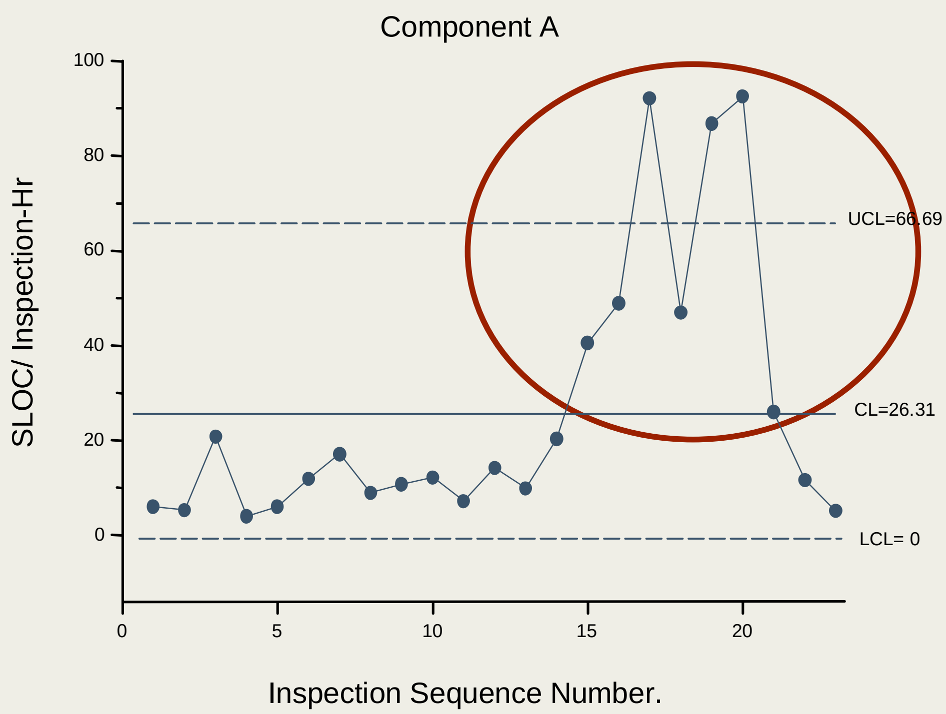
Component A Review Rate



Investigation resulted in removal of separate cause systems included in inspection packages:

- data tables
- lists
- arrays
- different review process

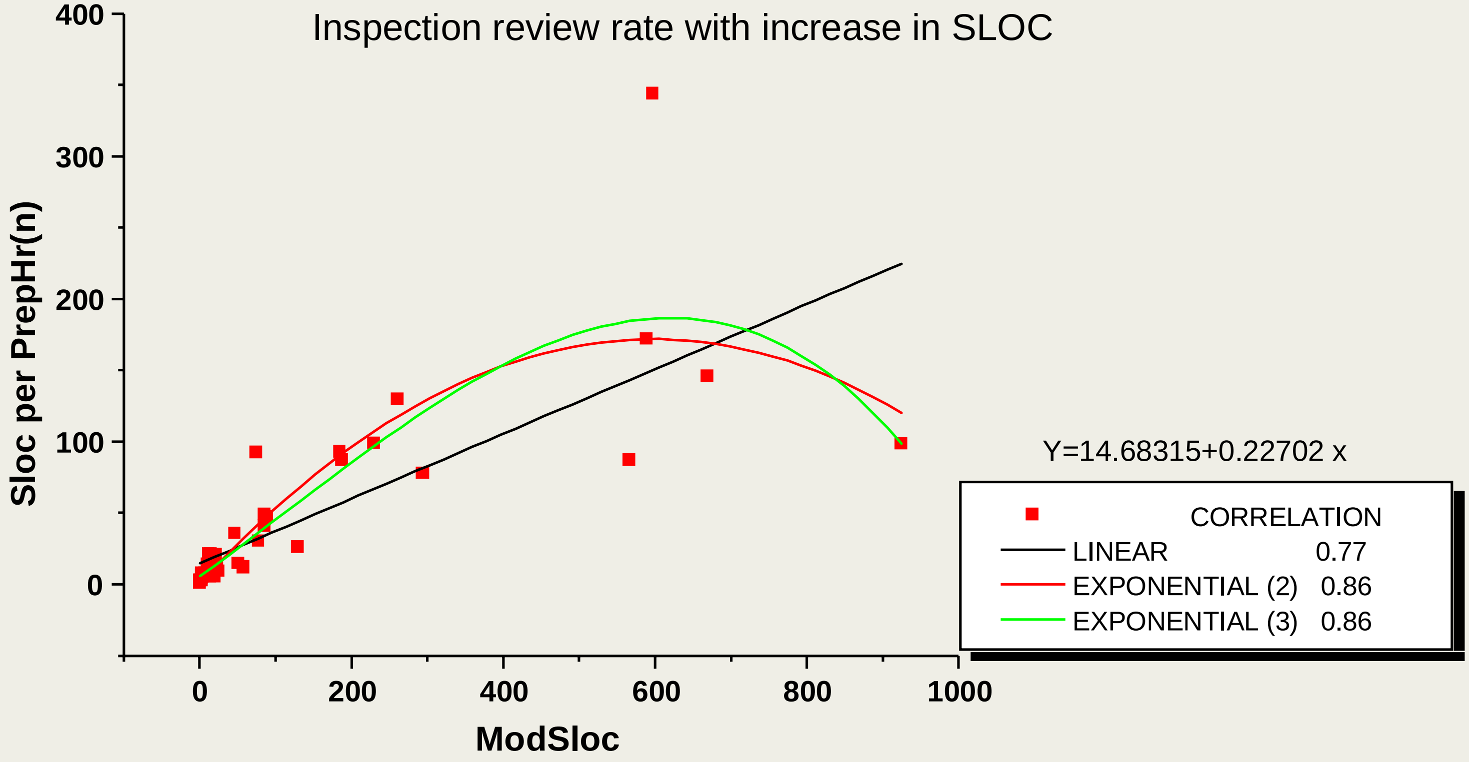
Component A Revision



Process Instability: Apparent shift of process performance after #15

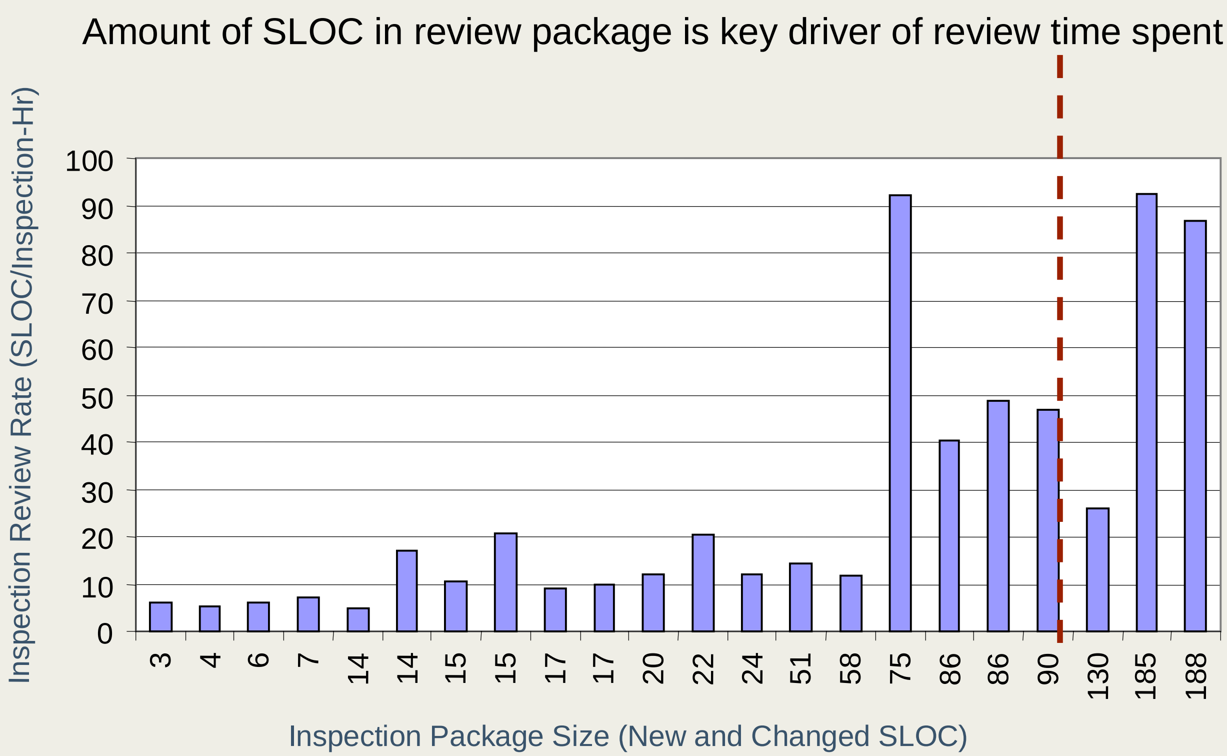
Leads to investigation of changes in process cause systems

Cause-and-Effect Relationships

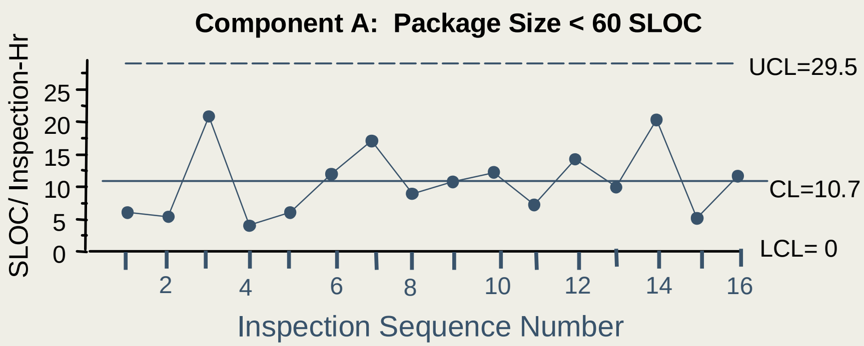


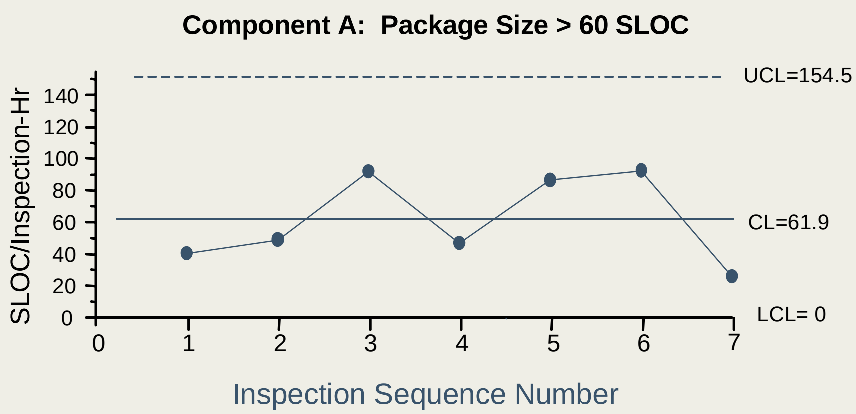
Component A Review Rate

Distribution of review rates by SLOC size



Component A Review Rate





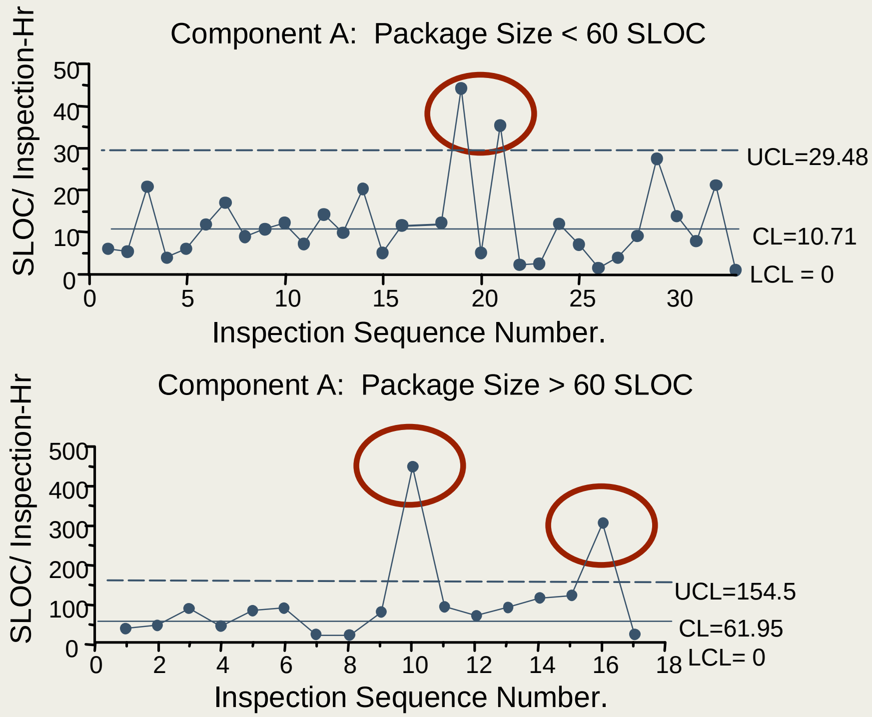
Replot data using two charts:

- 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

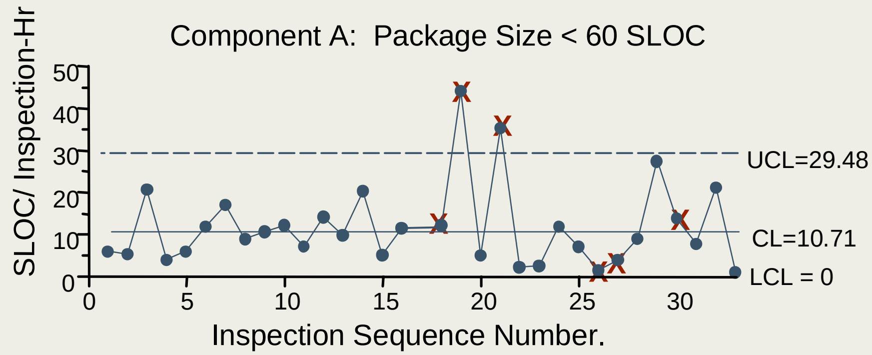
Component A Review Rate

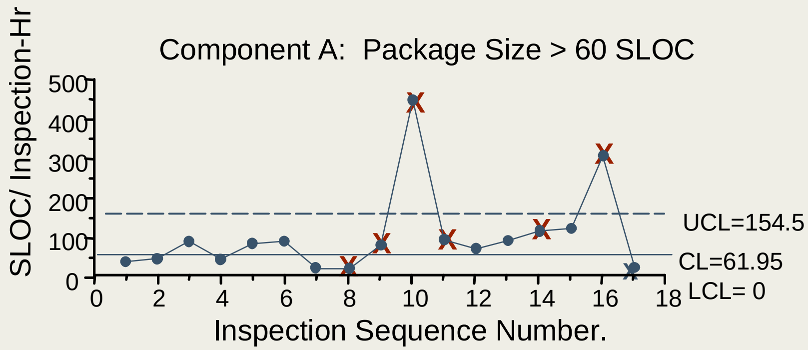


Additional observations identify more assignable causes

Investigation determines that assignable cause observations from re-inspection process

Component A Review Rate





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

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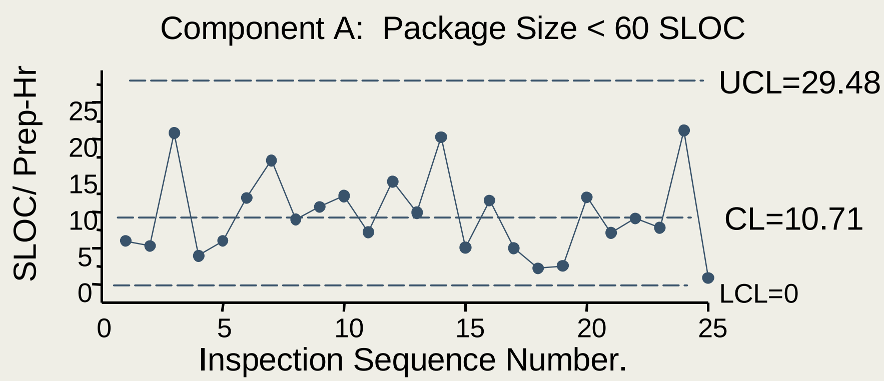
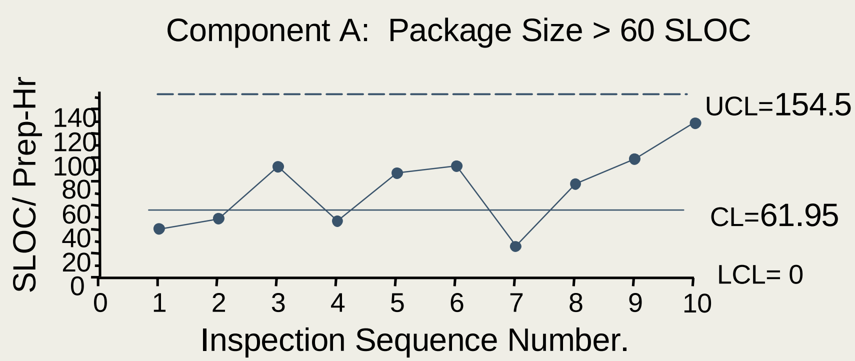
Component A Review Rate





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

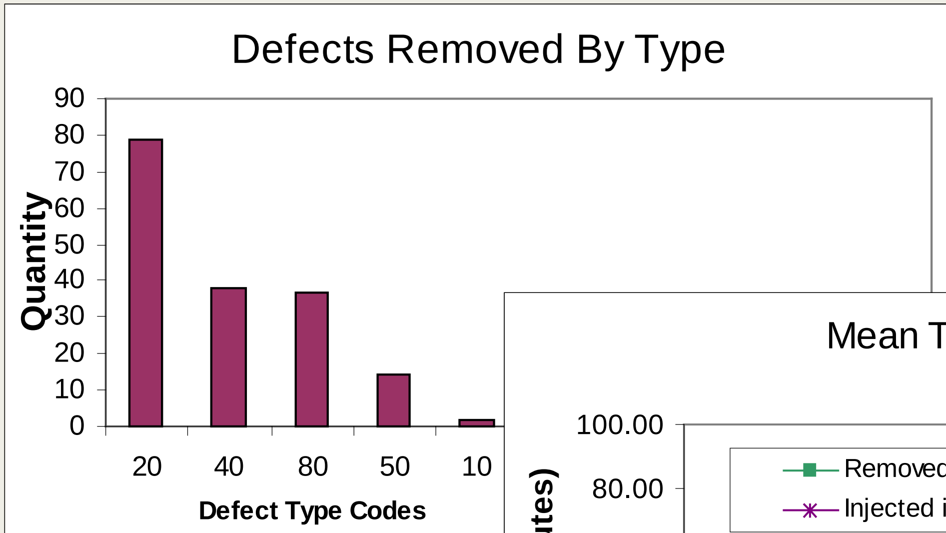
Explore cause-effect relationships

Prioritize issues

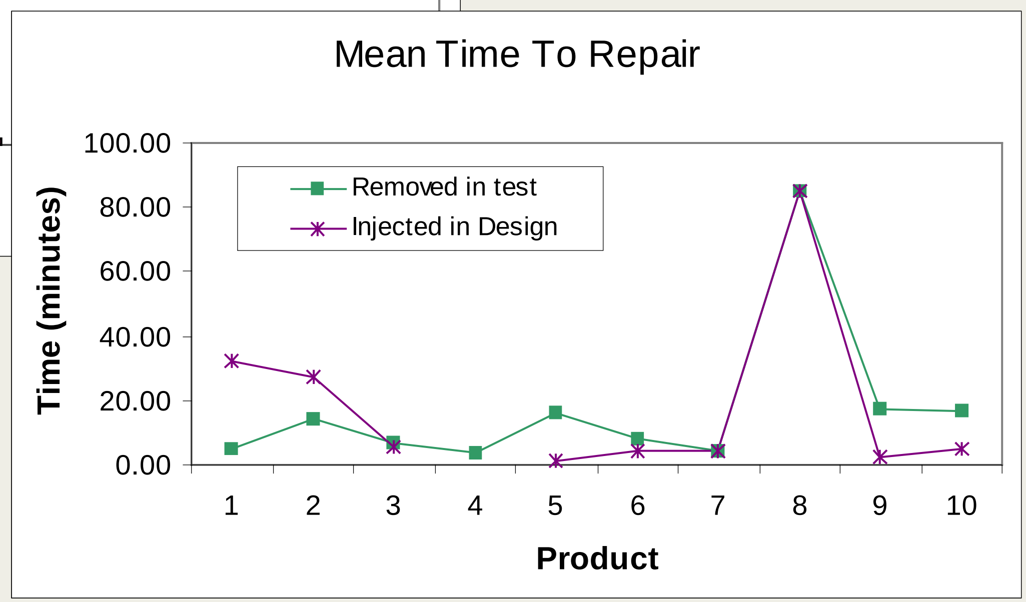
Determine stability and capability of processes

7 Basic Tools: Chart Examples 1

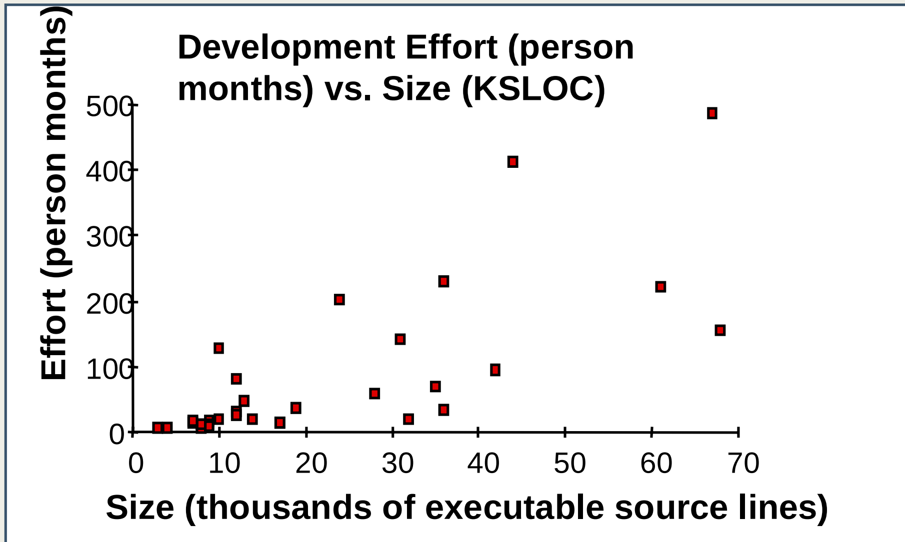
Pareto Chart



Run Chart

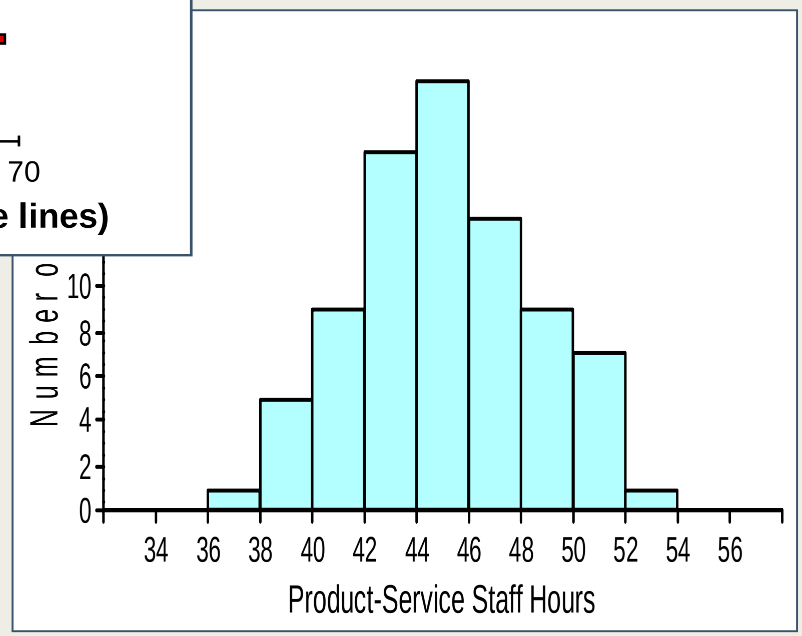


7 Basic Tools: Chart Examples 2

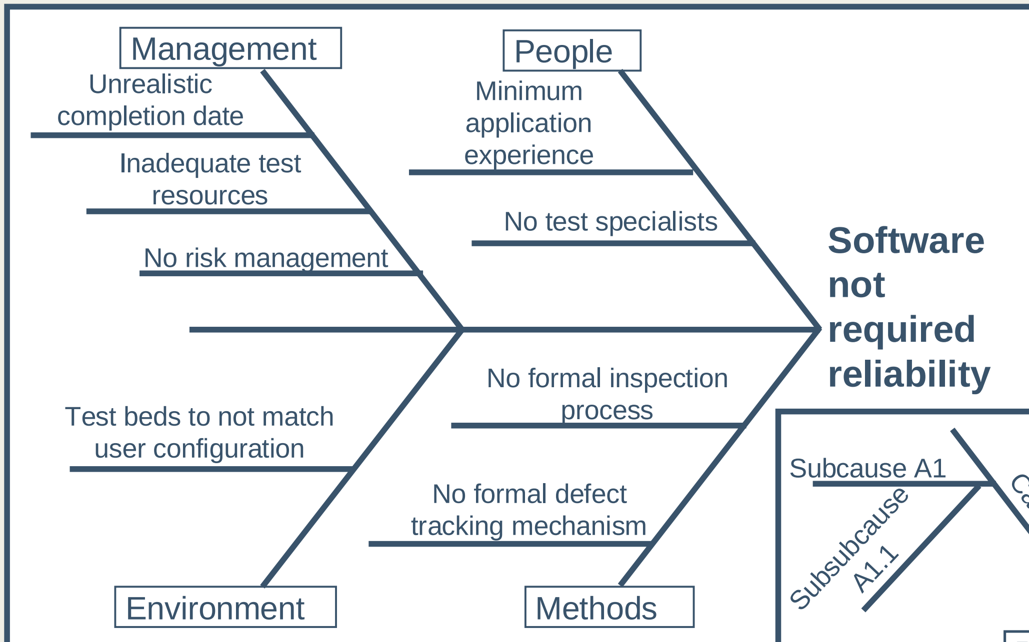


Scatter Plot

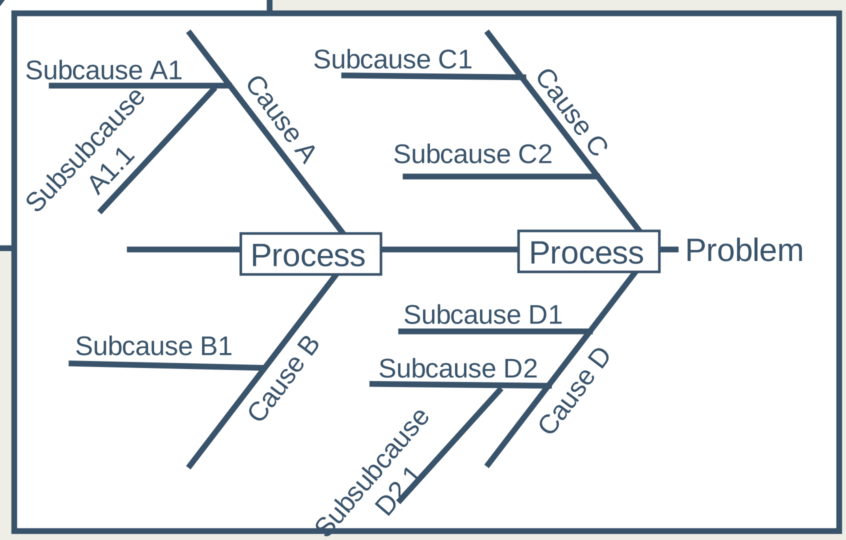
Histogram



7 Basic Tools: Cause & Effect



Traditional diagram

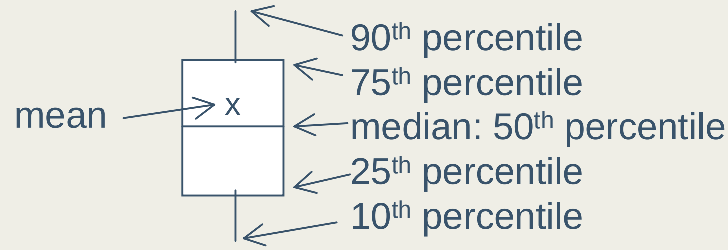


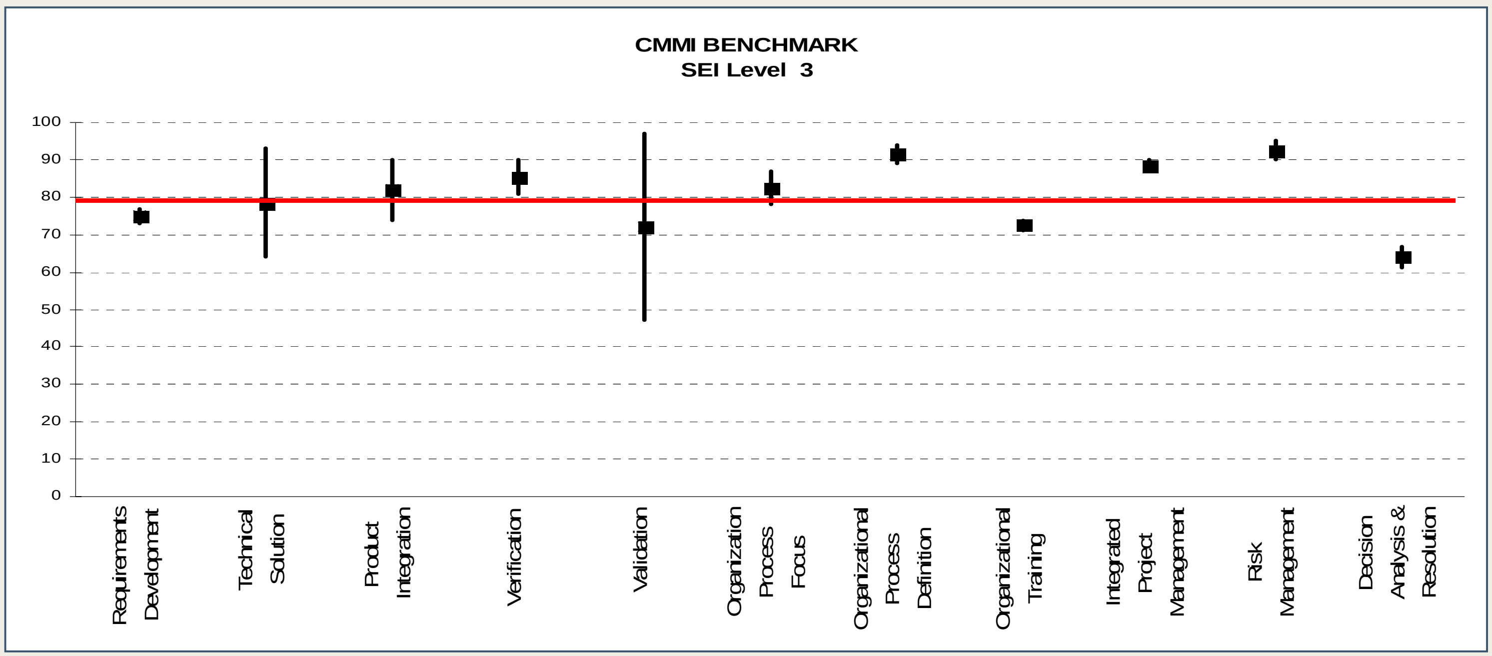
Variation

[Westfall]

7 Basic Tools: Chart Variations

Box & Whisker Plot
for assessment data

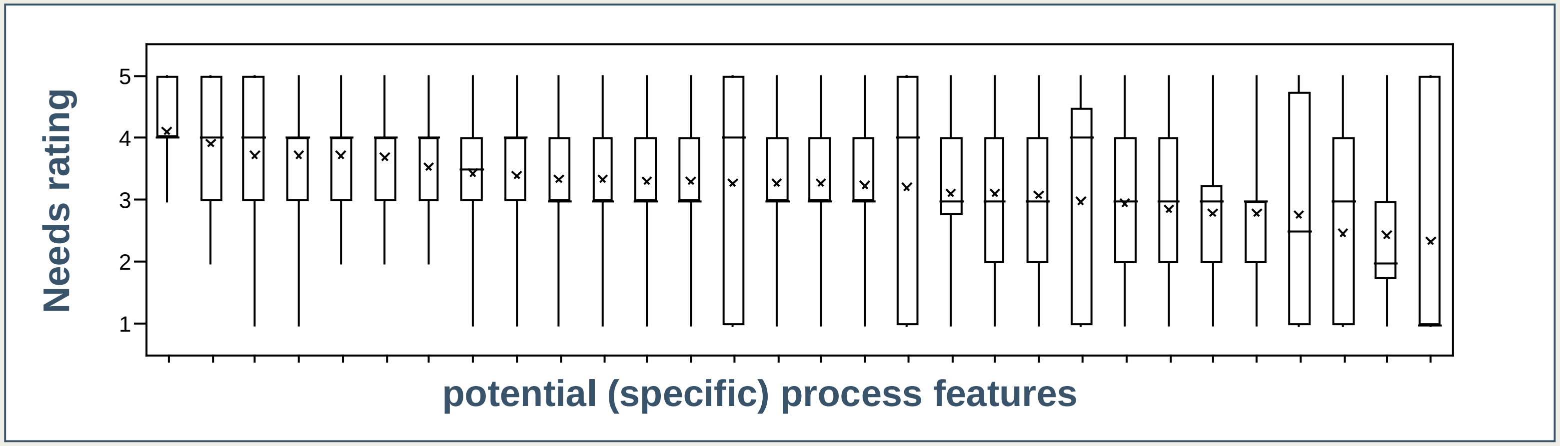




7 Basic Tools: Chart Variations

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

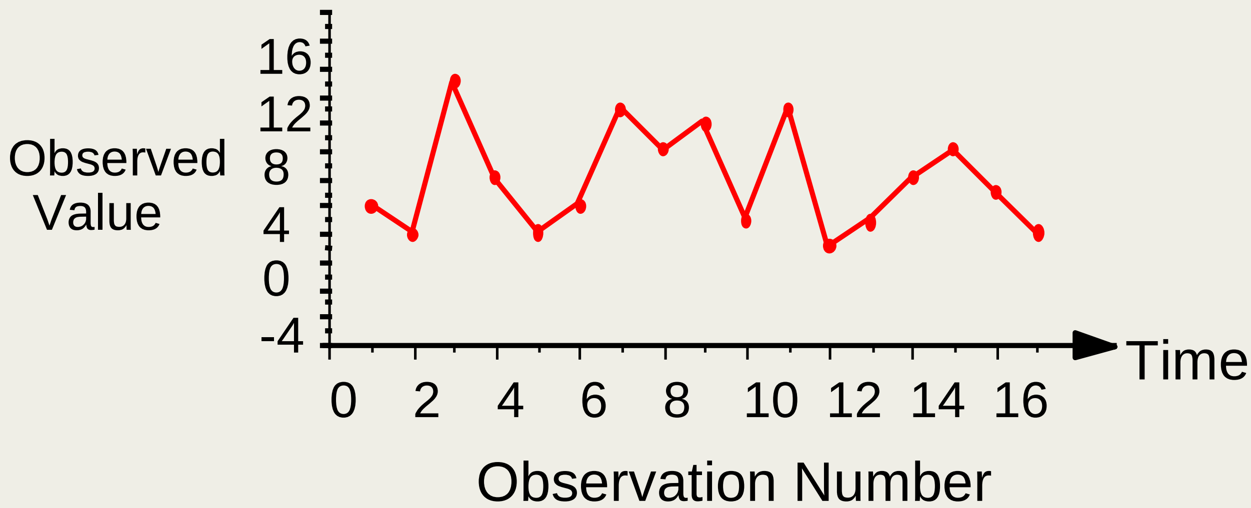
Description

- 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

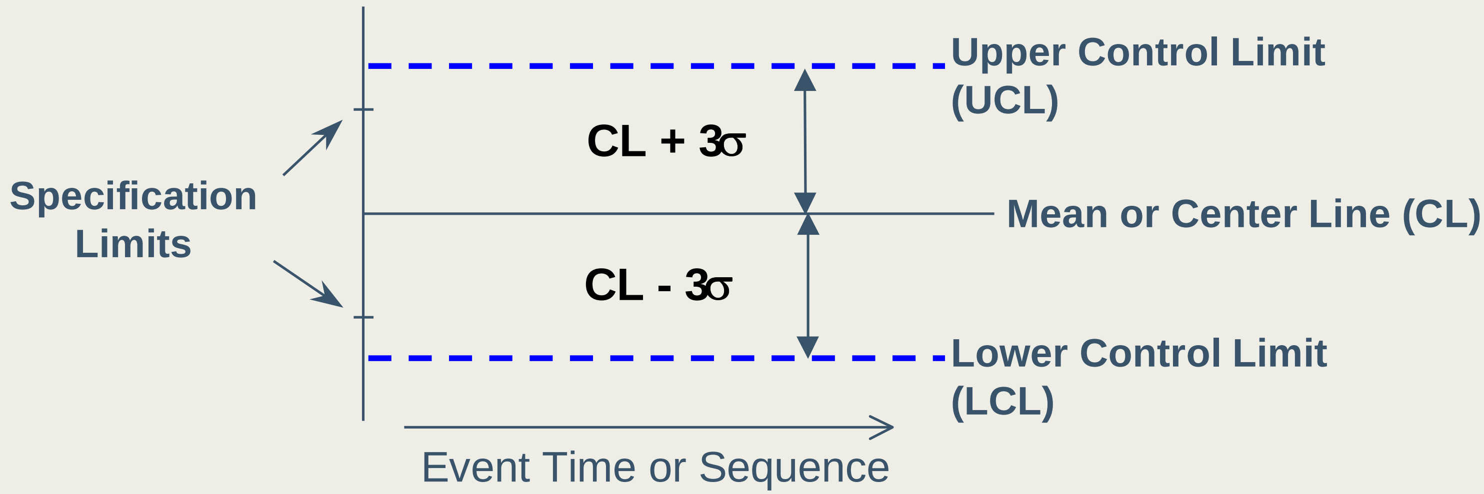
Description

- 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



Limits

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

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

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!

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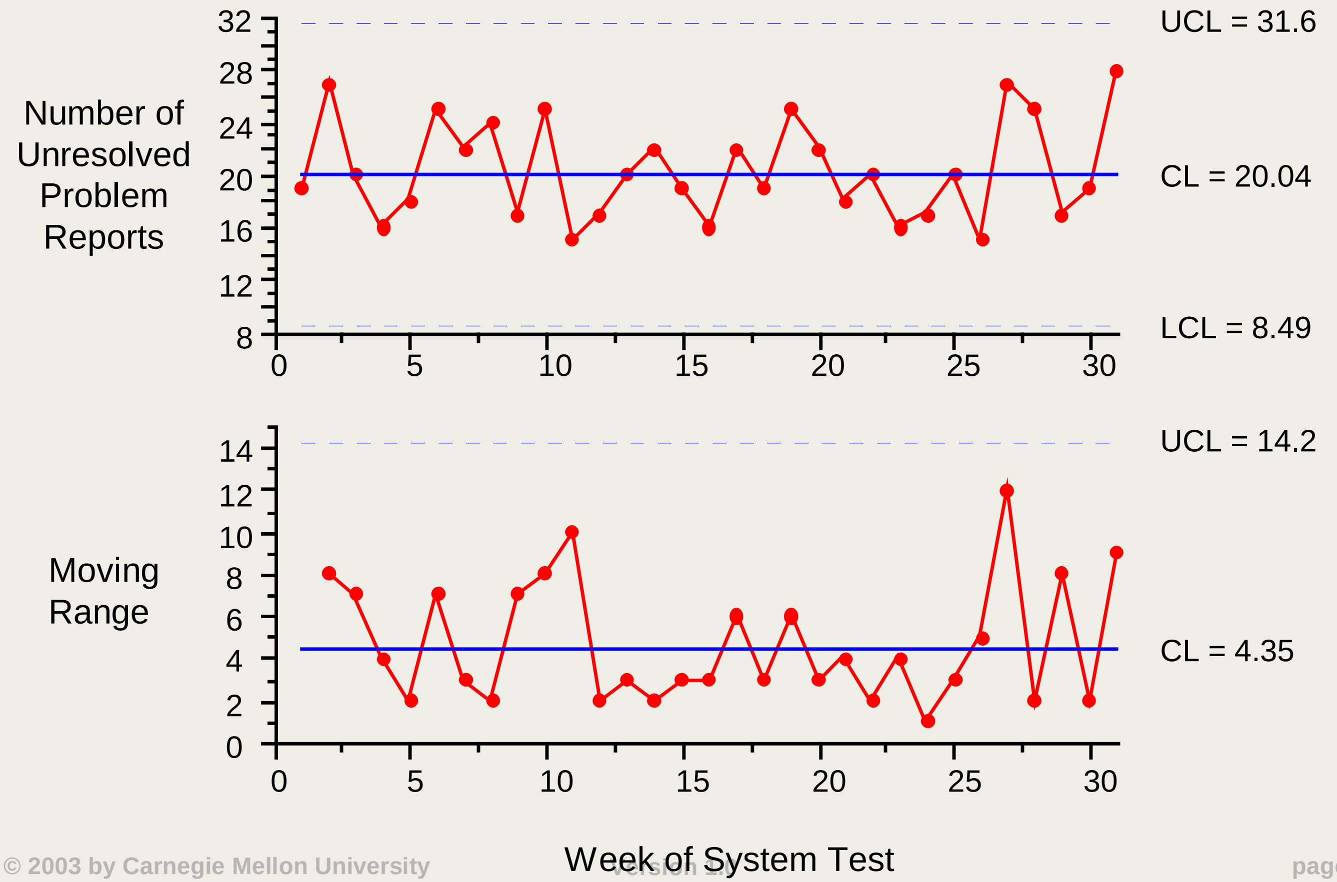
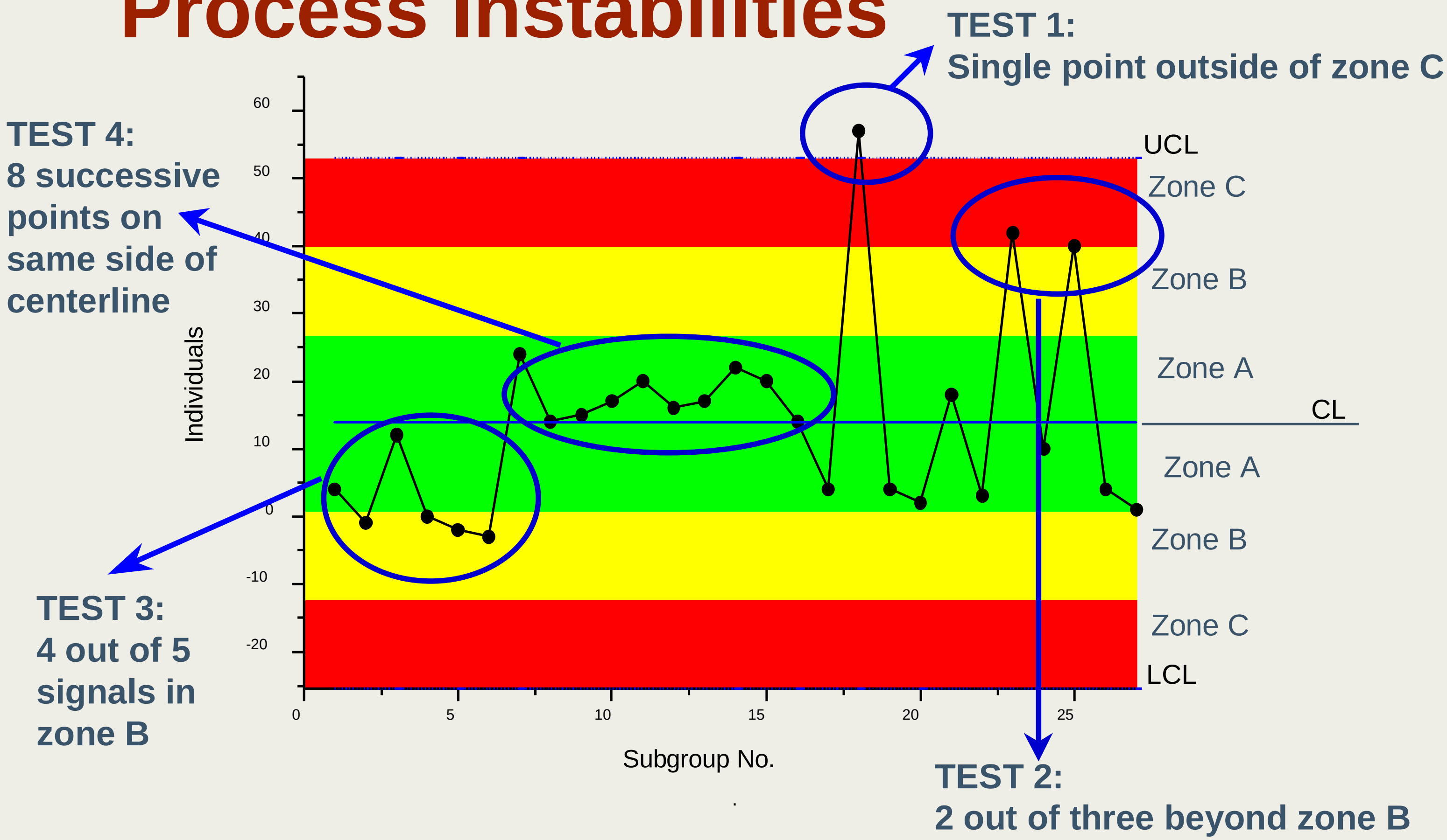
SPC: Example



SPC: Rules for Detecting Process Instabilities



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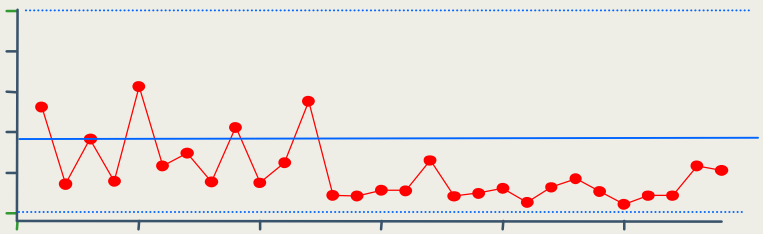
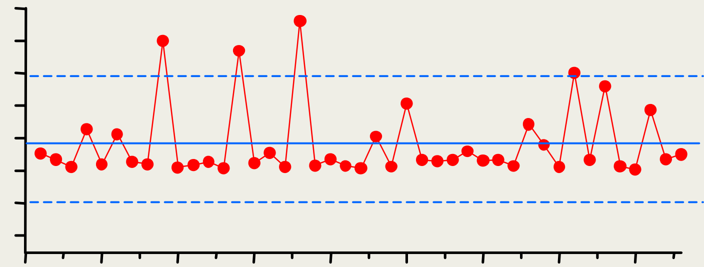
SPC: Anomalous Patterns

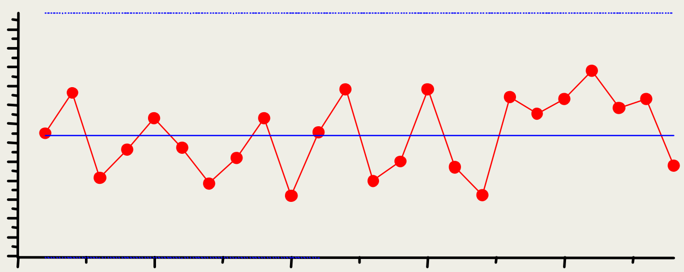
Rapid Shift in Level



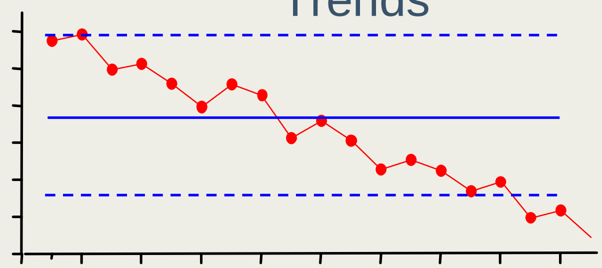
Unstable Mixture



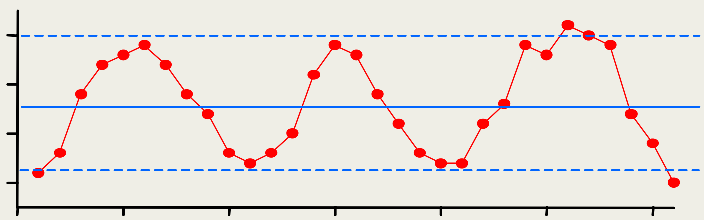
Stratification



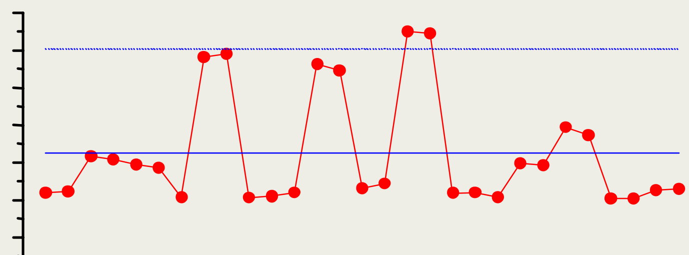
Trends



Cycles Pattern



Bunching or Grouping



Tooltip: Scatter Plots

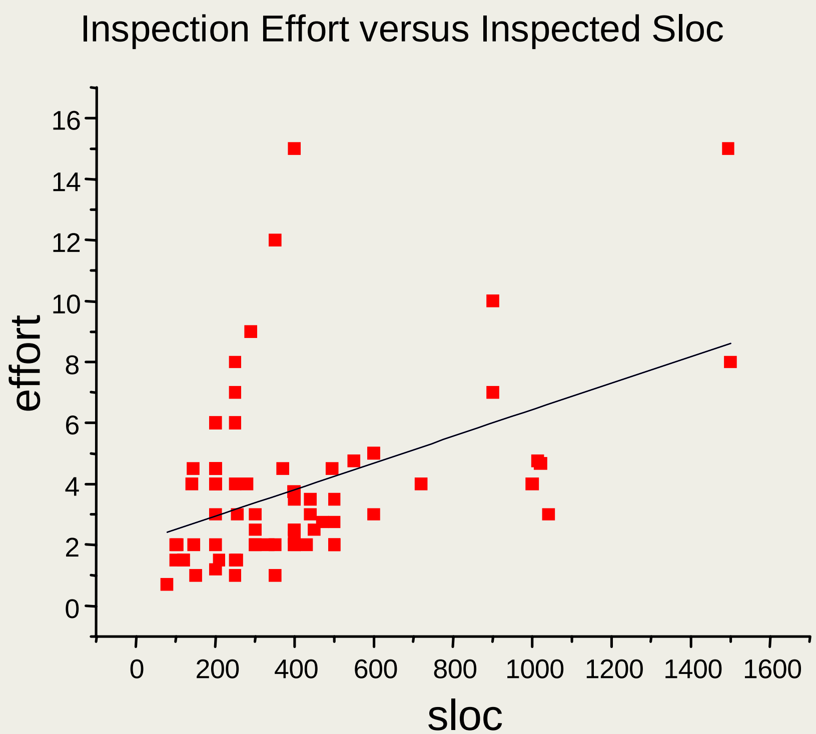
Description

- 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



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

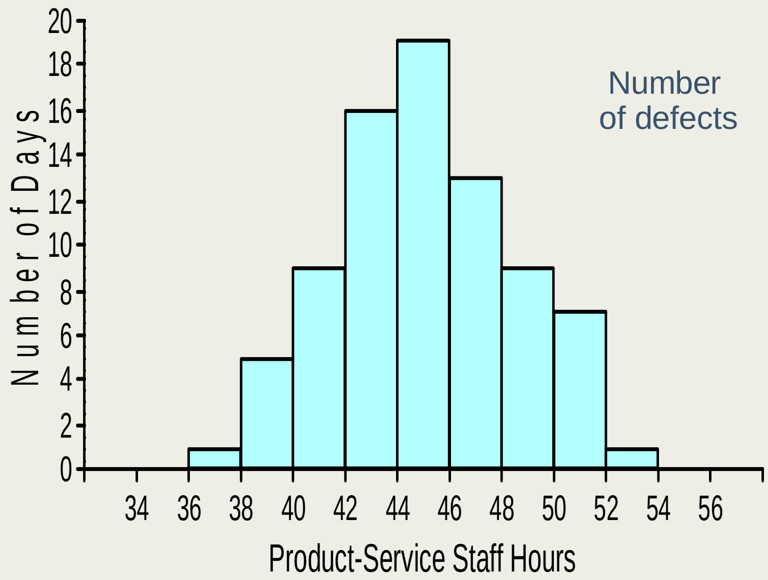
Description:

- 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

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.

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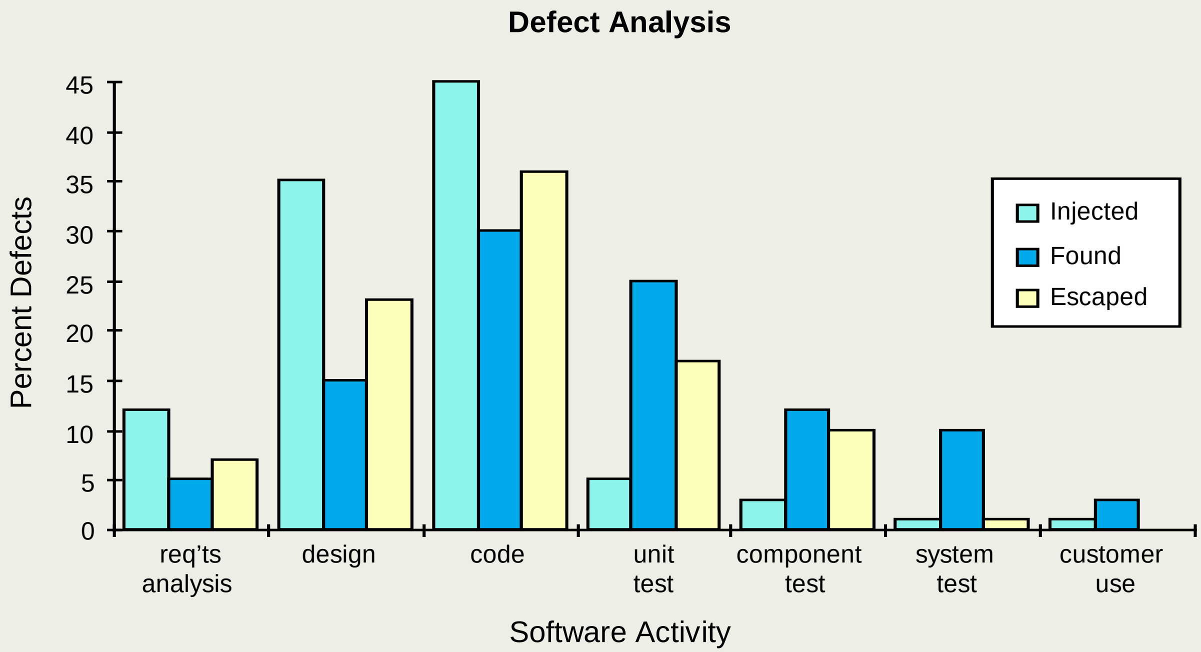
Bar Charts: Example



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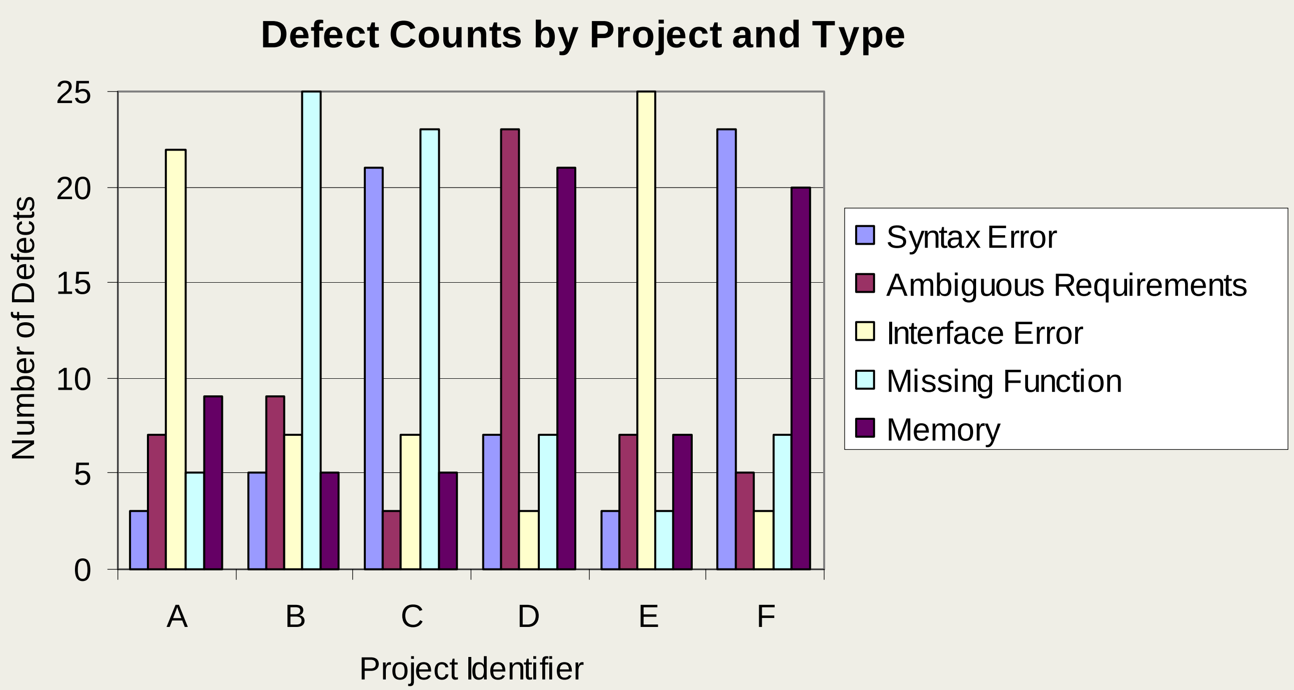
Bar Charts: A Word of Caution

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



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.

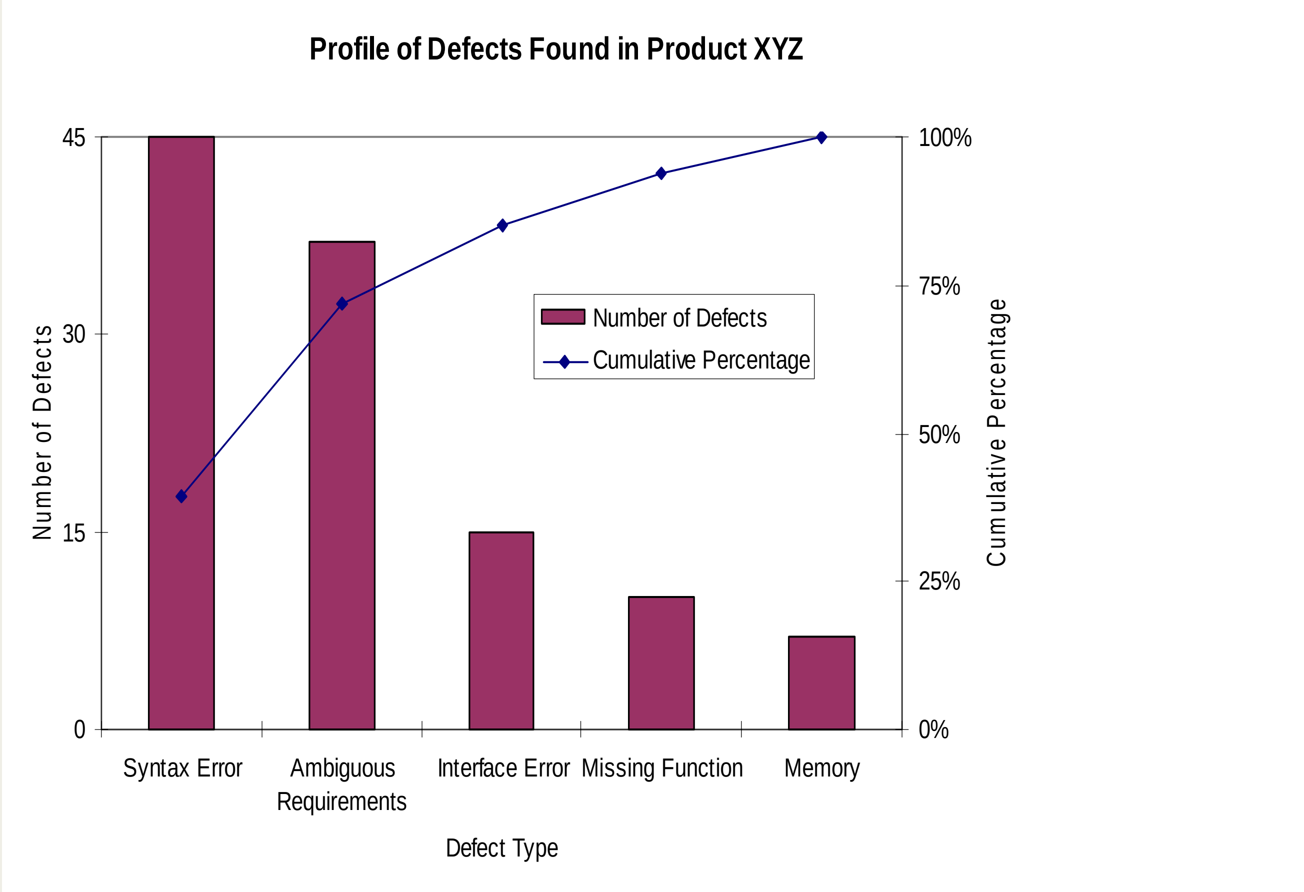
Usage:

- 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



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.

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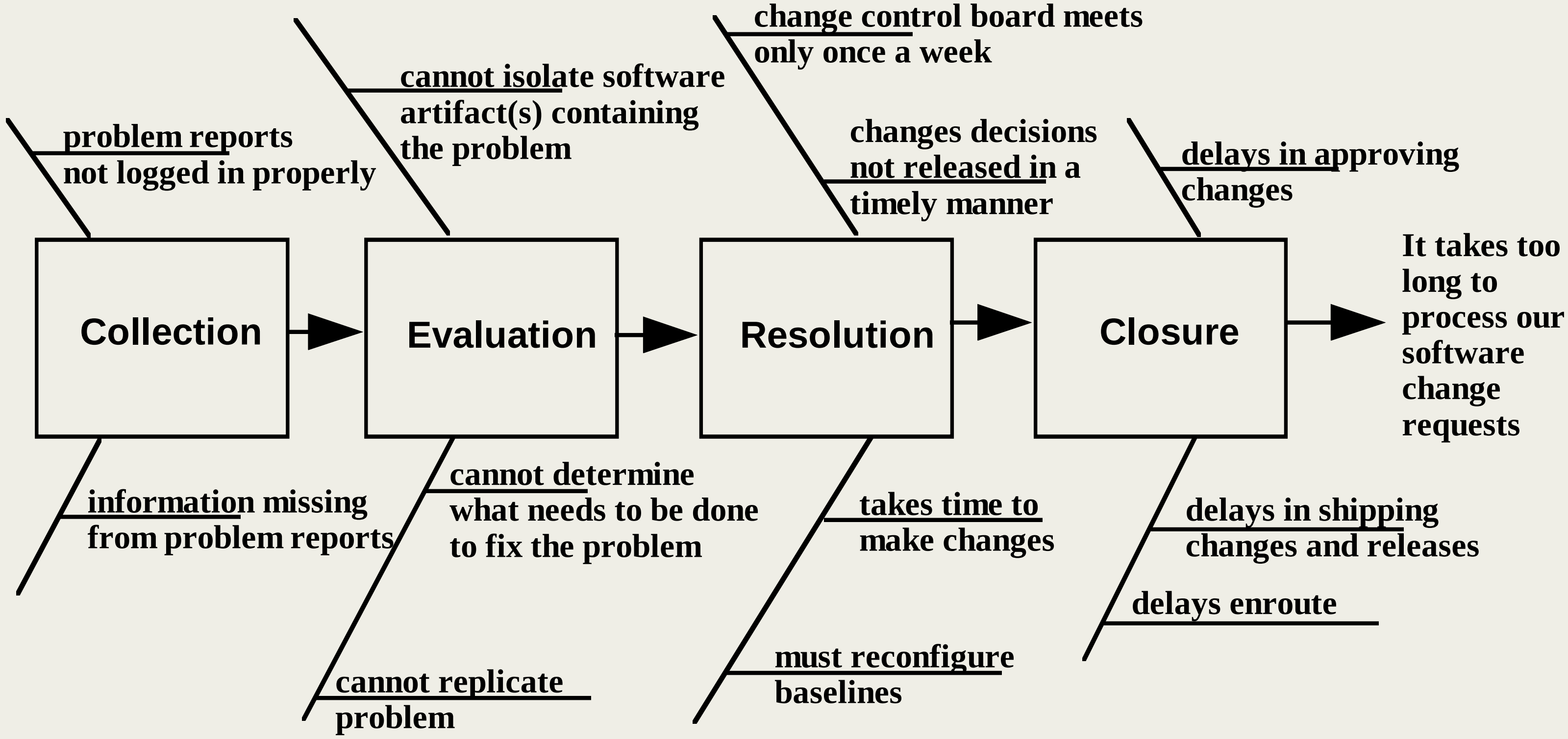
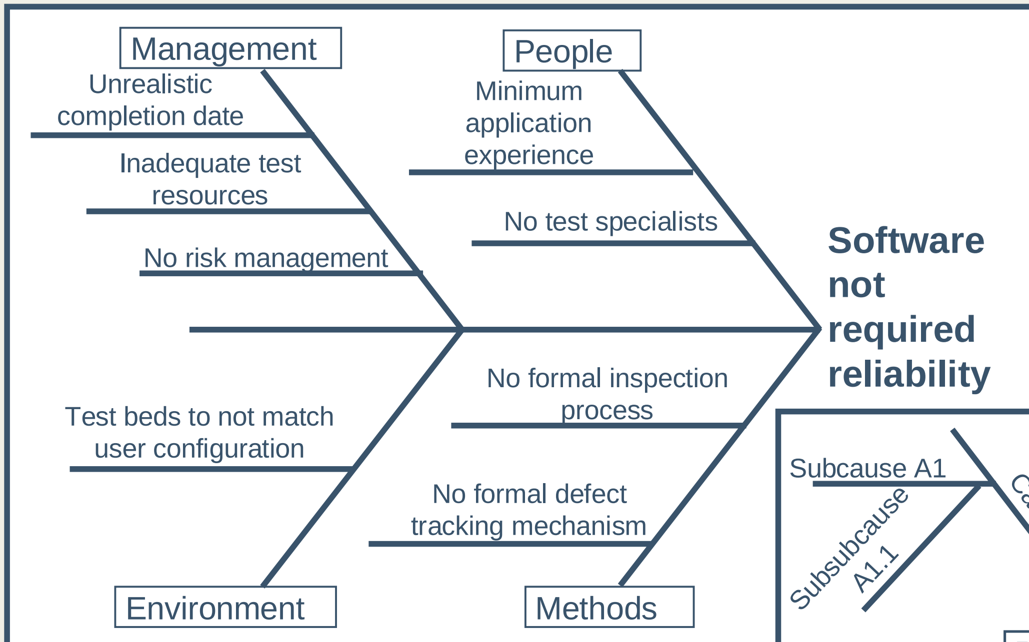
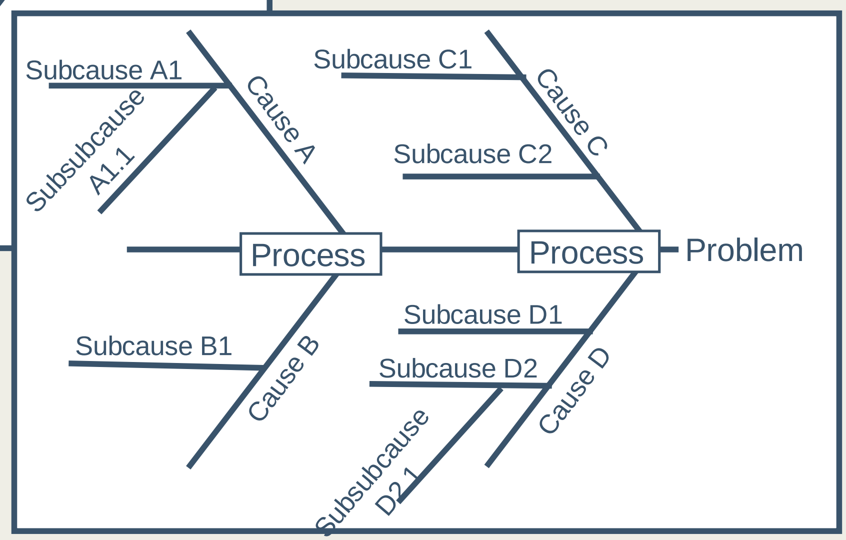
Cause & Effect Diagram: Example



Basic Tools: Cause & Effect

Traditional diagram





Variation

[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

[Hexsab 02]

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.)

[Hexsab 02]

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

	Y's:								
	Y ratings:								
Process steps	**X's**	**X relationship to Y**							**Sum**

[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

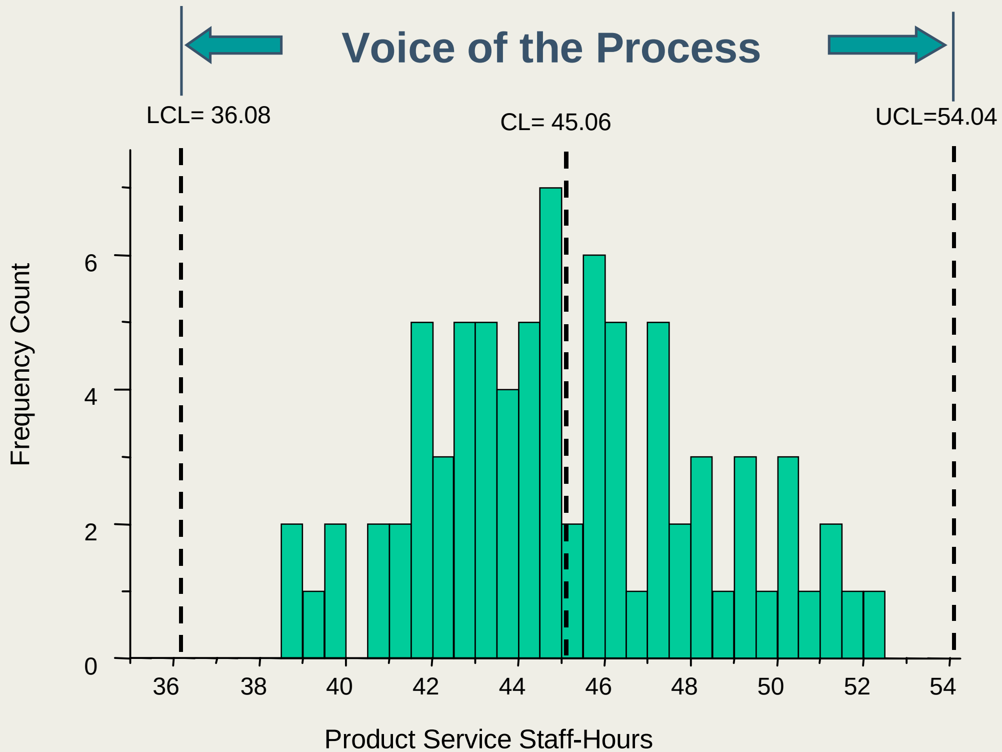
Description

- 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.

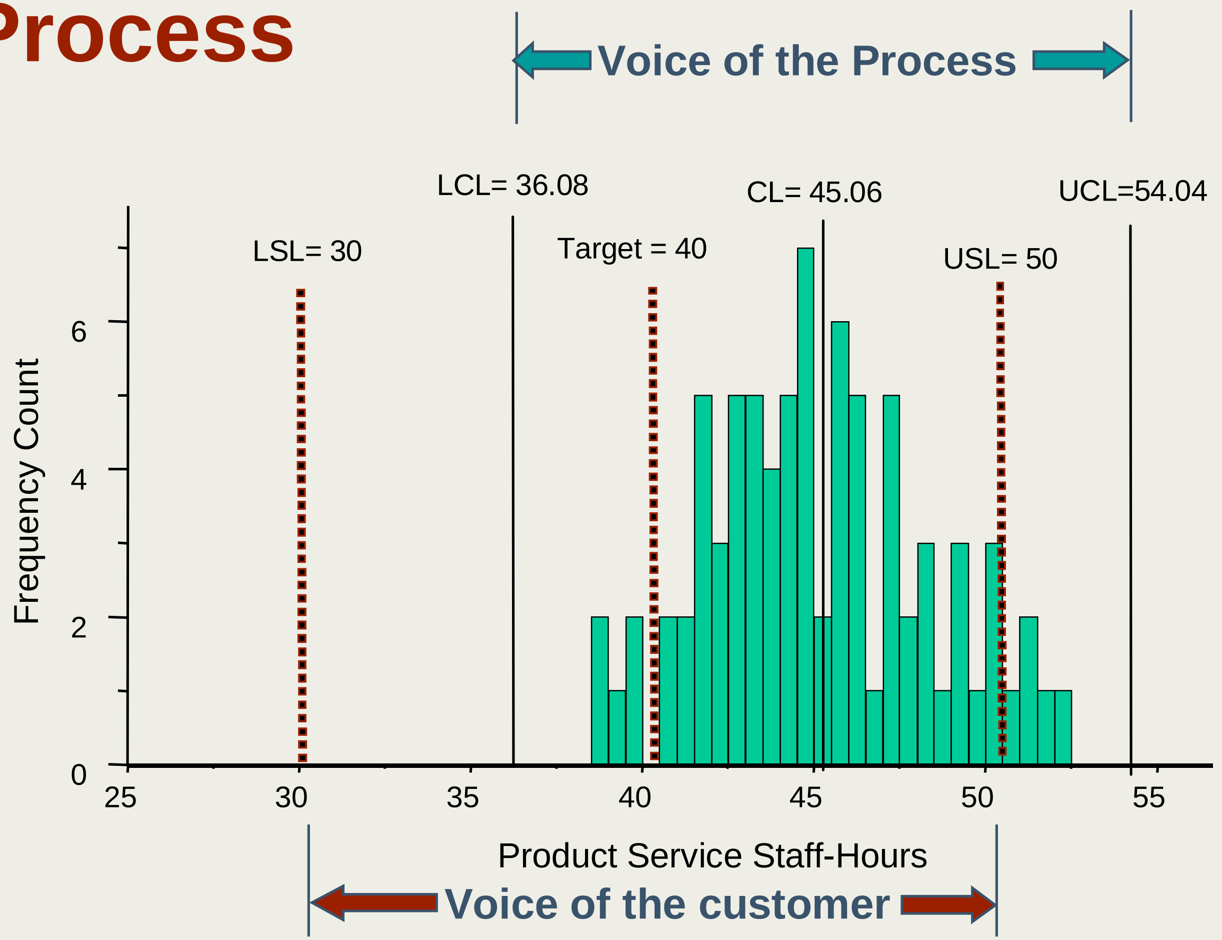
Usage

- 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



Process Capability vs. Capable Process



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.

[isixsigma]

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 Ł feeds QFD
  - a technical solution
  - a feature requirement Ł 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

			Classification						
Customer comment	**Interpreted, reworded**	**I/E**	perception, experience, context	barrier	root issue?	results, success	need	solutions	Keyword for sorting
We are already at maturity level x, so why do more?		E	✓	✓					competing initiatives

VOC: Analysis

Prioritization Method	Customer Time	Preparation Complexity	Analysis Complexity	Quality of Resulting Prioritization	Number of customers needed	Number of Needs to Prioritize	Recommend
Frequency of Response	short	low	low	low	large	large	NO
Constant Sum	medium	medium	medium	medium	medium	small	Yes
Rating	short	low	low	medium	medium	med-large	Yes
Simple Ranking	medium	low	low	medium	medium	small-med	Yes
Q-Sort	short	low	low	medium	medium	large	Yes
Paired Comparison	long	medium	high	high	large	small	Yes
Regression	short	medium	high	high	large	small-med	Yes

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.

MBF: 5 Whys

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	Counter Measures & Activities	Impact, Capability
List of gaps in performance and true root cause	List of specific actions, who has ownership and due date	List of expected benefits and impact of **each** countermeasure

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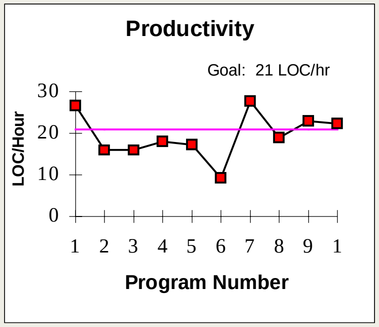
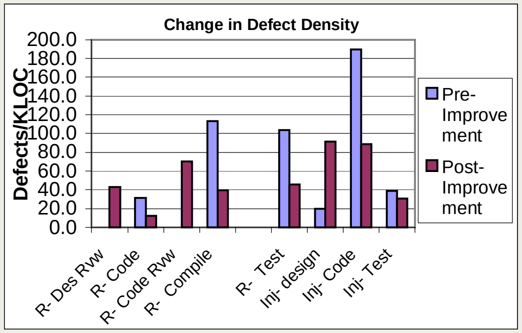
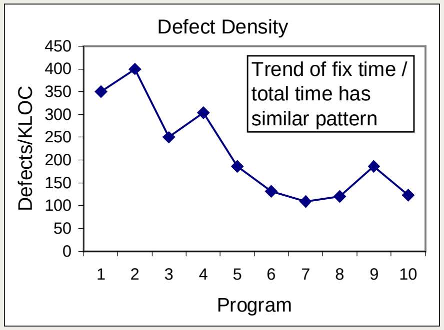
MBF: Example

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	Counter Measures & Activities	Who	When	Expected Benefit/Impact
Large Quantity of Syntax & Similar defects that are repaired in <10 minutes on avg *Goal is 50% reduction in time, relative to historical data*	Clarify type definitions	jms	✓4/30/2001	About 1/2 of goal. In normalized terms, ~1 LOC/hr increase
	Improve subcategory data collection	jms	✓4/30/2001	
	Build a cause & effect diagram to be used for next round of analysis, improvement planning	jms		
	Increase correction efficiency by seeking all occurrences of a defect upon the detection of the first occurrence	jms	✓4/30/2001	
	Increase and log (new) usage of off-line programs to test small pieces of functionality	jms		
	Create & Use a syntax checklist	jms	✓4/30/2001	
"Big Hitter" (>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*	Time breaks: phase completion & every hour	jms	✓4/30/2001	About 1/2 of goal. In normalized terms, ~1 LOC/hr increase.
	Conduct a phase check prior to moving on	jms	✓4/30/2001	
	Increase and log (new) usage of off-line programs to test small pieces of functionality	jms	✓4/30/2001	
	Improve subcategory data collection to use for developing a more directed design review	jms	✓4/30/2001	
	Build a cause & effect diagram to be used for next round of analysis, improvement planning	jms		

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 → **Detect Defects** → **Trouble-shoot** → **Correct Defects** →

Plan
◇ Artifacts to inspect
●, 🡅 Artifact size
● Reviewers
✱ Data repository

Detect Defects
◇ Review Rate
◇ , ✱ Checklists
●, ✱ Inspection method, procedure
🡅 Proficiency
🡅 Taxonomy interpretations

- Defect Log
- Record of plan

Trouble-shoot
What would you list?
◇Defect attributes
● Proficiency
● Effort
● Tools

- Direct Cause
- Root Cause

Correct Defects
What would you list?
◇ Correction action
✱ Config control
○ ●, Effort

- Corrective Action

△	Inspection	◇	Critical Inputs	✱	Standard Procedure
○	Rework	🡅	Noise	●	Control Knobs

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

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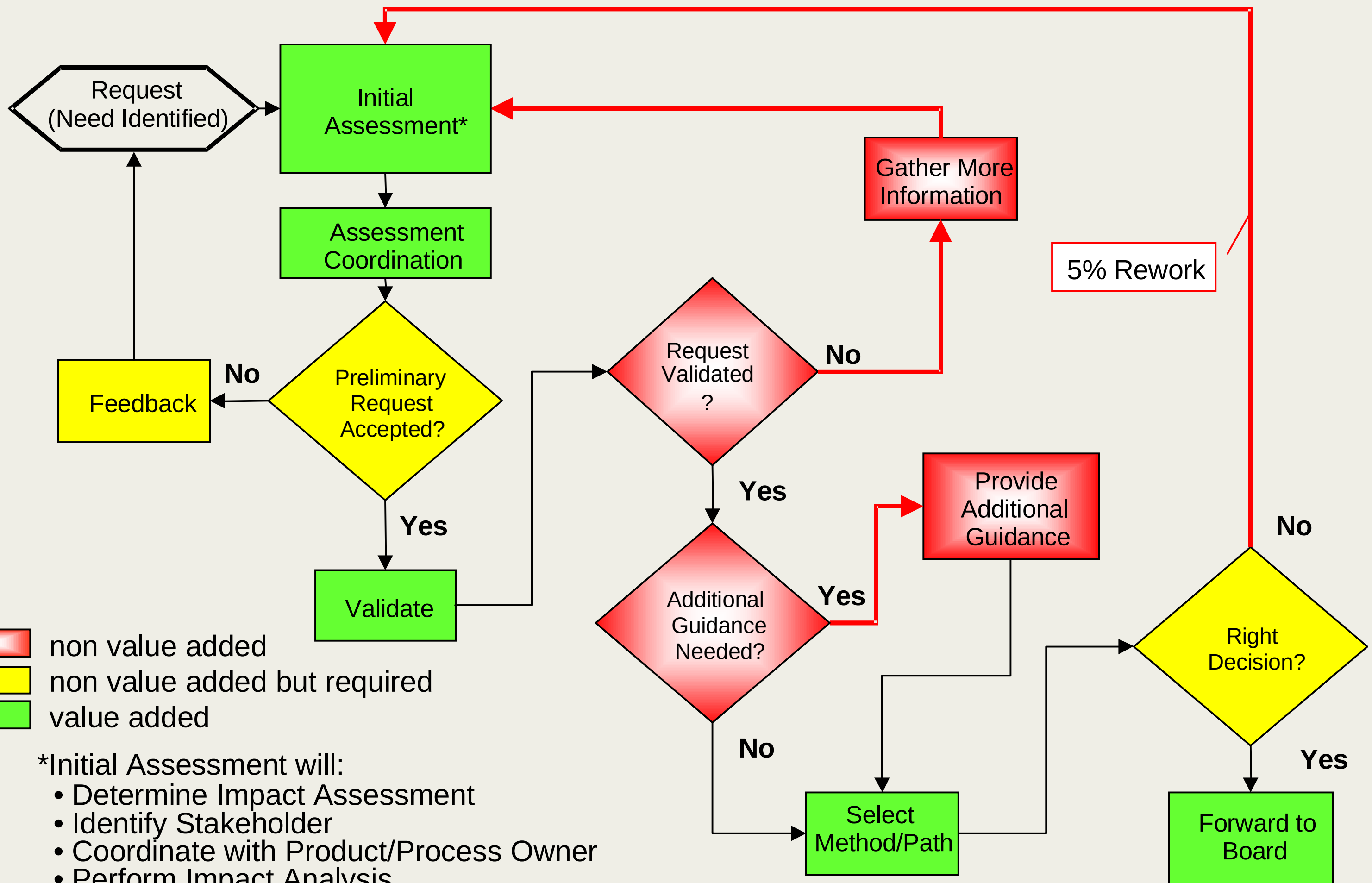
Value Mapping: Change Request



- non value added
- non value added but required
- value added

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