Carnegie Mellon
Software Engineering Institute

Pittsburgh, PA 15213-3890

Bridging the Gap Between CMMI and Six Sigma Training:

An Overview and Case Study of Performance-Driven Process Analysis

Jeannine Siviy, SEI

Dave Hallowell, Six Sigma Advantage

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Report Documentation Page

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Objectives

During this tutorial, we will describe

- Motivation and design principles for an analysis course that also serves CMMI and Six Sigma
- A problem-solving methodology and its relationship to CMMI
  - plus, a selection of its steps and analytical tools
- A cost and schedule variance reduction case study

At the completion of this tutorial, you should be able to explain

- considerations for building your own training courses (if you need to do so)
- an overview of the DMAIC methodology
- performance driven process improvement
- process variation
- Y to x flowdown (or "critical to quality" flowdown)
- performance driven subprocess selection
- how to examine and improve the quality of your data set
- baselining and "the basic tools"
- an example of a process performance models

Outline

Context: The Value Proposition
- our (your) multi-initiative reality
- Six Sigma as a strategic enabler
- measurement & analysis as an integrating platform

Approach to building integrated training

A roadmap for performance-driven improvement

Roadmap connections to CMMI

Roadmap execution: a case study overview

Roadmap execution: demystifying steps and methods

Summary

What Drives Process Improvement?

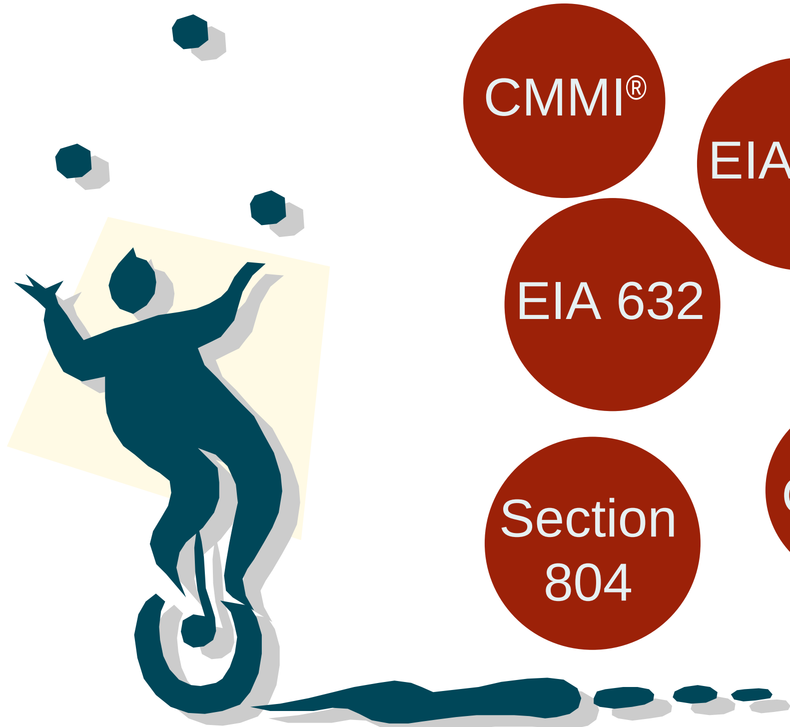
Performance issues: product, project—
and, eventually, process issues

Regulations and mandates
- Sarbanes Oxley
- “Level 3” requirements to win contracts

Business issues and “burning platforms”
- lost market share or contracts
- continuous cost and cycle time improvement
- capitalizing on new opportunities

There is compliance-driven improvement,
and there is performance-driven improvement.

Many Solutions



- RUP
- Agile
- Score-card
- CMMI®
- EIA 731
- ISO 9000
- COBIT
- EIA 632
- ISO 12207
- ITIL
- Section 804
- GQIM
- PSM
- TSP℠

? What solutions is your organization implementing?
How do they support your organization's mission?

Implementation Considerations

Many organizations are implementing one or more models, standards, or technologies simultaneously.

Selection and development considerations include:

- What is the goal?
- What model(s) or references should be used?
- Should they be implemented in parallel or sequentially?
- Can they be used "off-the-shelf" or is tailoring needed?
- What needs to be created internally?

Integrated process solutions that are seamless and transparent to the engineer in the field significantly contribute to an organization's success.

CMMI Staged and Six Sigma

5 / 4
- Organization-wide 6σ improvements and control
- Correlation between key process areas & 6σ methods
- 6σ used within CMM efforts

3
- Infrastructure in place
- Defined processes feed 6σ

2 / 1
- 6σ philosophy & method focus
- 6σ "drilldown" drives local (but threaded) improvements
- 6σ may drive toward and accelerate CMMI solution

Optimizing
Process improvement

Quantitatively Managed
Process measured and controlled

Defined
Process characterized for the organization and is proactive

Managed
Process characterized for projects and is often reactive

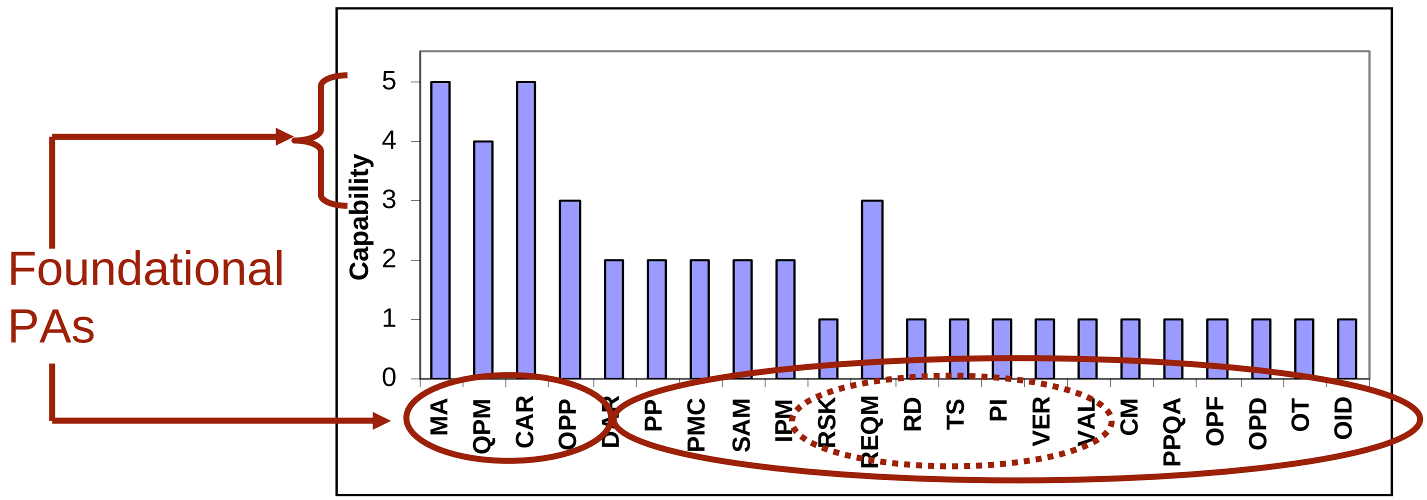
Initial
Process unpredictable and poorly controlled

Six Sigma is enterprise wide.
Six Sigma addresses product and process.
Six Sigma focuses on "critical to quality" factors.

Six Sigma and CMMI Continuous

One possible approach:

- Achieve high capability in PAs that build Six Sigma skills: MA, QPM, CAR, OPP
- Use capability to help prioritize remaining PAs



Remaining PAs ordered by business factors, improvement opportunity, etc. which are better understood using foundational capabilities. CMMI Staged groupings and DMAIC vs. DMADV are also factors that may drive the remaining order. [Vickroy 03]

A Different Tact: Six Sigma as Transition Enabler

The SEI conducted a research project to explore the feasibility of Six Sigma as a transition enabler for software and systems engineering best practices.

Hypothesis

- Six Sigma used in combination with other software, systems, and IT improvement practices results in
  - better selections of improvement practices and projects
  - accelerated implementation of selected improvements
  - more effective implementation
  - more valid measurements of results and success from use of the technology

Achieving process improvement… better, faster, cheaper.

Primary Conclusions

- Six Sigma is feasible as an enabler of the adoption of software, systems, and IT improvement models and practices (a.k.a., “improvement technologies”).

- The CMMI community is more advanced in their joint use of CMMI & Six Sigma than originally presumed.

  Noting that, for organizations studied, Six Sigma adoption & deployment
  - was frequently decided upon at the enterprise level, with software, systems, and IT organizations following suit
  - was driven by senior management’s previous experience and/or a burning business platform
  - was consistently comprehensive.

[IR&D 04]

Selected Supporting Findings 1

Six Sigma helps integrate multiple improvement approaches to create a seamless, single solution.

Rollouts of process improvement by Six Sigma adopters are mission-focused, flexible, and adaptive to changing organizational and technical situations.

Six Sigma is frequently used as a mechanism to help sustain—and sometimes improve—performance in the midst of reorganizations and organizational acquisitions.

Six Sigma adopters have a high comfort level with a variety of measurement and analysis methods.

Selected Supporting Findings $_2$

Six Sigma can accelerate the transition of CMMI.

- moving from CMMI Maturity Level 3 to 5 in 9 months, or from SW-CMM Level 1 to 5 in 3 years (the typical move taking 12-18 months per level)
- underlying reasons are strategic and tactical

When Six Sigma is used in an enabling, accelerating, or integrating capacity for improvement technologies, adopters report quantitative performance benefits using measures they know are meaningful for their organizations and clients. For instance,

- ROI of 3:1 and higher, reduced security risk, and better cost containment

[Hayes 95]

CMMI-Specific Findings

Six Sigma is effectively used at all maturity levels.

Participants assert that the frameworks and toolkits of Six Sigma exemplify what CMMI high maturity requires.

Case study organizations do not explicitly use Six Sigma to drive decisions about CMMI representation, domain, variant, and process-area implementation order. However, participants agree that this is possible and practical.

CMMI-based organizational assets enable Six Sigma project-based learnings to be shared across software and systems organizations, enabling a more effective institutionalization of Six Sigma.

IT-Specific Findings

High IT performers (development, deployment, and operations) are realizing the same benefits of integrated process solutions and measurable results.

- However, they are using the technologies and practices specific to their domain (ITIL, COBIT, and sometimes CMMI).

CMMI-specific findings apply to IT organizations who have chosen to use CMMI.

Interpretations & Moving Ahead

There are many potential benefits from thoughtful and strategic integration of multiple technologies and practices.

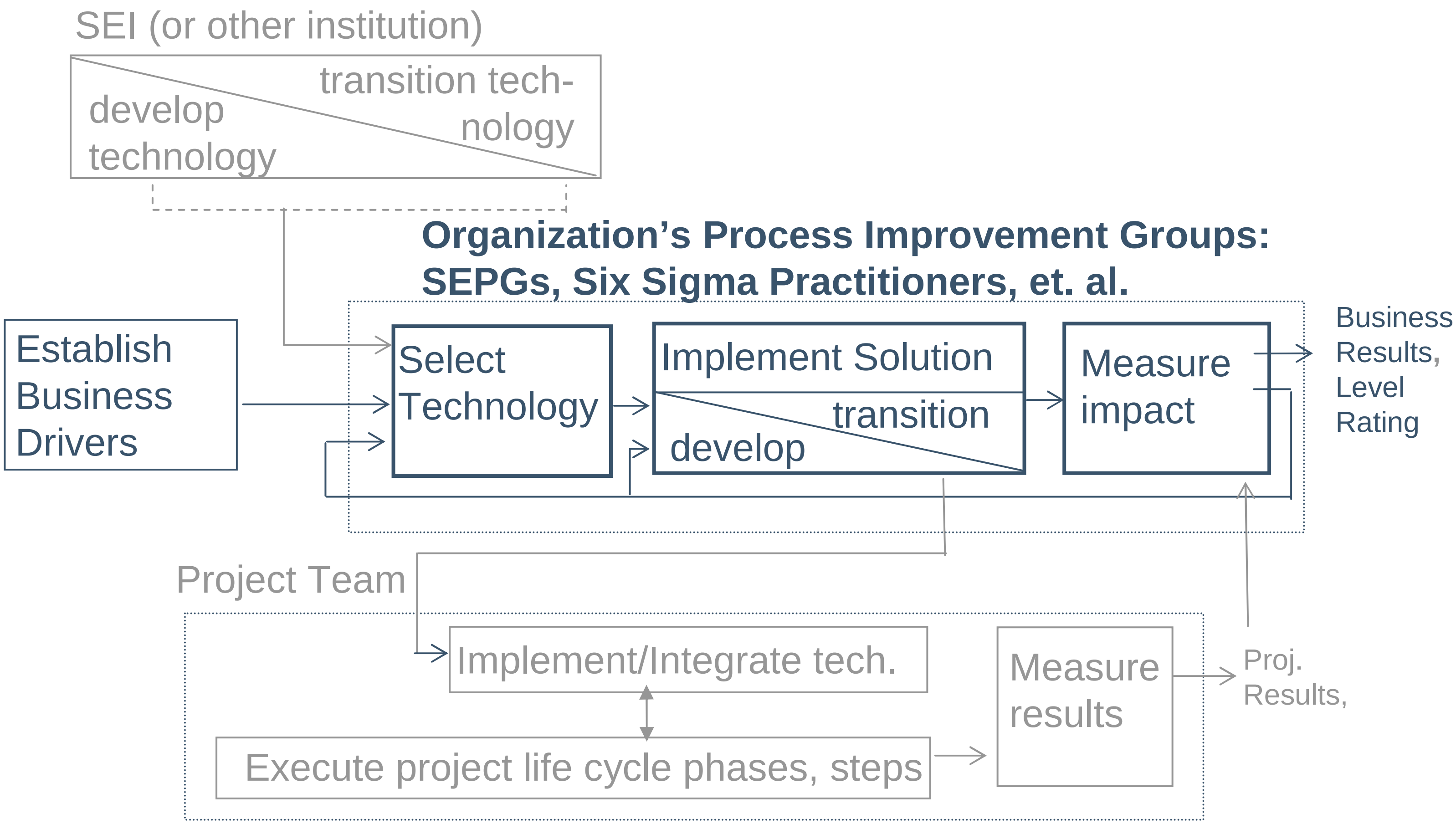
Such integration is currently “state of the art”

Six Sigma and other technologies, can play a role in evolving this to “state of the practice”

How do Process Improvement Groups design and rollout technologies, integrated or otherwise?

- How does training, particularly “integrated training,” support their efforts?

A High Level Implementation Process



Effective Transition Planning

"Transition" is indicated by each of the following:

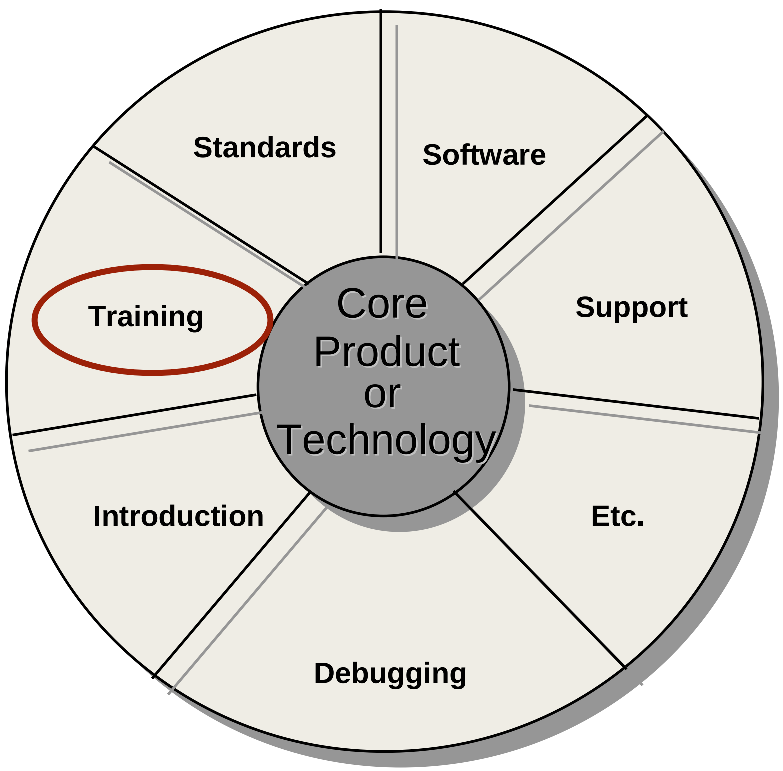
- maturation, introduction, adoption, implementation, dissemination, rollout, deployment, or fielding

Features of effective transition planning include:

- precision about the problem, clarity about the solution
- transition goals and a strategy to achieve them
- definition of all adopters and stakeholders and deliberate design of interactions among them
- complete set of transition mechanisms: a whole product
- risk management
- either a documented plan or extraordinary leadership throughout the transition

[Forrester], [Schon], [Gruber]

The “Whole Product” Concept*



Economies of scale are needed in training.

A holistic, “connected” approach is needed in training.

Leaving students to their own devices to make connections can be risky and/or time-consuming.

[Moore]

Training Challenges

Many technologies have their own training.

- It's not practical to send everyone to all training courses.
- Yet it's also not practical to custom-build all training.

Cross training (i.e., CMMI & Six Sigma)

- At a strategic level: how to increase awareness so that experts in one technology can make judicious decisions about adoption and implementation of another technology.
- At a tactical level: how to balance the expertise.

Who and how many should be trained? For instance,

- Train whole organization in internal process standards and possibly basic Six Sigma concepts.
- Train fewer in Six Sigma BB, CMMI, measurement and analysis, and other specialty areas.

Benchmarking

Integrated training solutions underway:

- DFSS training that includes awareness sessions of relevant technologies
  - SEI's Product Line Practices, ATAM, CMMI engineering PAs
- DFSS training that leverages ATAM
- DMAIC training that references PSP-based instrumented processes

Strategic Emphasis (the first bullet and its sub-item)

Tactical Emphasis (the second and third bullets)

Our approach uses *measurement & analysis* as an *integrator*.

Outline

- Context: The Value Proposition
- ➡ Approach to building integrated training
- A roadmap for performance-driven improvement
- Roadmap connections to CMMI
- Roadmap execution: a case study overview
- Roadmap execution: demystifying steps and methods
- Summary

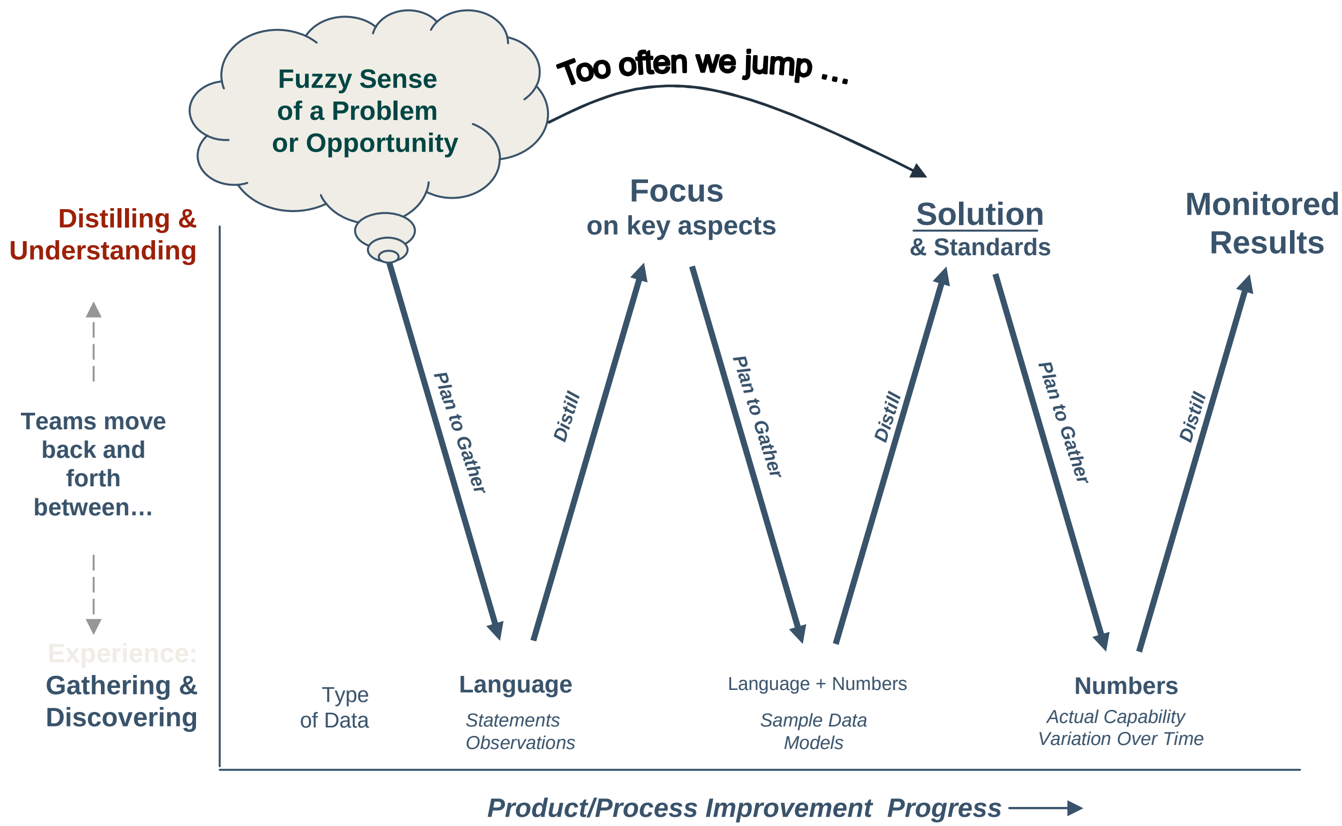
Intent of New Analysis Courses

Our task is to build new courses that

- Focus on *analysis*
  - but more than just SPC
- Focus on building skills ➔ hand-on practice
- Support CMMI
- Appeal to many roles
  - process improvement personnel
  - measurement personnel
  - project team members
  - CMMI appraisers (maybe)
  - Six Sigma practitioners
  - and so on
- Resonate with organizations at any maturity level

A Base Architecture

- Connecting all the Improvement Models



[Kawakita], [Shiba]

Design Strategy

Our Goal for the courses

- When you return home, you will have the skills to tackle process improvement projects in a way that is informed by your data.

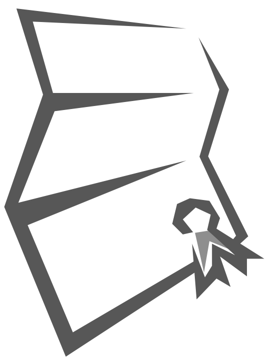
Doing this requires

- a structured, but easily tailored, approach
- confidence and skills to use basic statistical methods
  - sufficient awareness of other methods to know when to get help
- experience using a real statistics package and Excel

Considerations

- Leverage other technologies and initiatives.
  - reuse demonstrated frameworks and toolkits
  - build explicit connections to models
  - return to common roots; don't reinvent the wheel
  - define "certification" boundaries and options
- Use a project process (incl. design phases and piloting)
  - Assemble a cross-organizational development team
  - Use Gagne's Model for instructional design
  - Use Kirkpatrick's Four-Level Evaluation model
  - Design for fit with existing measurement courses
- Design for extensibility: case study approach
  - allows easy swap-in of other domains and technologies
  - allows easy updates as core technologies evolve
- Couple with an annual Measurement Practices Workshop (future)

Certificates and Certifications



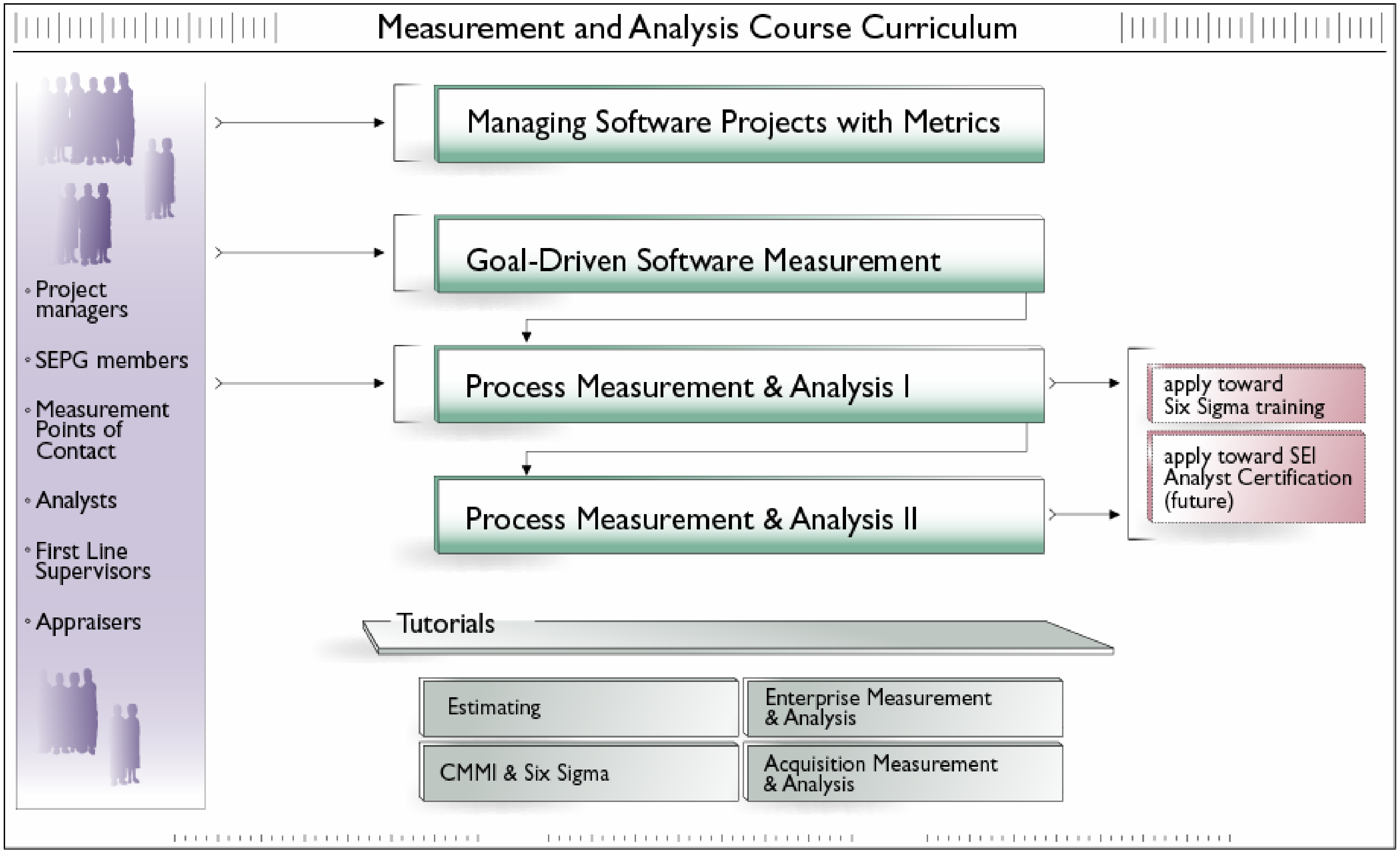
SEI Certificate Programs

- analyst (future)

Six Sigma Practitioner Certification

- SEI Partners who provide Six Sigma training and certification can leverage courses
  - adjunct, domain-specific, Black Belt training
  - domain-specific Yellow Belt training

SEMA M&A Curriculum



Focus of Each Analysis Course

Process Measurement & Analysis I

- Reduce defects, waste, and cycle time by correcting special cause variation and repairing and/or improving processes.

Process Measurement & Analysis II

- Prevent defects and ensure performance by using data for early detection/correction of issues and by optimizing front-end planning, requirements, and design processes.

Design Highlights: Course Outlines

Today's illustrations

Process Measurement & Analysis I

- Introduce DMAIC flowchart
- Call Center Case: DMAIC Process
- Defect Containment Case: Data Stratification
- Cost & Schedule Case: Variance Reduction

Process Measurement & Analysis II

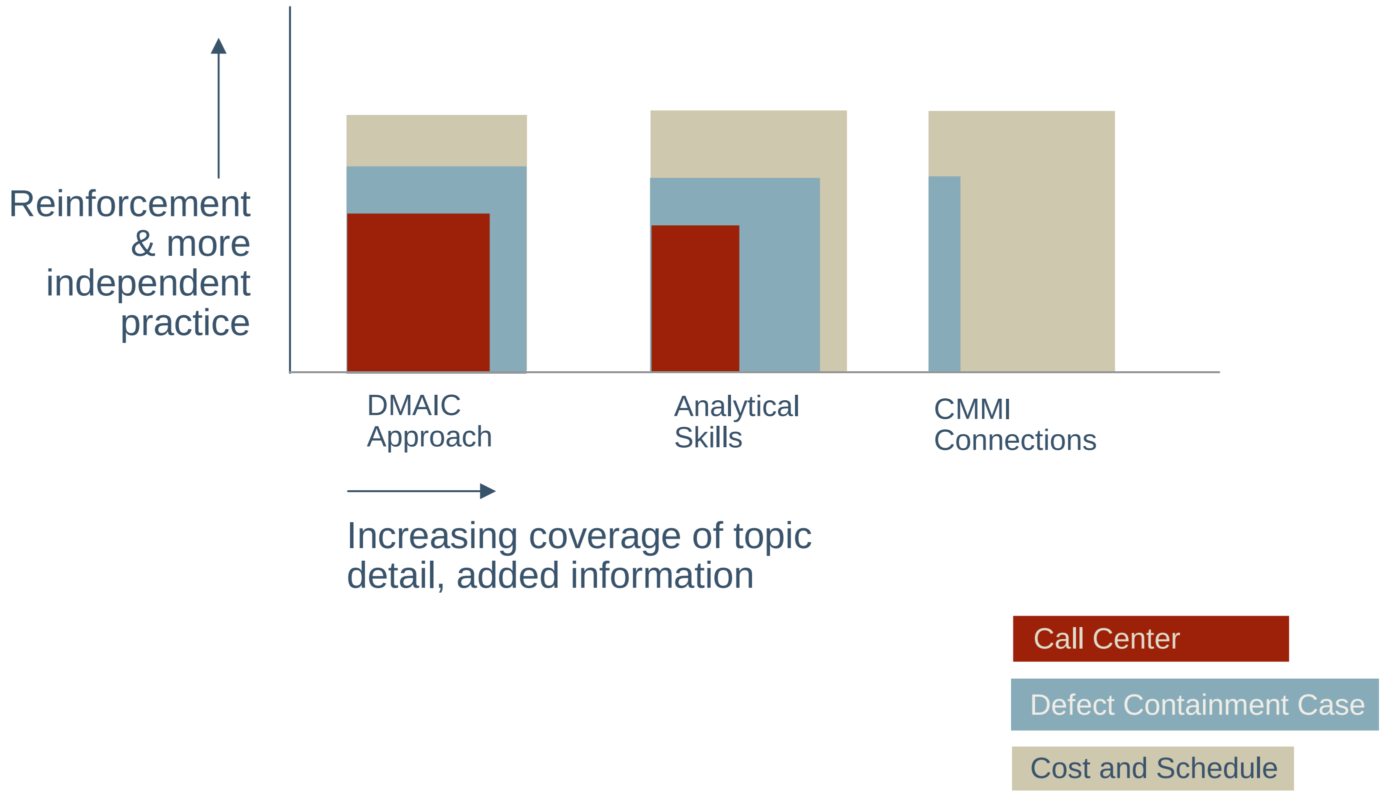
- Project Simulation: Organization and Project Baseline
- Defect Containment Case:
  - optimize inspection, improve design processes
- Cost & Schedule Case:
  - optimize estimating, improve requirements processes
- Project Process Optimization Case:
  - model simultaneous improvements in multiple, interrelated processes via simulation

Analysis 1 Case Studies

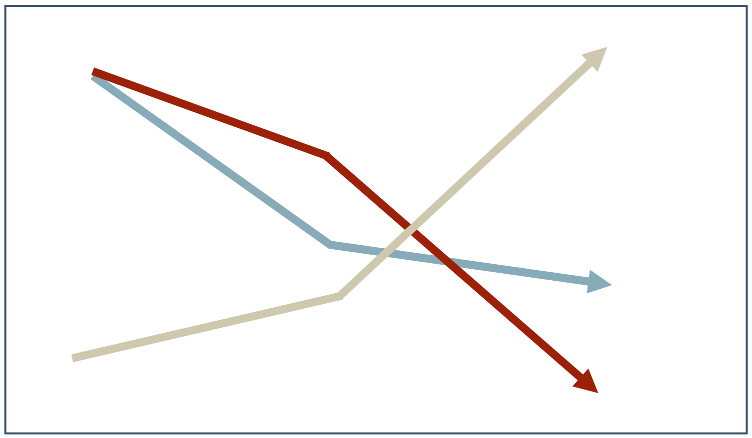
This course uses case studies to help you build skills.

- Call Center Case focus
  - DMAIC approach and associated guidance questions on basic analytical methods
- Defect Containment Case focus
  - understanding variation, basic analytical methods, and SPC charts
- Cost Schedule Case focus
  - tailoring the DMAIC approach, understanding variation, excluding data properly, presenting data analysis so that it is practical and useful; CMMI links

Analysis 1: Reinforcing & Expanding Skills



Analysis 1: Balancing Lecture & Practice



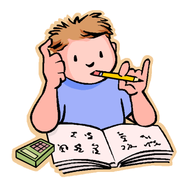
Case 1:
Call Center

Case 2:
Defect Containment

Case 3:
Cost & Schedule Variance

Lectures

Guided Exercises



Independent & Group Exercises

Outline

Context: The Value Proposition

Approach to building integrated training

➡ A roadmap for performance-driven improvement

Roadmap connections to CMMI

Roadmap execution: a case study overview

Roadmap execution: demystifying steps and methods

Summary

A General Purpose Problem-Solving Methodology: DMAIC

Problem or goal statement (Y)

↓

Define → **Measure** → **Analyze** → **Improve** → **Control**

Define ↓

- Refine problem & goal statements.
- Define project scope & boundaries.

Measure, Analyze, Improve, Control ↓

- An improvement journey to achieve goals and resolve problems by discovering and understanding relationships between process inputs and outputs, such as
  Y = f(defect profile, yield)
  = f(review rate, method, complexity……)

DMAIC: Relevance and Robustness

Codified method in use across many industries

Domain specificity

- Added aspects of GQ(I)M, PSM, and CMMI to make the “domain independent” methodologies more relevant to the software and system engineering domains
- Presenting domain-specific case studies

Can be used to

- discover an ill-defined problem or opportunity
- gather and evaluate information to refine the problem or goal statement
- gather and evaluate more information to reach a proposed solution
- implement the solution
- gather data to monitor success

DMAIC Roadmap

Define → **Measure** → **Analyze** → **Improve** → **Control**

Define
- Define project scope
- Establish formal project

Measure
- Identify needed data
- Obtain data set
- Evaluate data quality
- Summarize & baseline data

Analyze
- Explore data
- Characterize process & problem
- Update improvement project scope & scale

Improve
- Identify possible solutions
- Select solution
- Implement (pilot as needed)
- Evaluate

Control
- Define control method
- Implement
- Document

Phase Exit Review

Define Guidance Questions

Define

Define project scope

- What is the current problem to be solved?
- What are the goals, improvement targets, & success criteria?
- What is the business case, potential savings, or benefit that will be realized when the problem is solved?
- Who are the stakeholders? The customers?
- What are the relevant processes, and who owns them?

Establish formal project

- Have stakeholders agreed to the project charter or contract?
- What is the project plan, including the resource plan and progress tracking?
- How will project progress be communicated?

Measure Guidance Questions

Define → **Measure**

- Does the measurement system yield accurate, precise, and reproducible data?
- Are urgently needed improvements revealed?
- Has the risk of proceeding in the absence of 100% valid data been articulated?

Identify needed data

- What are the process outputs and performance measures?
- What are the process inputs?
- What info is needed to understand relationships between inputs and outputs? Among inputs?
- What information is needed to monitor the progress of this improvement project?

Obtain data set

- Is the needed measurement infrastructure in place?
- Are the data being collected and stored?

Evaluate data quality

Summarize & baseline data

- What does the data look like upon initial assessment? Is it what we expected?
- What is the overall performance of the process?
- Do we have measures for all significant factors, as best we know them?
- Are there data to be added to the process map?
- Are any urgently needed improvements revealed?
- What assumptions have been made about the process and data?

Analyze Guidance Questions

Analyze

Explore data

- What do the data look like?
- What is driving the variation?
- What is the new baseline?
- What are associated risks and assumptions associated with the revised data set and baseline?

Characterize process and problem

- Are there any hypotheses that need to be tested?
- What causal factors are driving or limiting the capability of this process?
- What process map updates are needed?
- Are there any immediate issues to address? Any urgent and obvious needs for problem containment?

Update improvement project scope and scale

- Should the improvement goal be updated?
- Is additional data exploration, data decomposition, and/or process decomposition needed? Is additional data needed?
- Can I take action? Are there evident improvements and corrections to make?
- Have I updated the project tracking and communication mechanisms?

Evaluate data quality

Summarize, baseline data

solutions

method

Improve Guidance Questions

- What type of improvement is needed?
- What are solution alternatives to address urgent issues and root causes of identified problems?
- What are the process factors to be adjusted?
- What is the viability of each potential solution?
- What is the projected impact or effect of each viable solution?

Improve

Identify possible solutions

Select solution

Implement (pilot as needed)

Evaluate

- What are the relative impacts and benefits?
- What are relevant technical and logistical factors?
- What are potential risks, issues, and unintended consequences?

- What is the action plan with roles, responsibilities, timeline and estimated benefit?
- Is piloting needed prior to widespread implementation?

- Did the solution yield the desired impact?
- Has the goal been achieved?
- If piloted, are adjustments needed to the solution prior to widespread rollout? Is additional piloting needed?
- How will baselines, dashboards, and other analyses change?

Control Guidance Questions

Define → Measure → Analyze → Improve → **Control**

Control

Define control method
- Should data be compared to a range? If so, which range?
- Does procedural adherence need to be monitored?

Implement
- What updates are needed in the measurement infrastructure?
- What process documentation needs to be updated?
- What new processes or procedures need to be established?
- Who is the process or measurement owner who will be taking responsibility for maintaining the control scheme?

Document
- Have we documented improvement projects for verification, sustainment, and organizational learning?
- What are the realized benefits?
- Is the project documented or archived in the organization asset library?
- Have documentation and responsibility been transferred to process or measurement owner?

Toolkit

Define

Benchmark

Contract/Charter

Kano Model

Voice of the Customer

Voice of the Business

Quality Function Deployment

Measure

GQIM and Indicator Templates

Data Collection Methods

Measurement System Evaluation

Analyze

Cause & Effect Diagrams/ Matrix

Failure Modes & Effects Analysis

Statistical Inference

Reliability Analysis

Root Cause Analysis, incl 5 Whys

Hypothesis Test

Improve

Design of Experiments

Modeling

ANOVA

Tolerancing

Robust Design

Systems Thinking

Decision & Risk Analysis

PSM Perform Analysis Model

Control

Statistical Controls:

- **Control Charts**
- Time Series methods

Non-Statistical Controls:

- Procedural adherence
- Performance Mgmt
- Preventive measures

7 Basic Tools (**Histogram, Scatter Plot, Run Chart**, Flow Chart, Brainstorming, **Pareto Chart**), **Control charts** (for diagnostic purposes), **Baseline**, Process Flow Map, Project Management, **"Management by Fact", Sampling Techniques**, Survey Methods, **Defect Metrics**

Exercise / Discussion

In groups of 3:

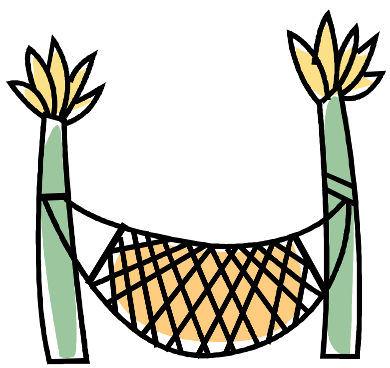
- Answer the “Define Project Scope” questions for a problem that each of you faces in your organization.
  - What is the current problem to be solved?
  - What are the goals, improvement targets, & success criteria?
  - What is the business case, potential savings, or benefit that will be realized when the problem is solved?
  - Who are the stakeholders? The customers?
  - What are the relevant processes, and who owns them?

- Discuss the “fit” of the DMAIC roadmap in your organization
  - How does it fit with your defined processes?
  - How might it help you define new processes?
  - If you are a Six Sigma organization, how does our roadmap fit with your internal roadmap?

Debrief: Voluntary Sharing

TAKE A FEW NOTES. YOU WILL NEED THEM LATER.

Copies of Slides



Later today: case study and practice sessions

If you would like copies of our slides,
add your name to our signup sheet, or
send an email to Debra Morrison, dtm@sei.cmu.edu.

- Put "SEPG Tutorial" in the subject line.

Outline

Context: The Value Proposition

Approach to building integrated training

A roadmap for performance-driven improvement

➡ Roadmap connections to CMMI

Roadmap execution: a case study overview

Roadmap execution: demystifying steps and methods

Summary

CMMI-SE/SW/IPPD/A - Continuous

CMMI

Process Management
- Organizational Process Focus
- Organizational Process Definition
- Organizational Training
- Organizational Process Performance
- Organizational Innovation and Deployment

Project Management
- Project Planning
- Project Monitoring and Control
- Supplier Agreement Mgmt.
- Integrated Project Mgmt.
- Risk Management
- Quantitative Project Mgmt.

Engineering
- Requirements Management
- Requirements Development
- Technical Solution
- Product Integration
- Verification
- Validation

Support
- Configuration Mgmt.
- Process and Product Quality Assurance
- Measurement & Analysis
- Decision Analysis and Resolution
- Causal Analysis and Resolution

IPPD
- Organizational Environment for Integration
- Integrated Team

Acquisition
- Supplier Selection and Monitoring
- Integrated Supplier Management
- Quantitative Supplier Management

Capability Evolution of Measurement via Generic Practices

Generic Practice	Focus
2.8 Monitor and control the process	Monitor and control the process against the plan for performing the process and take appropriate corrective action
3.2 Collect improvement information	Collect work products, measures, measurement results, and improvement information derived from planning and performing the process to support the future use and improvement of the organization's processes and process assets
4.1 Establish quality objectives	Establish and maintain quantitative objectives for the process about quality and process performance based on customer needs and business objectives
4.2 Stabilize sub-process performance	Stabilize the performance of one or more subprocesses to determine the ability of the process to achieve the established quantitative quality and process performance objectives
5.1 Ensure continuous process improvement	Ensure continuous improvement of the process in fulfilling the relevant business objectives of the organization
5.2 Correct common cause of problems	Identify and correct the root causes of defects and other problems in the process

DMAIC Relationship to CMMI PAs

Overall
- DMAIC: a problem solving approach
- CMMI: a process & measurement deployment approach

PAs that align with DMAIC include the following:
- MA, GPs
- QPM, CAR, OID (either "continuous" or high-maturity view)

A DMAIC project may leverage these existing processes:
- PP, PMC, IPM
- OPP for organization level execution, mgmt, oversight

PAs through which DMAIC may be incorporated into organizational process definition include the following:
- OPF, OPD

[Penn & Siviy 05]

Relationship to CMMI PAs

PAs "eligible" for DMAIC-based improvement

- all

PAs with links to the analytical toolkit include

- Decision Analysis & Resolution
  - e.g., concept selection methods, such as Pugh's
- Risk Management
  - e.g., Failure Modes & Effects Analysis (FMEA)
- Technical Solution
  - e.g., Design FMEA, Pugh's

[Penn & Siviy 04]

Relationship to CMMI Goals & Practices

"Define" Roadmap Steps

- Define project scope ⇔ Align process improvements with business objectives
  - Organization Process Focus (SG 1)
  - Organization Process Performance (SG 1)
  - GP 4.1, GP 5.1

- Establish formal project ⇔ Establish improvement projects
  - Organization Process Focus (SG 1)
  - Organization Innovation and Deployment (SG 1)
  - Implied by GP 4.1, GP 5.1

Relationship to CMMI Goals & Practices

"Measure" and "Analyze" Roadmap Steps

- Define data and establish repositories
  - Measurement and Analysis (SG 1)
  - Organization Process Definition (SG 1)
  - Organization Process Performance (SG 1)
  - Causal Analysis and Resolution (SG 2)
  - Quantitative Project Management (SG 2)
  - GP 2.2, GP 3.2, GP 5.1
- Baseline data
  - Organizational Process Performance (SG 1)
- Analyze data
  - Measurement and Analysis (SG 2)
  - Organization Process Performance (SG 1)
  - Causal Analysis and Resolution (SG 1)
  - GP 2.8, GP 5.2

Relationship to CMMI Goals & Practices

"Improve" and "Control" Roadmap Steps

- Identify Improvement Alternatives
  - Decision Analysis and Resolution (SG 1)
  - Organization Innovation and Deployment (SG 1)
  - Organization Process Performance (SG 1)
  - GP 5.1

- Control Processes
  - Measurement and Analysis (SG 2)
  - Organization Process Performance (SG 1)
  - Organization Innovation and Deployment (SG 2)
  - Causal Analysis and Resolution (SG 2)
  - Quantitative Project Management (SG 2)
  - GP 2.8, GP 4.2

Discussion / Exercise

Our lists are not exhaustive.

In your group of 3

- Are there other dimensions via which DMAIC and CMMI are connected?
- Are there other goals which link to DMAIC?
  - Do any specific practices come to mind?
- Are there any other
- Are there other analytical methods from the Six Sigma toolkit that are frequently used within a Process Area?
- How are CMMI and DMAIC different? Synergistic?

Debrief: Voluntary sharing

Outline

Context: The Value Proposition

Approach to building integrated training

A roadmap for performance-driven improvement

Roadmap connections to CMMI

➡ Roadmap execution: a case study overview

Roadmap execution: demystifying steps and methods

Summary

Pre-Case Discussion

What is the cost and schedule performance of one of the projects in your organization? Of your organization’s projects as a whole?

Does your answer reflect

- total variance from initial estimate? Or variance from most recent re-estimates?
- all projects? Or just certain types of projects?
- “level of effort” or maintenance work?

We are going to “run through” a high level view of the cost-schedule variance reduction case from the course.

Keep track of any methods or approaches that you don’t understand. We will ask in ~1 hour.

Organizational Context

Motivation for project

- improve customer satisfaction
  - indicated by field defects and effort and schedule variance

Project portfolio

- both development and maintenance
- size and complexity vary
- schedules from <1 month to >18 months

CMMI implementation

- assessed at SW-CMM Level 3 five years ago
- began transition to CMMI four years ago
- Working toward high maturity
- striving to implement new Process Areas to add value, not just achieve compliance

Starting Points

Partial list of work that is already complete

- measurement infrastructure for project and product metrics
- measurement infrastructure akin to GP2.8 and GP3.2 for processes implemented per SW-CMM
- SPC pilots within selected organizational units
- initial data rollups for management
- initial benefits calculations (ROI and other indicators)

Excerpt of CMMI Plans

What "M&A" type efforts lie ahead, to fulfill CMMI-related goals?

- ensure compliance to MA Process Area
- organizational and project baselines (OPP and QPM SPs)
- model building at the project level (QPM SPs)
- relating process behavior and performance to product and service quality (OPP and QPM SPs)
- quantitatively manage key processes and subprocesses (QPM SPs)

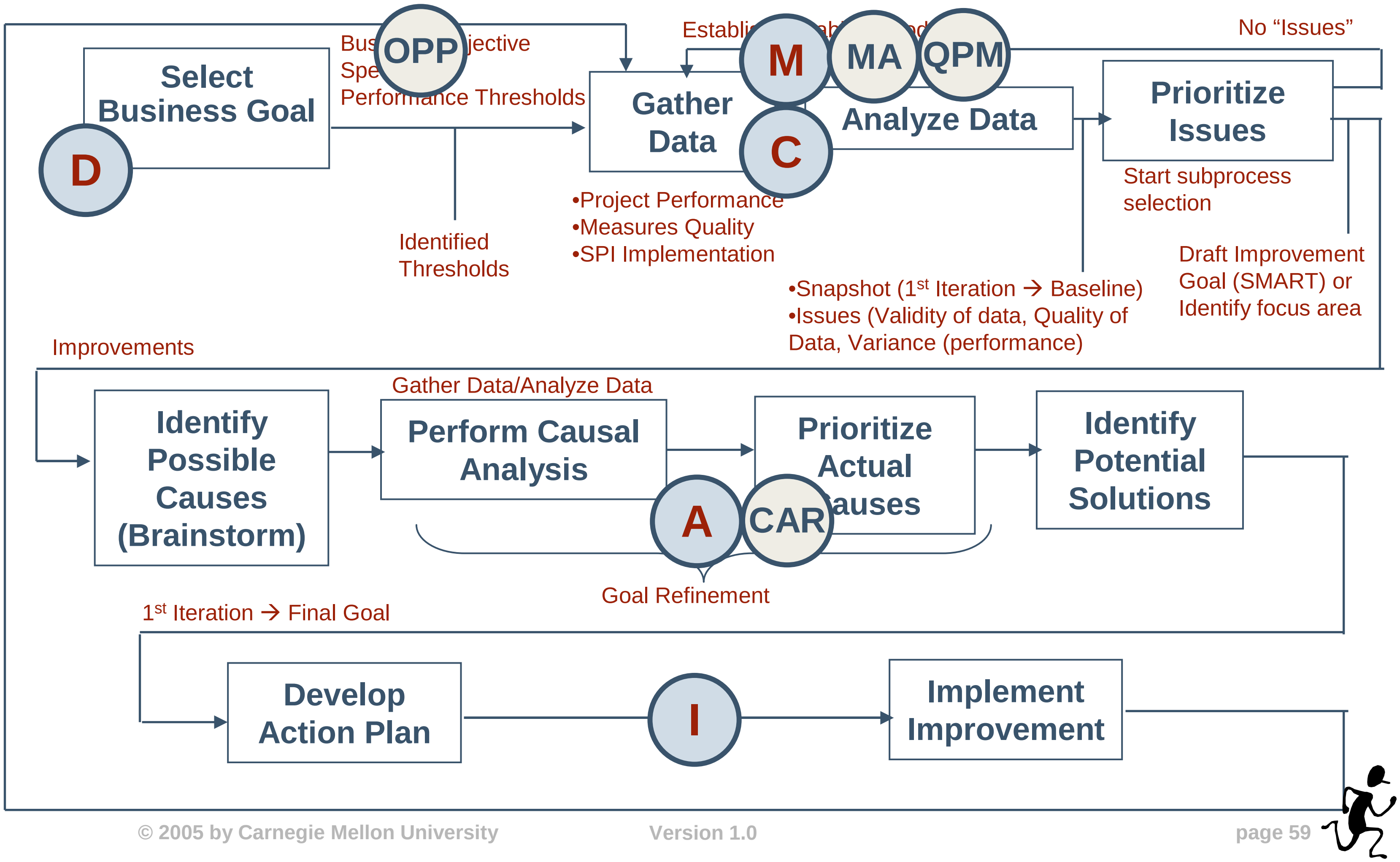
Problematic CMMI language and practices

- "process performance model" (OPP SPs)
- subprocess selection (QPM SPs)

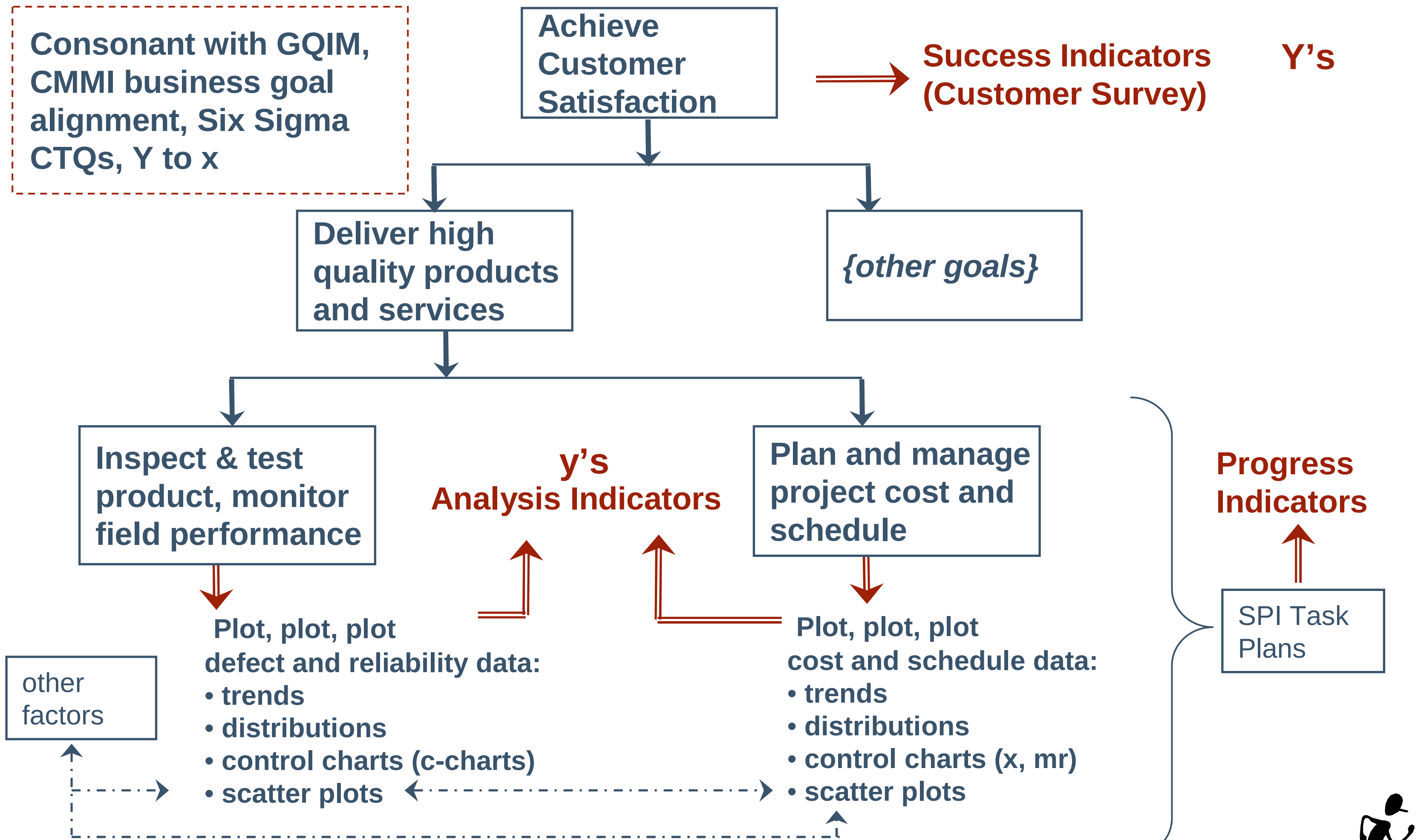
If you are working on Level 2 & 3 PAs, don't tune out…

- *Remember our research project findings: the lessons from this case can be applied to build a foundation for high maturity*

Documented M&A Process



Customer Satisfaction Goal Structure



Cost/Schedule Measurement System

Monthly effort, schedule (earned value based)

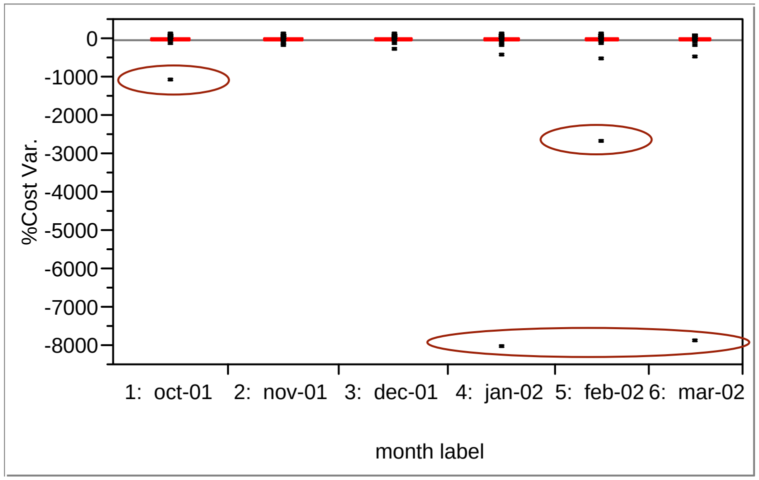
- variance: (current actual – most recent estimate)
  - compared to variance specification (+/- 20%)
  - text entry for out of specification explanations
- data manually transferred from project files to monthly report
- cost in terms of effort hours
- schedule performance derived from effort hours

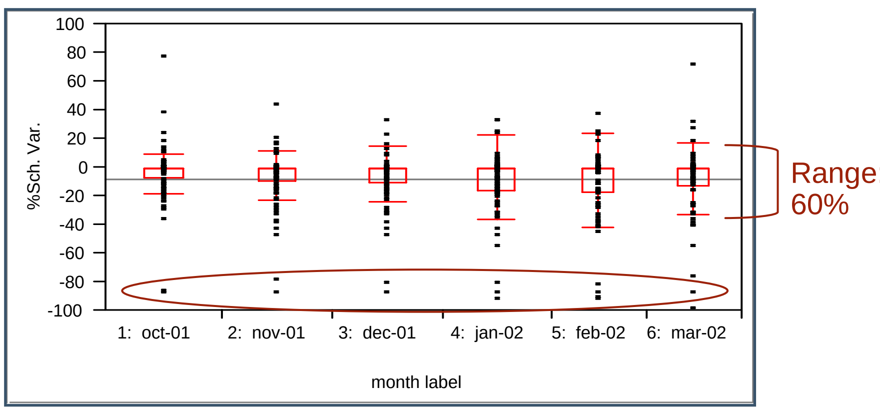
Completed project data: *a special data collection*

- variance: (original plan – final actual)
  - categorized by internal and external causes
  - categorized by life-cycle phase
- cost in terms of effort + purchase costs
- schedule in terms of calendar days
- each replan recorded

What is Monthly Average & Variability?

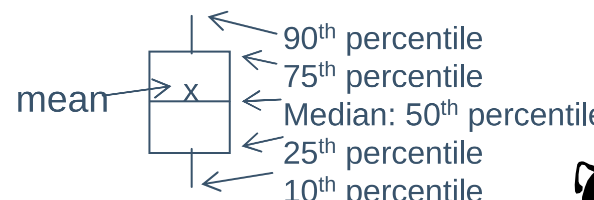
Cost/Schedule Performance Baseline





All Org Units, all projects, October to March

- Reminder: This is (current actual – most recent estimate)
- Averages within spec, and close to 0
- Need to examine extreme values, especially for cost
- even if extreme values are outliers, it looks like we need to investigate variability



Disposition of Extreme Values

Extreme values investigated

- removed all documentation projects
- removed small project that was re-baselined 26 times

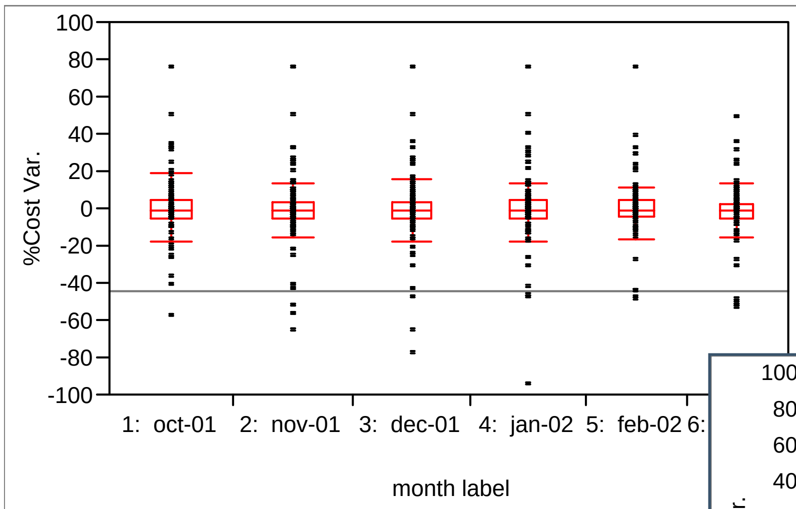
Immediate improvement opportunity

- establish data validation guidelines

We'll talk more about measurement system evaluation and outliers this afternoon

What is Monthly Average & Variability?

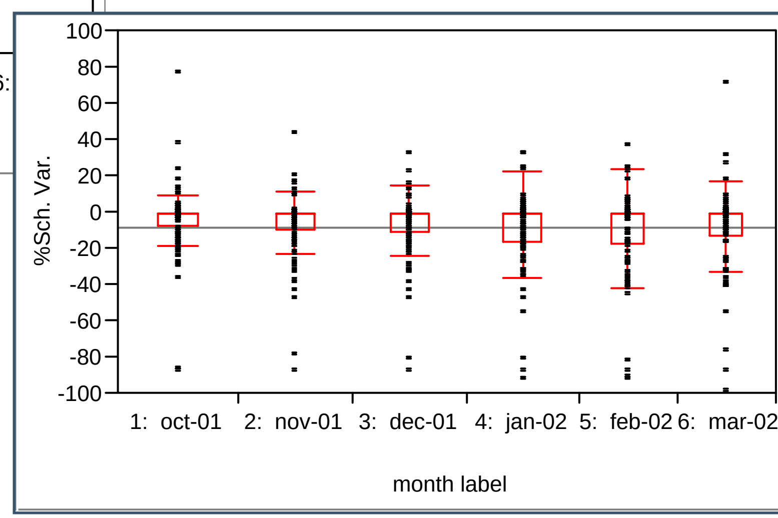
Cost/Schedule Performance Baseline, Outliers Removed



Scaled to match schedule variance chart, some values below -100

Even with outliers removed, variance has more variability than expected.

There is month to month consistency.



This and following slides consonant with Six Sigma toolkit, CMMI MA, QPM, OPP, CAR

Overall Monthly Performance Stats

Cost/Schedule Performance Baseline, Outliers Removed

In-process effort/cost data

- All life-cycle phases, all projects, Oct – June

	cost	schedule
average	-2	-7.6
standard deviation	25	19.2
n	770	770
% outside spec	17%	17%

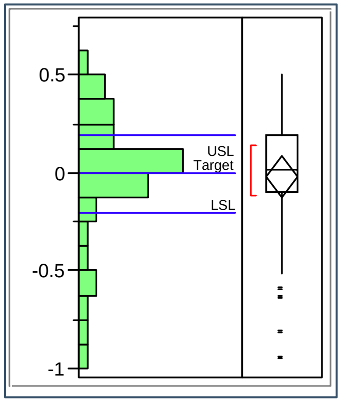
Reminder: variance = current actual – most recent estimate

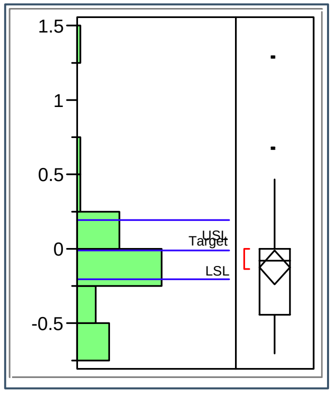
Observations
- averages running close to target
- more data than expected outside of spec
- high variability

How Do Projects Typically End?

Cost/Schedule Performance Baseline, Outliers Removed

	% 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





Reminder: This is the total cumulative variance.
- (initial plan – final actual)
- customer-driven changes are included

Some extreme values still present
- there are no valid reasons to remove or segment the data

Large % of data outside specification
- process not capable

Cost/Schedule Data Quality

Accuracy
- re-baselining project estimates biases the data, promotes the perception that performance is better than it actually is

Repeatability
- different estimating methods across life cycle, across projects
- unclear definition of “project”

Completeness
- Which project types are “in” and which are “out”?
- sparse data – some parts of organization better represented
- completed project data missing from organization data

Sampling Homogeneity
- All monthly data was being rolled together, regardless of which part of life cycle it represented

Initial Baseline Summary (All Data)

Existing customer satisfaction information was positive.

Cost/Schedule data frequently and consistently "out of spec," both monthly and final data.

- But, the average looked great!

There were few field defects and the inspection process seems to be effective.

Many measurement infrastructure improvements were identified

- customer surveys
- improved operational definitions
- improved automation
  - to improve quality and minimize quantity of missing data
- add completed project data into central repository
- group data by life cycle phase or project %complete for reporting

Why Pursue Cost & Schedule Variation Reduction?

Why should we care about effort & schedule variance reduction?

- our customers are pretty happy
- our project managers seem to have things under control

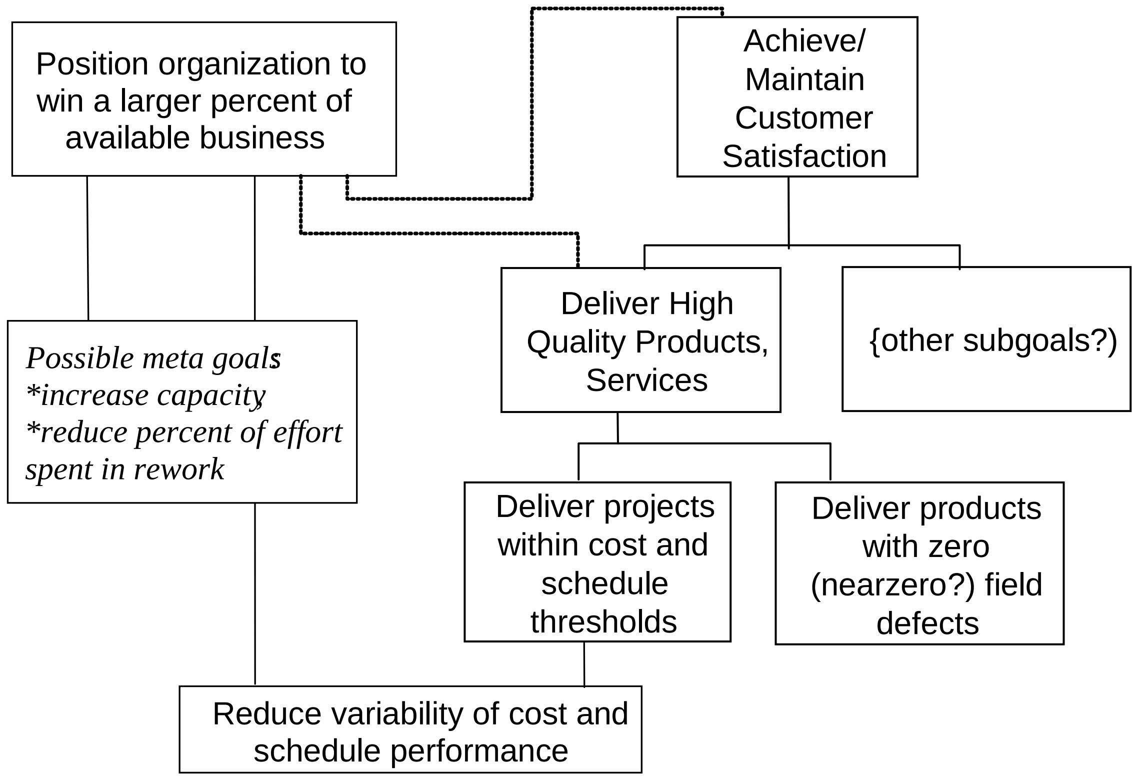
What are the business drivers? What is the benefit for the effort that will likely be invested?

- competitive advantage
- funding increasingly harder to obtain
- credibility
- domino effect of projects running late
- more small projects anticipated
- fewer “level of effort” projects anticipated
- operational cost-based budget

?

Why does YOUR organization care about cost & schedule performance?

Goal Realignment



While the re-alignment may not change the specific improvement activities, it will positively affect "change management" efforts.

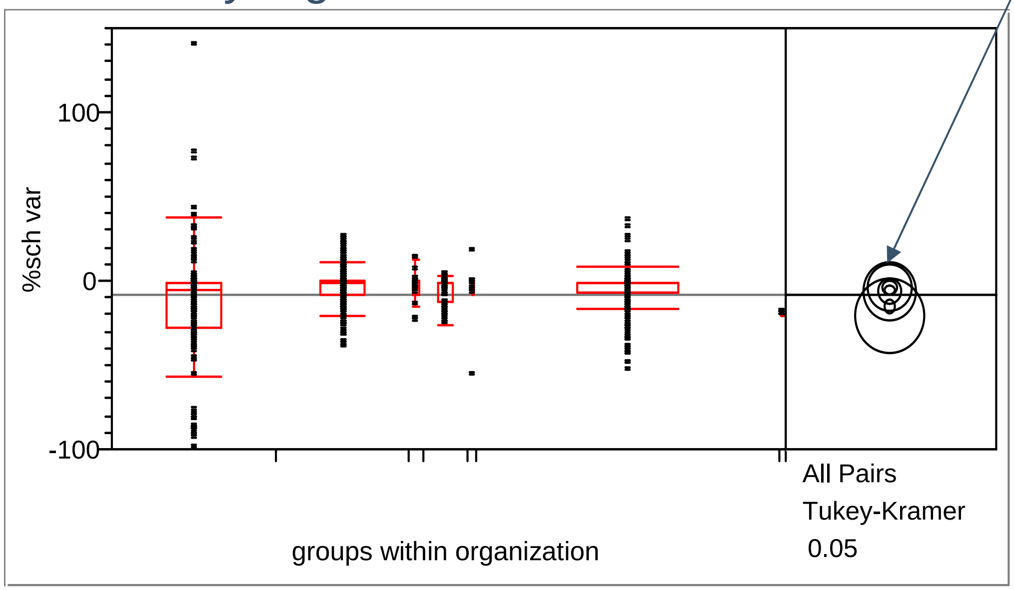
Next Steps

Cost and schedule variance and measurement quality selected as primary improvement opportunities

Dashboard established to monitor unintended consequences while organizational focus shifts to cost & schedule improvements

Segmenting the Data: Are there Differences by Org Unit?

Schedule Variance, all projects, Oct 01 to Jun 02
Charted by organizational unit



Visual indicator of significant difference

Circle size influenced by sample size

Concentric circles indicate no difference.

Separate circles indicate difference.

Overlapping circles are somewhere in between.

Are there statistically significant group-to-group differences: NO

Variance Causal Analysis

Brainstorming Workshop

- process and measurement points of contact met for 2 days to review data, brainstorm about sources of variation

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

Process decomposition

- decomposed process into four main subprocesses
- mapped cause codes to process
- identified cause codes that are resolved in-process

Cause Code Taxonomy

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

Coded historical data by cause codes.

Evaluated for frequency, severity of impact.

Co-Optimized Pareto Analysis

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

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 (defined via GQIM Indicator Template):

- trend for each cause independently
- trend for total variance

Goal statements address what needs to be changed, scope of the organization, current and target measure and timeline:

> *To [increase/decrease] primary metric [where?] [from existing level] to [target] by [when?]*

**Make your goals SMART:*

> *Specific*
> *Measurable*
> *Attainable or Agreed-upon*
> *Relevant or Realistic*
> *Timely or Timebound*

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Schedule Variance
Sub Process Selection

Cause Code: Underestimated tasks
Process: Project management
Subprocesses: Planning

- establish requirements
- define project process
- perform detailed planning

Requirements Management

CMMI Friendly

As subprocesses are explored, **process mapping and input/output analysis** may be used with (or based on) ETVX diagrams.

Six Sigma Friendly

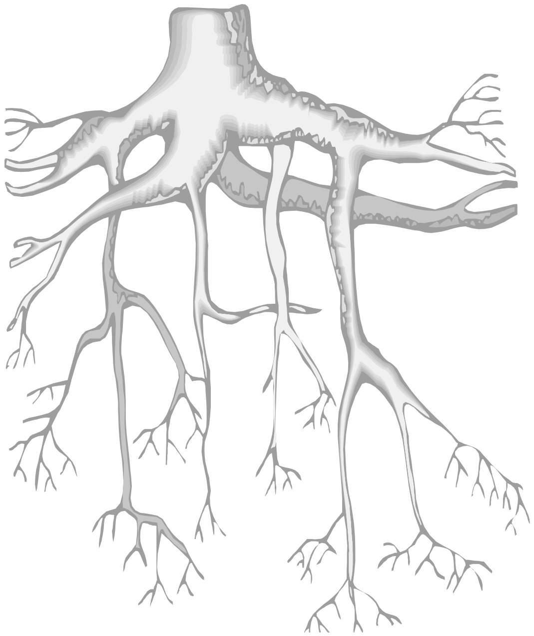
Schedule Variance Root Cause

Root causes of common cause variation

- inexperience in estimation process
- flawed resource allocation
- estimator inexperience in product (system)
- requirements not understood

Root causes of special cause variation

- too much multitasking
- budget issues



Management by Fact

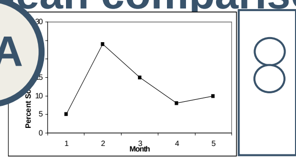
D

Problem / Goal Statement

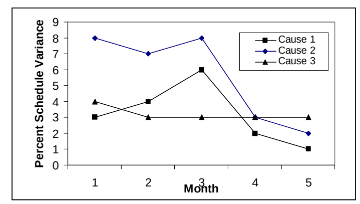
Reduce the total schedule variance by decreasing the variance of the top 3 internal causes by 50% in 1 year.

OPP M MA C

Total variance w/ mean comparison



Variance for top 3 causes:
- **underestimated tasks**
- **EV method problem**
- **missed requirements**



Prioritization & Root Cause

1. Inexperience
2. Resource allocation
3. Requirements not understood
4.….

A CAR

Counter Measures

First: Gather real time data and verify “data archaeology”
Then:
1.….
2.…

I CM OID

Impact, Capability

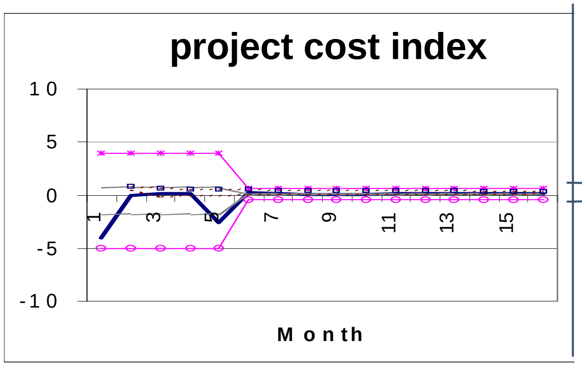
In total, these countermeasures will remove 15% of typical variance.
(as possible, list impact of each countermeasure)

From Organizational to Project View*: Variability Across the Life Cycle

It was hypothesized that there are more cost & schedule variabilities early in the project than later.

- *relative to most current estimate*

wider limits for projects in planning phase



narrower limits for projects in execution phase

**As a reminder: For those working on Level 2 and 3, the project view can be addressed as part of MA and the GPs for respective process areas. This can build a foundation for higher maturity.*

Within-Project Variance Results

Three groupings (practical and statistical basis):

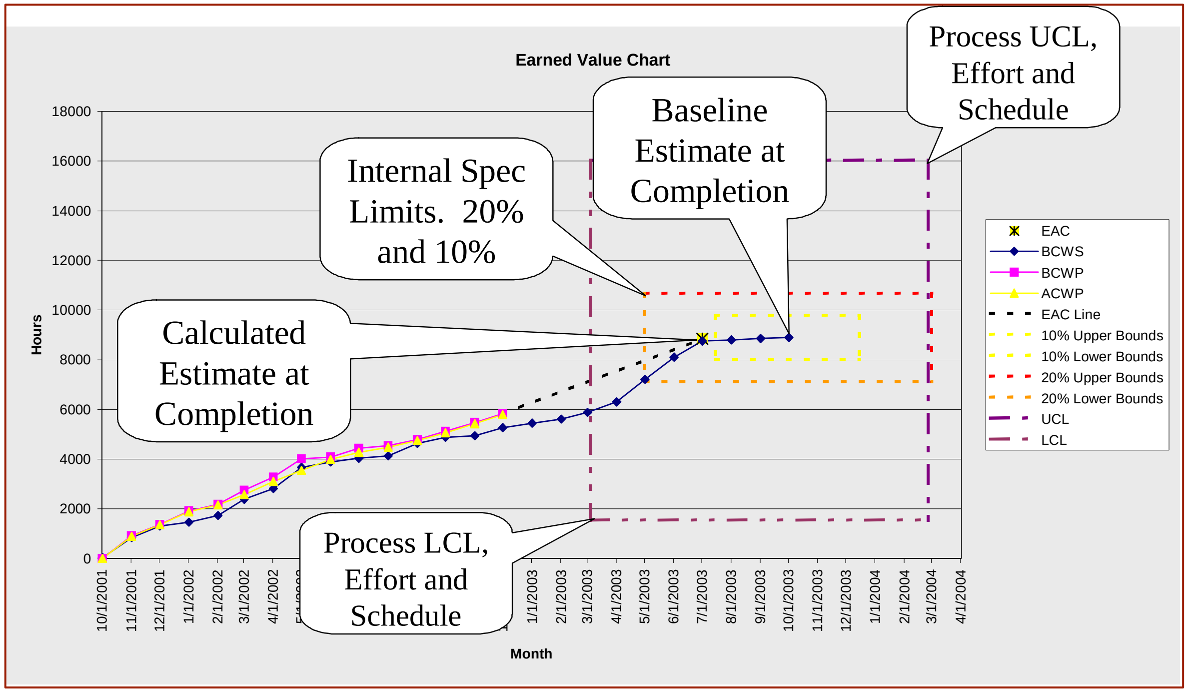
- <20% complete (planning)
- 20-80% complete (majority of effort; routine execution)
- >80% complete (converging on completion)

More data anomalies to resolve

- When *exactly* do projects start and stop?
- Are data from on-hold projects included? (No.)
- Should level of effort data be included? (Yes, but separately.)

EV Estimate-At-Completion Model

A transformation from traditional control chart view to traditional PM view



Limits for schedule and cost variance for each grouping projected to a range around the estimate-at-completion values.

Future enhancements: sensitivity analysis and prediction model

DMAIC Summary for Full Case

Multiple D-M-A iterations

- iteration 1: problem identification & project selection
  - Reduce cost and schedule variance
  - Improve data quality
- subsequent iterations:
  - "peel the onion" to better understand problems
  - establish specific quantitative goals

Improvements instituted

- measurement infrastructure expansion, automation
- cost and schedule variance cause code taxonomy
- estimating (training, minor process adjustments)
- adoption of "management by fact" (MBF) format
- homogeneous sampling for cost and schedule data

Monitoring & control mechanisms

- organization: dashboards with charts for cost, schedule, defects, data quality, and customer satisfaction
- projects: cost/schedule prediction model

Methodology/Model Connections

WV Model (the ‘base architecture’):
- DMAIC used for project identification

CMMI
- Process areas* used: MA, OPP, QPM, OID, CAR
- Process areas touched: PP, PMC, RD, REQM
- Terms addressed: Baseline, process performance model

Measurement best practices
- indicator template key component of measurement plan

Six Sigma
- problem-solving approach influenced design and definition of measurement & analysis processes
- used MBF as an organizational innovation
- indicator templates added as a domain-specific tool to the Six Sigma toolkit

*See Addenda for list of CMMI Process Areas

Skills-Building for the Full Case

In-class skills-building (practice) sessions

- baselining, using box plots, distributions, other charts
- Hypothesis testing, means comparison tests
- Prioritizing causes for action
- Failure Modes Effects Analysis

In-class discussions and other exercises

- What drives cost & schedule variance
- risks of using historical data
- small-sample sizes and homogeneous sampling
- corrective action guidance (as part of indicator template)

Copies of Slides

After lunch, we will
- decompose various elements of the case
- demystify selected roadmap steps and methods
- Practice

If you would like copies of our slides,
Add your name to our signup sheet, or
send an email to Debra Morrison, dtm@sei.cmu.edu.
- Put "SEPG Tutorial" in the subject line.

Outline

Context: The Value Proposition

Approach to building integrated training

A roadmap for performance-driven improvement

Roadmap connections to CMMI

Roadmap execution: a case study overview

➡ Roadmap execution: demystifying steps and methods

Summary

Our Approach for the Afternoon

We excerpted/shortened several lectures from the course

- Statistical thinking
- "Define": business benefits
- "Measure":
  - distilling data: segmentation, input/output analysis, Y to x
  - Baselining
  - Measurement system analysis
- "Analyze":
  - Exploring the data
  - Characterizing the process
  - Root Cause Analysis

We've interspersed the lectures with exercises, discussions and examples

- The exercises will be based on the cost-schedule case just shown, or on the DMAIC project scope you defined earlier today
- Examples are drawn from any of the 3 cases in the course

Evolution of Six Sigma Perspective

Internal View

Fitness to a
Standard

Compliance

Customer View

Fitness for
Use

Performance

Fitness to
Cost
and Speed

Lean Efficiency

Rapid Delivery

Fitness to
Latent
Requirement

Customer Intimacy
Innovation
Competitive Advantage

Six Sigma and 'Lean' - Natural Partners

Six Sigma

- Customer Focus:
  - Defects
  - Business Growth
- Performance
  - Thinking Statistically
  - Process 'Control'
- Systematic Development of Infrastructure:
  - 'Belts,' 'Champions,' Leadership Engagement

'Lean'

- Speed
- Flow
- Removing Constraints
  - Delays
  - Value-add analysis
  - Reducing Waste
- Reducing Complexity
- Increasing Flexibility

Powerful in Concert

DMAIC: Follow the Defects

Lean: Follow the Time

Lean Origins and Evolution

Seminal work at Toyota laid 'Lean' foundations:

- Understanding and reducing 'work in process' (WIP)
  - Highly visible in manufacturing
    - materials-waiting   scrap   inventory
  - Present, but often ***less visible***, in software and IT
    - decisions-waiting   rework   multiple projects underway
- Making process flow, timing, and costs ***visible***, so dynamics and constraints can be understood and exploited.

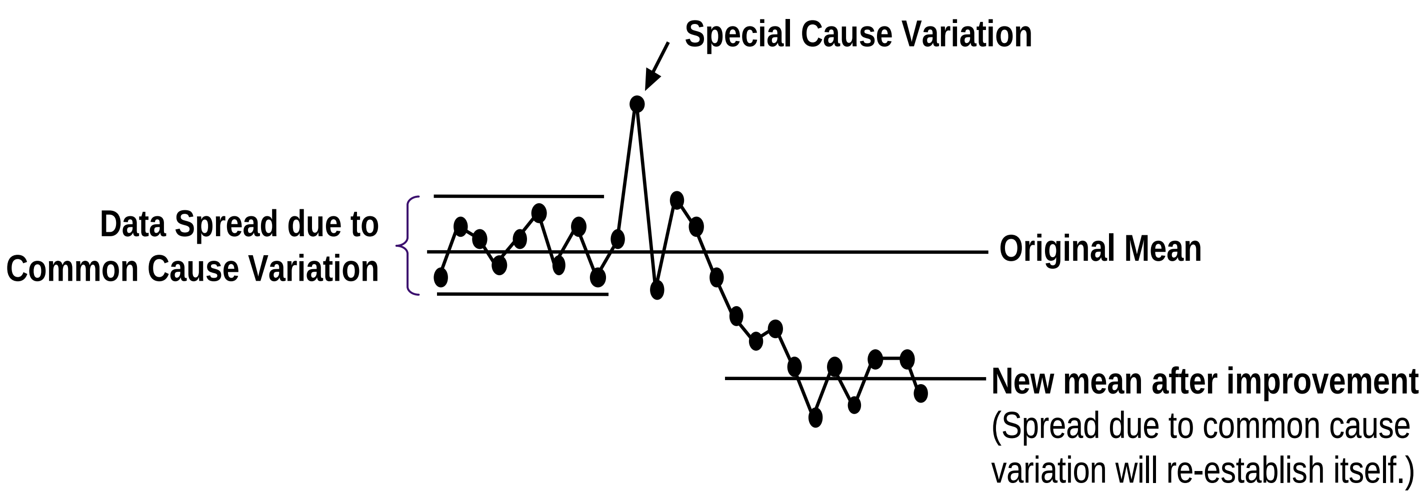
Extension to other processes has been a natural from the beginning
– with history of success in services
- emerging success stories in software and IT

Statistical Thinking: A Paradigm

Everything is a process.

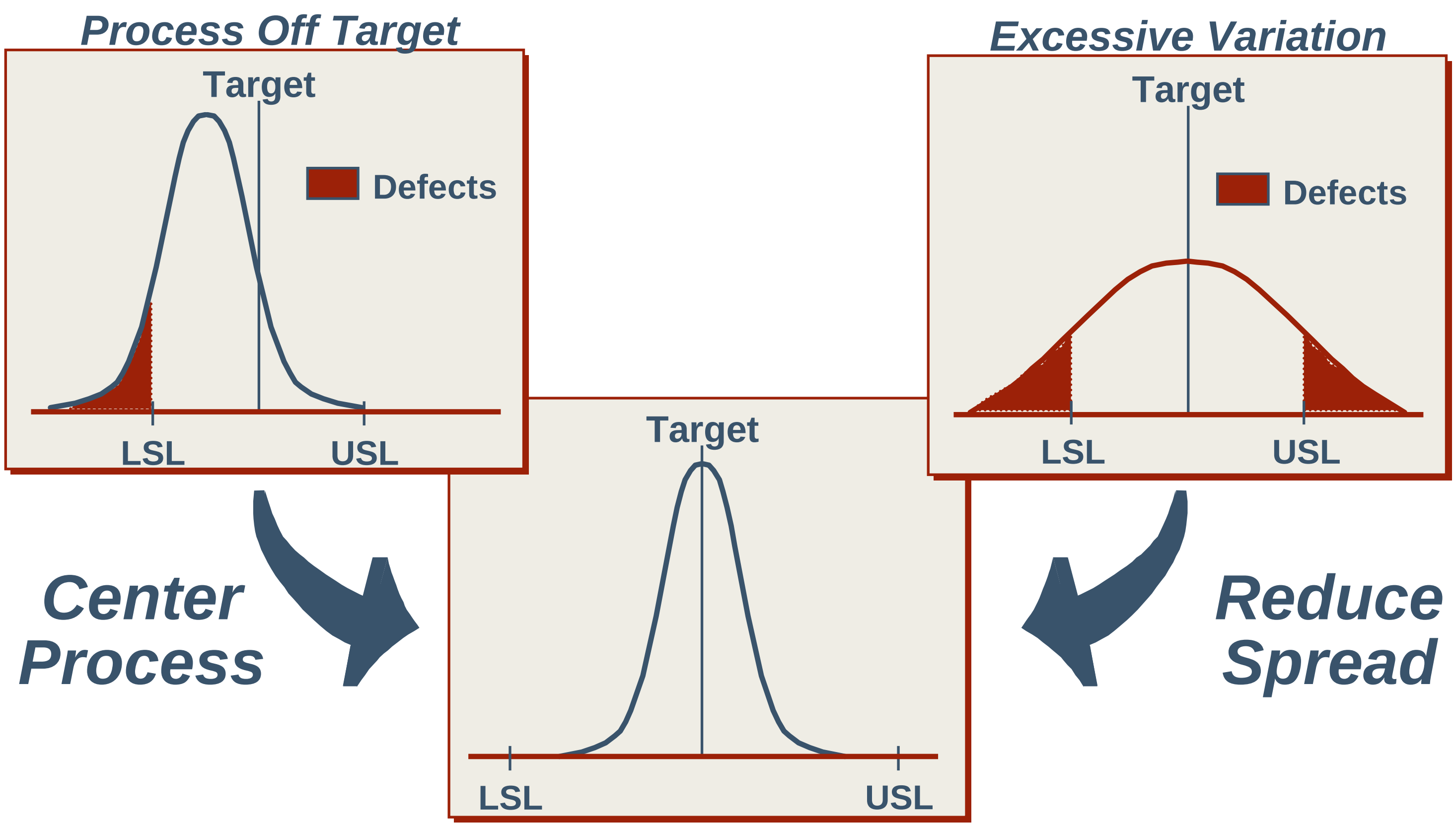
All processes have inherent variability.

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



[ASQ 00], [ASA 01]

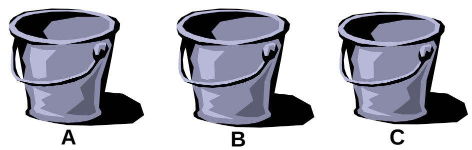
In Other Words…



Types of Data

Attribute
(a.k.a., nominal, categorical, digital)

Placing observations into categories



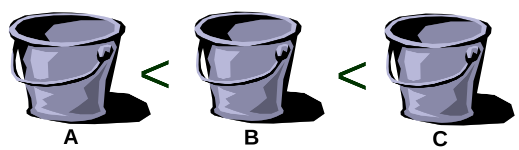
Examples

Defect counts by type

Job titles

Ordinal

Attribute data, with > or < relationships among the categories



Satisfaction ratings:
unsatisfied, neutral, delighted

Risk estimates: low, med, high

CMM maturity levels

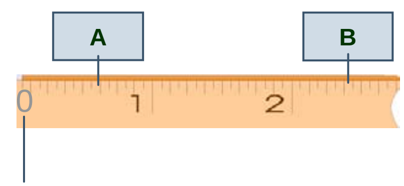
Increasing Information Content

Variables
(a.k.a., measures, continuous, analog)

Assignment of observations to points on a scale … enabling determination of interval sizes and differences

Interval

deg. F, C

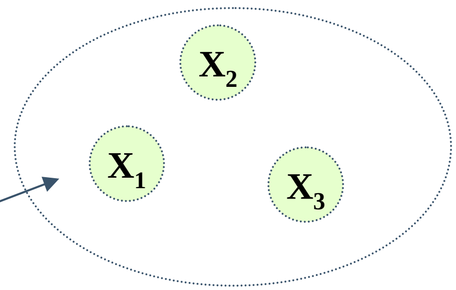


Ratio

Time
Cost
Code size

Terms & Definitions

A **population** consists of the totality of observations with which we are concerned.

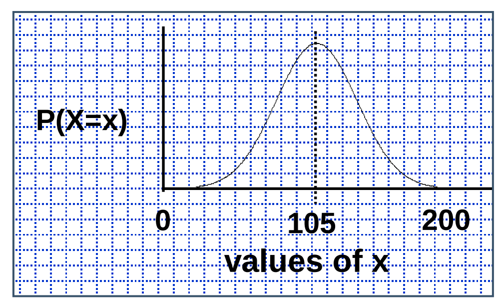


A **sample** is a set of observations selected from a population.

A **statistic** is a function that summarizes observations.

$$\text{average} = \frac{x_1 + x_2 + x_3}{3}$$

A **sampling distribution** maps values of a sample statistic (x) vs. their probability of occurrence (y).



Descriptive Statistics

Measures of *Central Tendency*: location, middle, the balance point

Mean = (the average)

$$\frac{\text{sum of n measured values}}{\text{n}}$$

$$= \frac{10486.3}{46} = 227.9$$

(the center of gravity by value)

Median = the midpoint by count

Mode = the most frequently observed point

Measures of ***Dispersion***: Spread, variation, distance from central tendency

Range maximum - minimum

σ^2

$$\text{Variance} = \frac{\sum_{i=1}^{n}(x_i - \mu)^2}{n}$$

Average squared distance from the population mean

σ

$$\text{Standard Deviation} = \sqrt{\text{Variance}}$$

In the units of the original measures; indicator of the spread of points from the mean

Inferential vs. Descriptive Stats

Do we have all the data ?

	Yes	No, a sample
	Descriptive Statistics	Inferential Statistics
Example	All of last quarter's calls to the support hotline	Surveys returned from about 120 customers
Statistics	Mean, median, mode, variance (σ^2), standard deviation (σ), range, etc.	Estimates of mean, median, mode, variance (s^2), standard deviation(s), etc.
Issues	Measurement system accuracy and repeatability	Measurement system accuracy and repeatability Sampling bias Choice of statistic

Greek letters (e.g. σ, μ) usually designate descriptive stats

Roman letters (e.g. s, y) usually designate inferential (sample) stats

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Define Guidance Questions

Define → Measure → Analyze → Improve → Control

Define project scope

- What is the current problem to be solved?
- What are the goals, improvement targets, & success criteria?
- What is the business case, potential savings, or benefit that will be realized when the problem is solved?
- Who are the stakeholders? The customers?
- What are the relevant processes and who owns them?

Establish formal project

- Have stakeholders agreed to the project charter or contract?
- What is the project plan, including the resource plan and progress tracking?
- How will the project progress be communicated?

OPP OPF GPs OID

Reconciling Different "Voices"

Voice of the Business (VOB)
- term to describe the stated and unstated needs or requirements of the business/shareholders

Voice of the Customer (VOC)
- term to describe the stated and unstated needs or requirements of the customer

Voice of the Process (VOP)
- term to describe the performance, capability of the organization's processes

Understanding the relationship between these voices
- enables appropriate selection of processes to begin study
- further refines project scope and enables the establishment of a formal project
- lays the foundation for work to be done in "measure, analyze, improve"

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Evaluating Business Benefits

Things to consider:

- What is the business motivation for this project?
  - How big is the problem?
  - What are the implications?
  - What is the projected payback or net value?
- Why now?
- What would be the consequences if we delayed or failed to execute?
- How does this project fit with others?
  - relative priority
  - leverage/support re: other initiatives

Measuring Benefits

$$ saved

Return on Investment

Return on Equity

Cash Flow Rate of Return

Cost of Poor Quality

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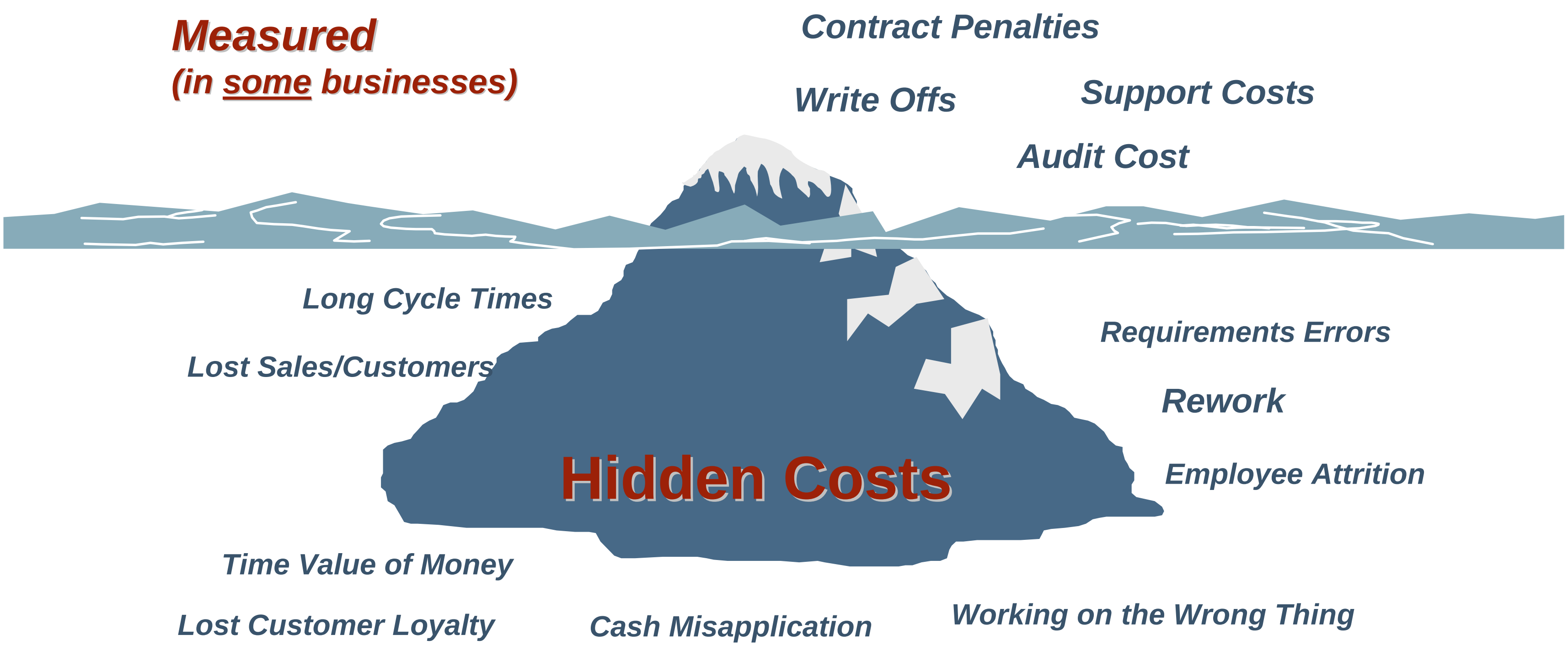
Cost of Poor Quality (COPQ)

Costs of Poor Quality (COPQ)



Evolving the COPQ Indicator

Identification: (based on a financial metric)

e.g. Y = unit cost per call =

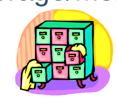
Rep

\$\$ +

Supervisor

\$\$ +

Storage/Monitoring



\$\$ + ?? \$\$

Classification:

Hard vs. soft savings

Appraisal cost vs. cost avoidance

Validation:

		Confidence
Define	Initial (I) COPQ	Moderate
Analyze	COPQ	↓
Improve	Pre-Implementation Cost-Benefit Analysis	↓
Control	Post-Implementation Cost-Benefit Analysis	↓
Realization	Verified (longer term) Cost-Benefit Analysis	High

Validating Business Costs & Benefits

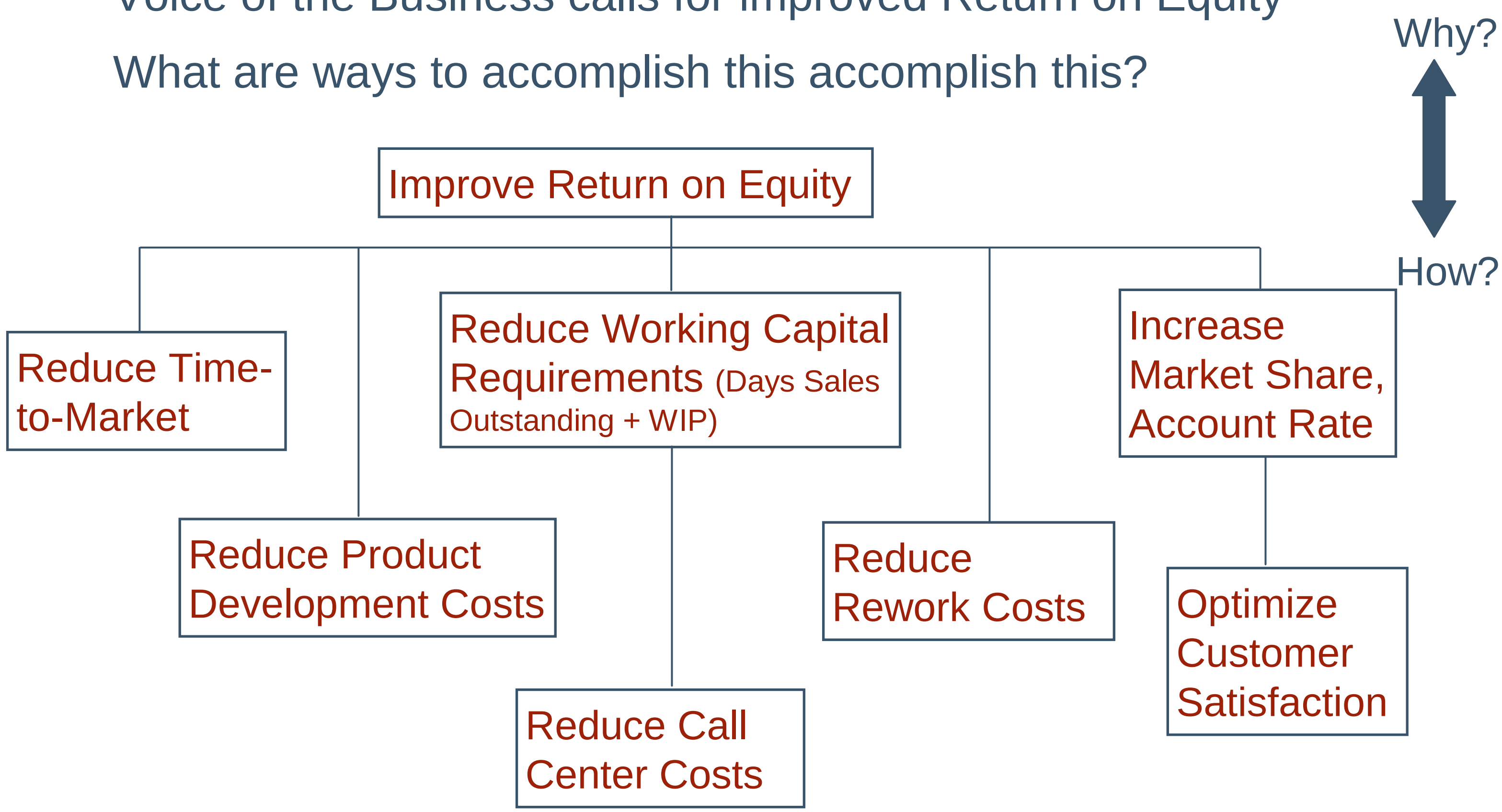
While you can estimate some non-value-added costs, it is important to validate costs with your organization's accounting department early in the project.

This will:
- confirm the business case
- document the project's "before" picture as a baseline
- document the project's net financial gains ('after' – project costs – "before")

Example: Call Center Case

Voice of the Business calls for improved Return on Equity

What are ways to accomplish this accomplish this?



Call Center Project Scope

Problem Statement (from benchmarking and high level baselining):
Competitors are growing their levels of satisfaction with support customers, and they are growing their businesses while reducing support costs per call. Our support costs per call have been level or rising over the past 18 months, and our customer satisfaction ratings at or below average. Unless we stop, or better, reverse this trend we are likely to see compounded business erosion over the next 18 months.

Business Case:
Increasing our new business growth from 1% to 4% (or better) would increase our gross revenues by about $3mm. If we can do this without increasing our support costs per call, we should be able to realize a net gain of at least $2mm.

Goal Statement:
Increase the call center's industry-measured Customer Satisfaction rating from its current level (75%) to the target level (85%) without increasing support costs, by end of Q4.

Measure Guidance Questions

Define → **Measure**

- Does the measurement system yield accurate, precise, and reproducible data?
- Are urgently needed improvements revealed?
- Has the risk of proceeding in the absence of 100% valid data been articulated?

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Identify needed data

- What are the process outputs and performance measures?
- What are the process inputs?
- What info is needed to understand relationships between inputs and outputs? Among inputs?
- What information is needed to monitor the progress of this improvement project?

Obtain data set

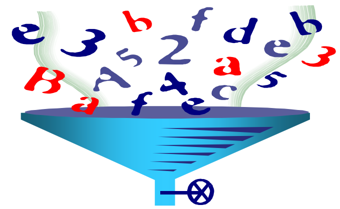
- Is the needed measurement infrastructure in place?
- Are the data being collected and stored?

Evaluate data quality

Summarize & baseline data

- What does the data look like upon initial assessment? Is it what we expected?
- What is the overall performance of the process?
- Do we have measures for all significant factors, as best we know them?
- Are there data to be added to the process map?
- Are any urgently needed improvements revealed?
- What assumptions have been made about the process and data?

Distilling Data



Raw Data

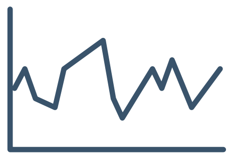
Events

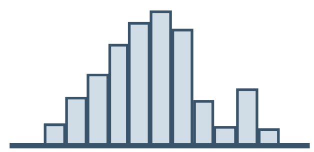
Measure

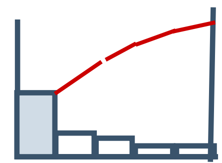
Measure & Analyze

Graphical Analysis

What? When? Where?
How? How much?







Patterns

Structure

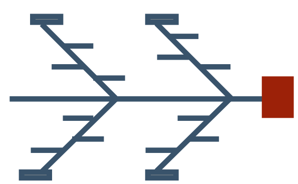
Analyze

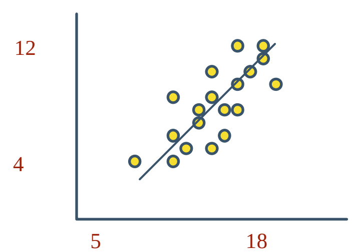
Causal Analysis

Why?

What's really going on?

What's driving the patterns?





TRANSFER FUNCTIONS and OPTIMIZATION

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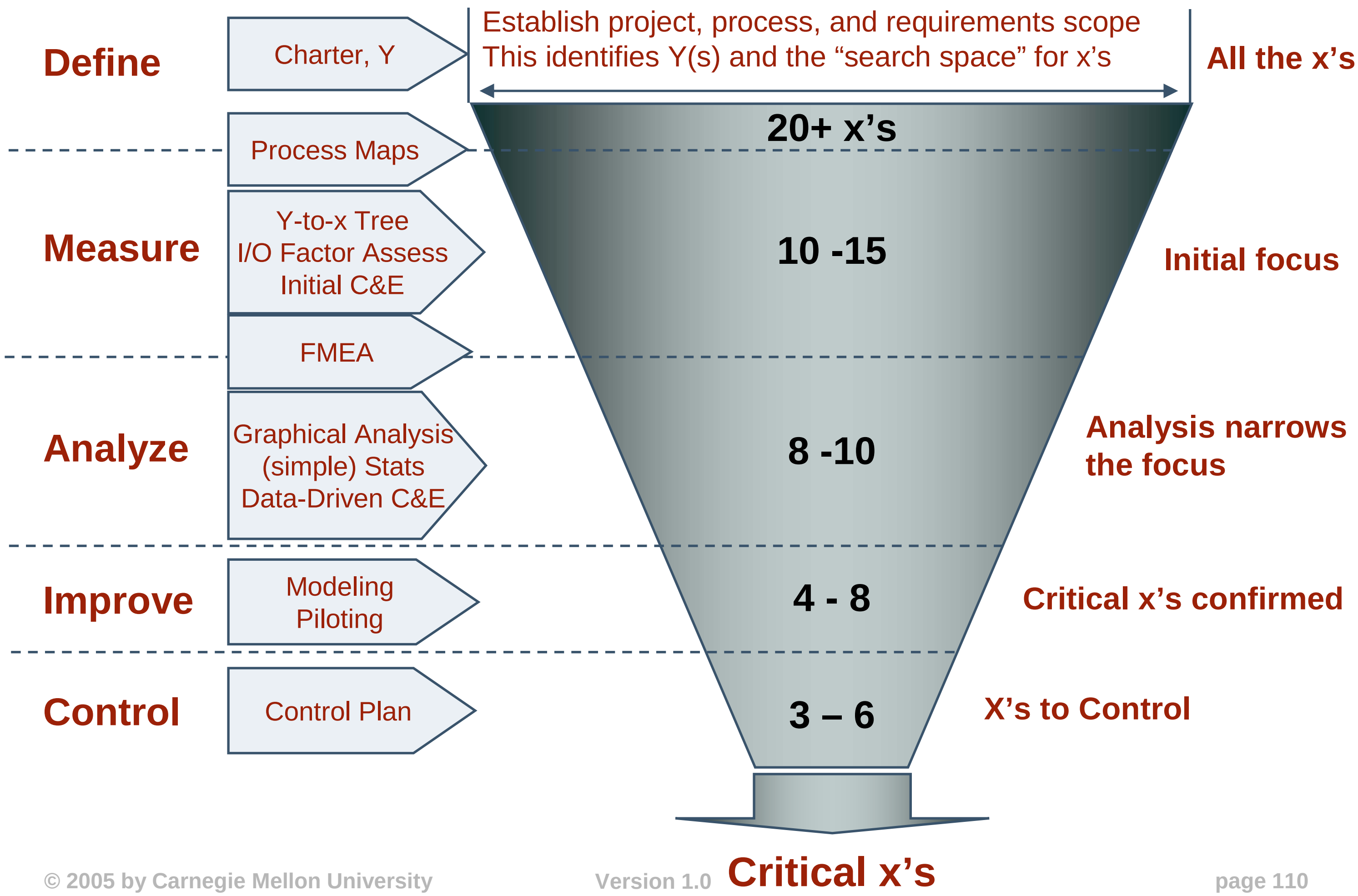
"Funneling" to the Critical x's



Methods to Narrow Our Focus

What are the process outputs (y's) that drive performance?
What are key process inputs (x's) that drive outputs (process performance) and overall performance?

Techniques to address these questions

- segmentation / stratification
- input and output analysis
- Y to x trees
- cause & effect diagrams
- cause & effect matrices
- failure modes & effects analysis

Using these techniques yields a list of relevant, hypothesized, process factors to measure and evaluate.

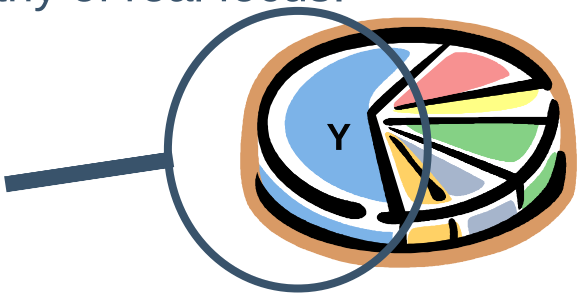
Natural Segmentation

Description

A logical reasoning about which data groupings have different performance, often verified by basic descriptive statistics.

Procedure

- Consider what factors, groupings, segments, and situations may be *driving the mean performance and the variation in Y.*
- Draw a vertical tree diagram, continually reconsidering this question to a degree of detail that makes sense.
- Calculate basic descriptive statistics, where available and appropriate, to identify areas worthy of real focus.

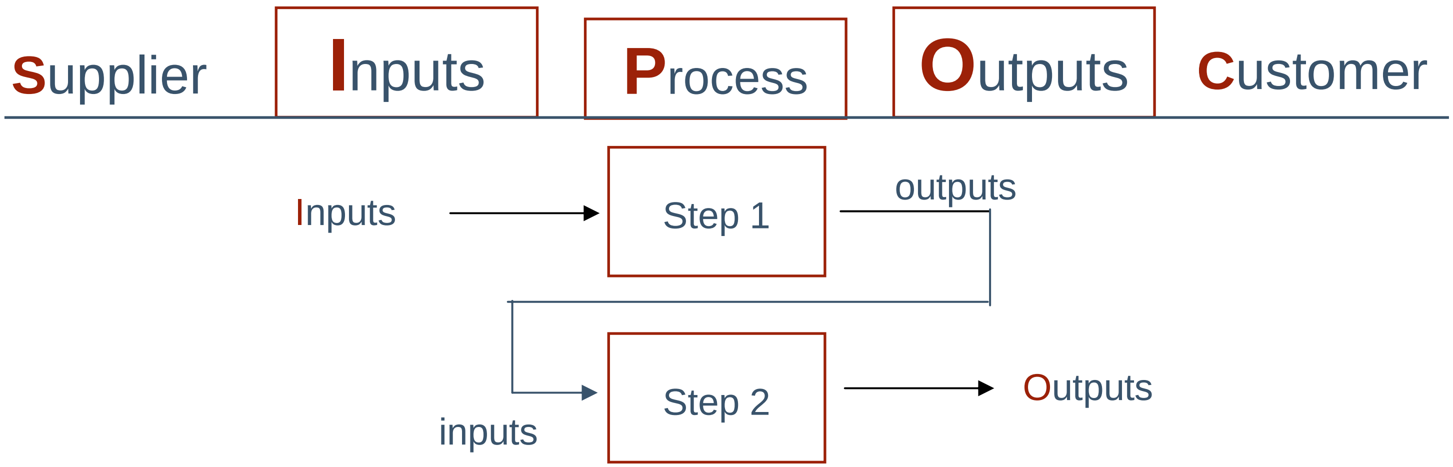


Segmentation vs. Stratification

Segmentation
- grouping the data according to one of the data elements (e.g., day of week, call type, region, etc.)
- gives discrete categories
- in general we focus on the largest, most expensive, best/worst – guides “where to look”

Stratification
- grouping the data according to the value range of one of the data elements (e.g., all records for days with “high” volume vs. all records with “low” volume days)
- choice of ranges is a matter of judgment
- enables comparison of attributes associated with “high” and “low” groups – what’s different about these groups?
- guides diagnosis

Input / Output Analysis



Assess the Inputs:

- Controllable: can be changed to see effect on key outputs (also called “knob” variables)
- Critical: statistically shown to have impact on key outputs
- Noise: impact key outputs, but difficult to control

Controlled and Uncontrolled Factors

Controlled factors are within the project team's *scope of authority* and are *accessed* during the course of this project.

Studying their influence may inform:

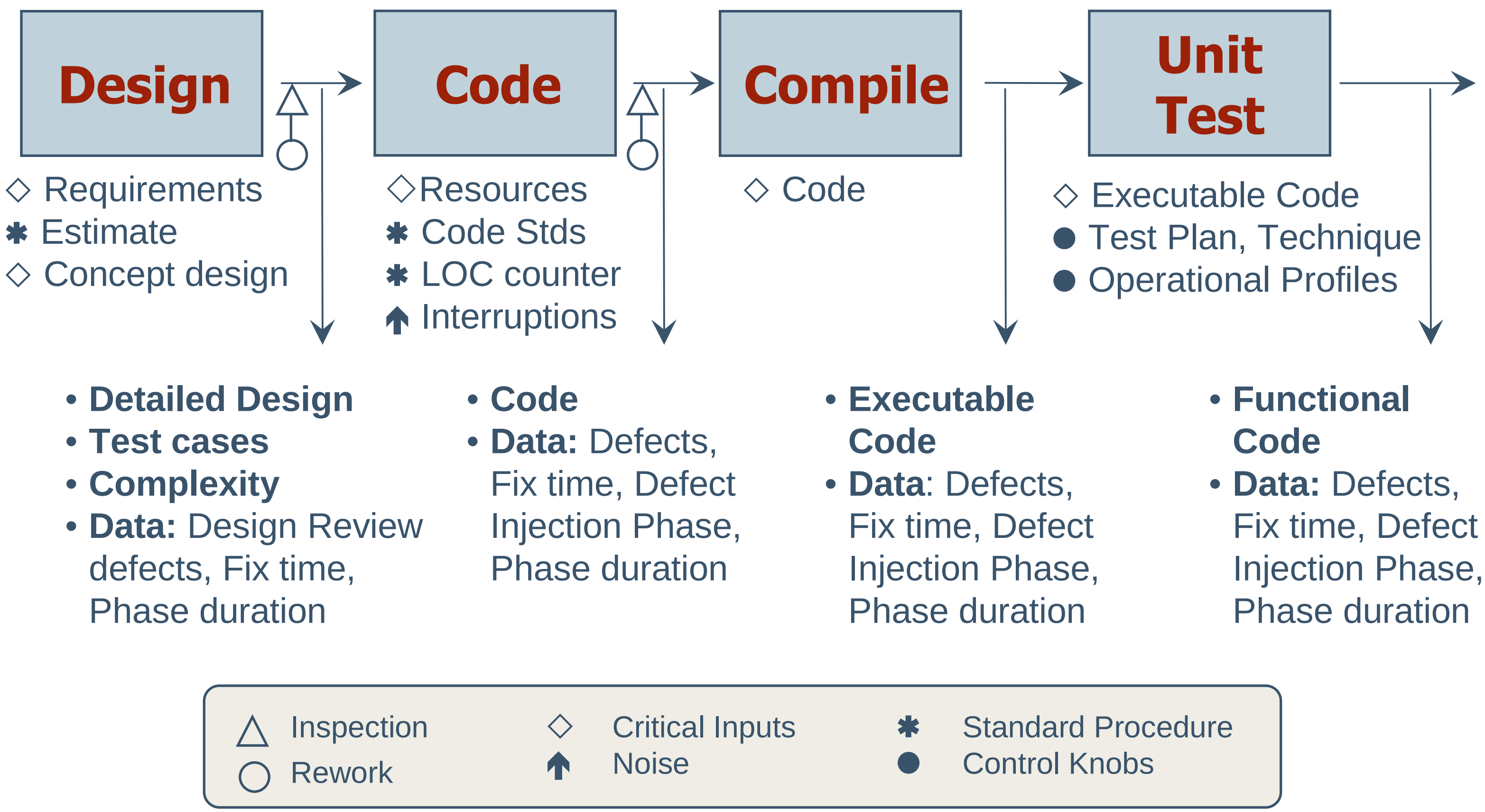
- cause-and-effect work during Analyze
- solution work during Improve
- monitor and control work during Control

Uncontrolled factors are factors we do not or cannot control.

We need to acknowledge their presence and, if necessary, characterize their influence on Y.

A robust process is insensitive to the influence of uncontrollable factors.

Example: Development Process Map



Lean Methods and Tools

Process Mapping

- (Customer)Value-Add / Non Value-Add / Business Value-Add
- Cycle time and throughput analysis (see "Little's Law)

Process Dynamics / Constraints Analysis

- Characterizing bottlenecks, queues
- Identifying throughput, capacity, and quality constraints

Mapping Variation: 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.

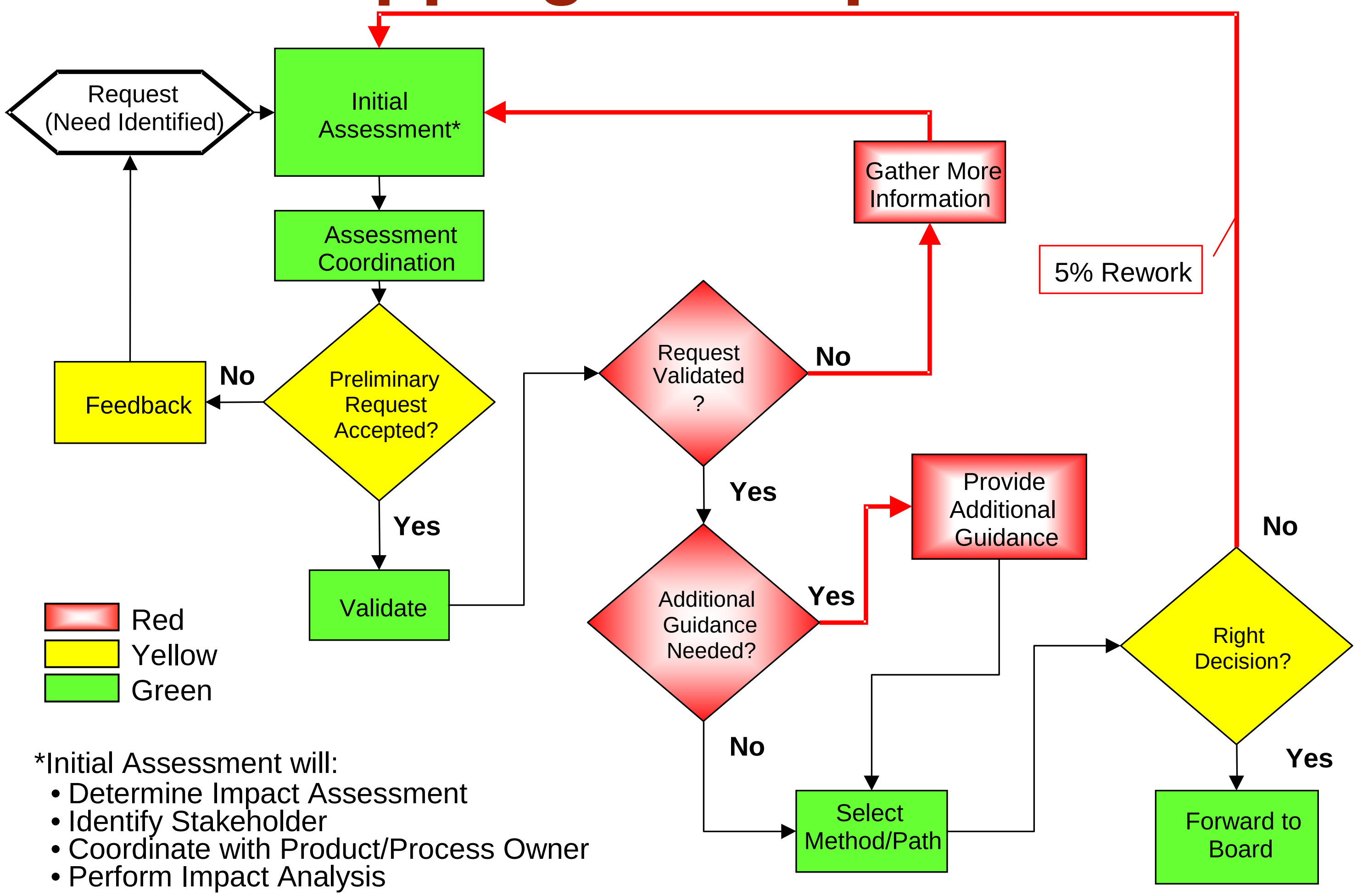
- green = value added
- red = non value added
- yellow = non value added but necessary

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: Example



*Initial Assessment will:

- Determine Impact Assessment
- Identify Stakeholder
- Coordinate with Product/Process Owner
- Perform Impact Analysis

Flowdown (Y-to-x) Tree -1

Description

- Y to x is a hypothesis tool
  - Depicts hypothesized causal relationships between customer-critical performance measures and process factors
  - represents portions of a transfer function over time

Procedure

- Draw a vertical tree diagram to depict the causal relationship.
  - Use information from process mapping, natural segmentation as inputs.
- Identify x's as uncontrollable vs. controllable and measurable.
- Select y's and x's for initial data collection and evaluation.

Flowdown (Y-to-x) Tree -2

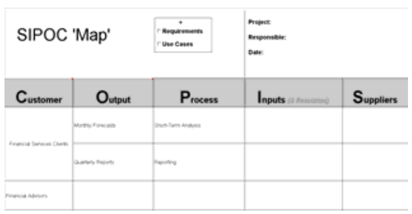
Considerations

- Flowdown trees are very useful when Y is hard to measure directly or hard to influence.
- Cause & effect diagrams are another means of diagramming hypothesized causal relationships.
- Subsequent “measure” and “analyze” tasks will help determine the strength and the nature of each important x–Y relationship.
- The initial selection of y’s and x's for data collection may be based on logic and data availability. As more about the process is understood, quantitative causal relationships will drive selections.

Tool Connections – "Finding X"

1 SIPOC

Identify suppliers, inputs, process, outputs, & customers. Discover Y's.



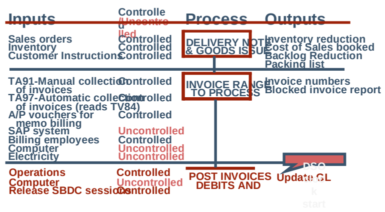
2 Y –to- x Tree

Discover x's.

Clarify x's

3 Input Output Analysis

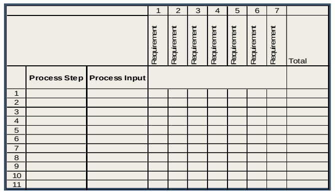
Classify x's.



Prioritize Steps and x's

4 Cause and Effects Matrix

Prioritize steps and x's.



Deep dive into process steps

5 Refined Process Map

Understand prioritized process steps.

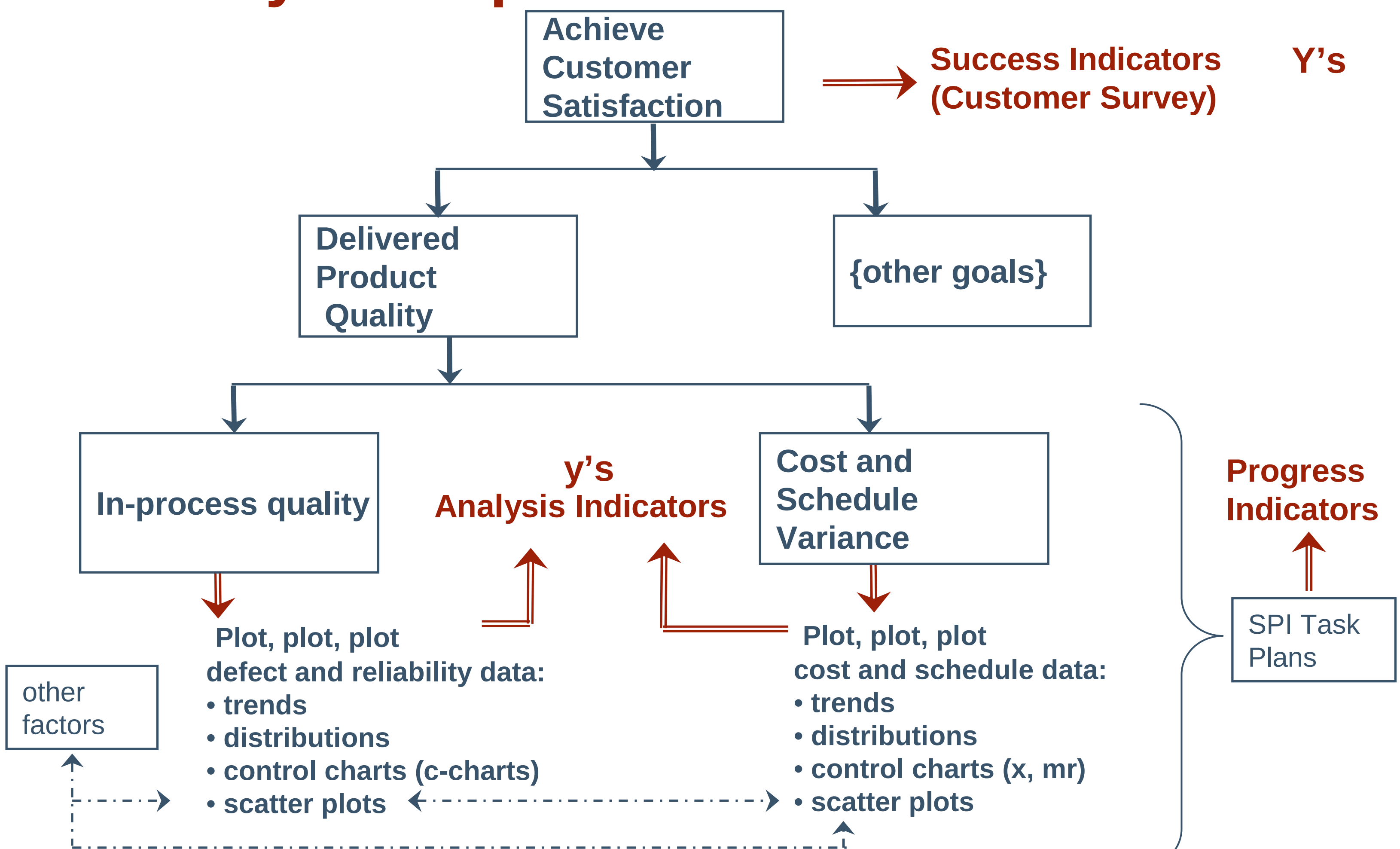
Process Understanding

6 FMEA

Begin to understand x's impact on Y's; further prioritize x's.

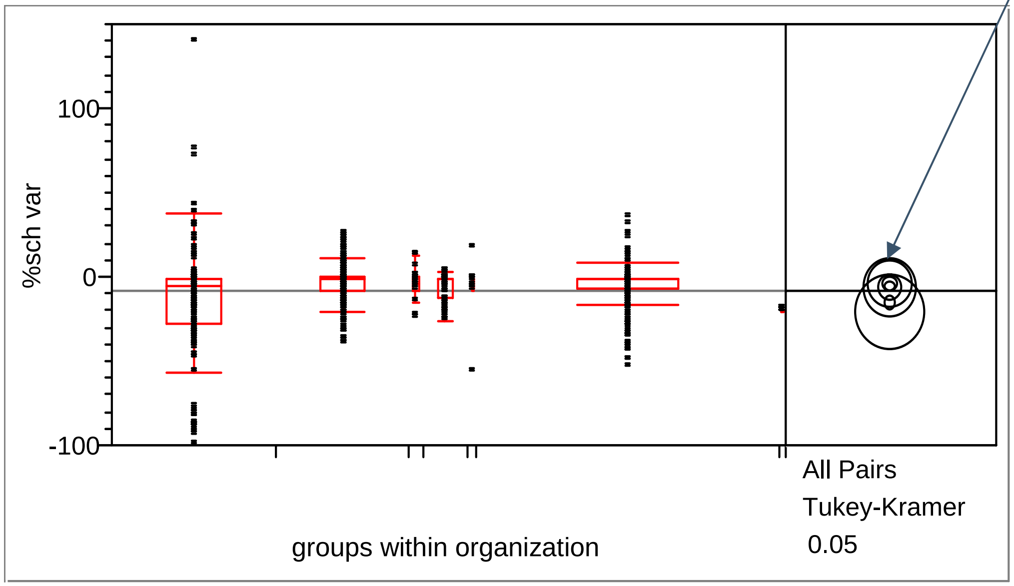
Function or Process Step	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Detection Provisions	DET	RPN
								0
								0
								0
								0

Y to y Example: Cost Schedule Case



Example: Cost-Schedule Case Segmentation by Organizational Unit

Schedule Variance, all projects, Oct 01 to Jun 02
Charted by organizational unit



Visual indicator of significant difference

Circle size influenced by sample size

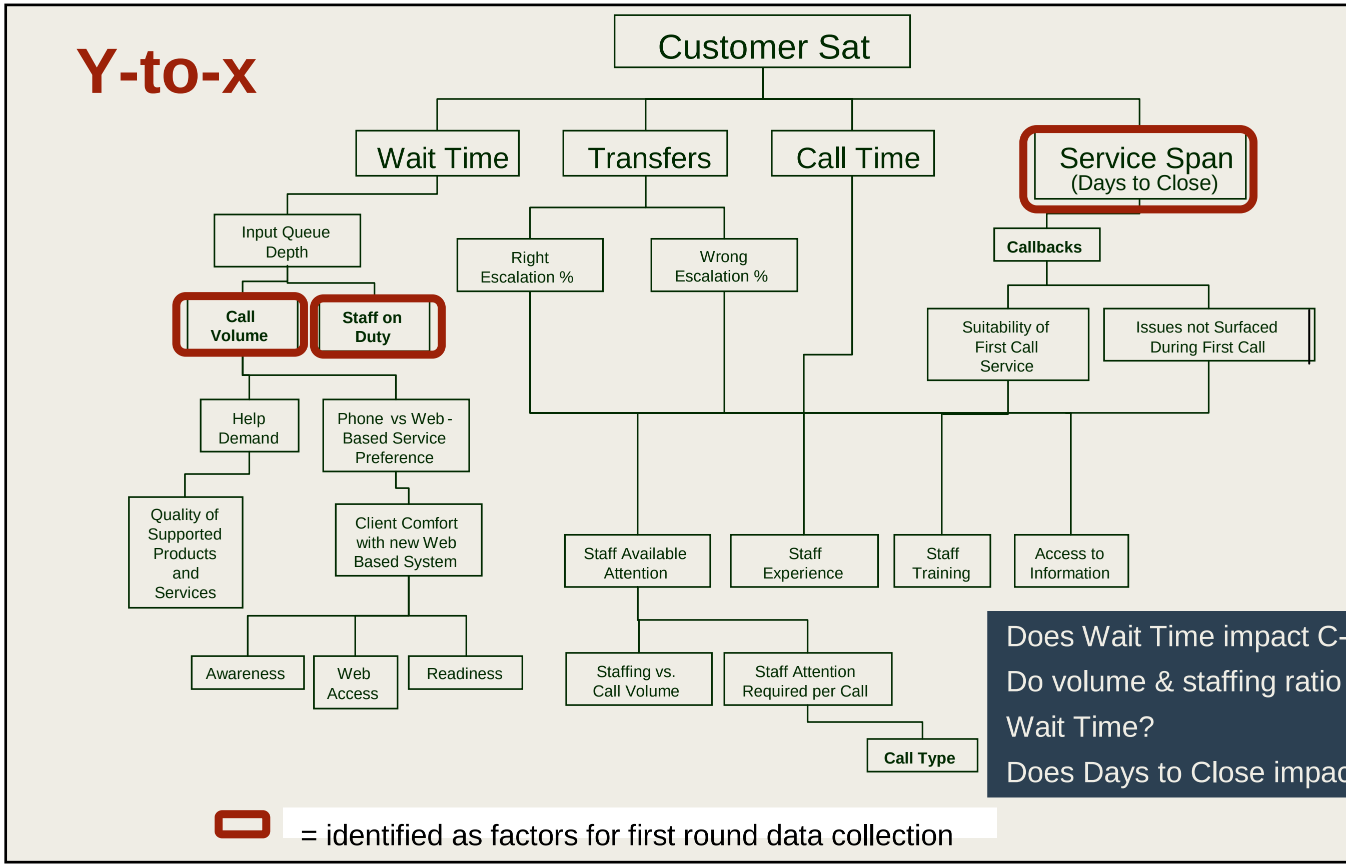
Concentric circles indicate no difference.

Separate circles indicate difference.

Overlapping circles are somewhere in between.

Are there statistically significant group-to-group differences: NO

Example: Call Center Customer Sat.

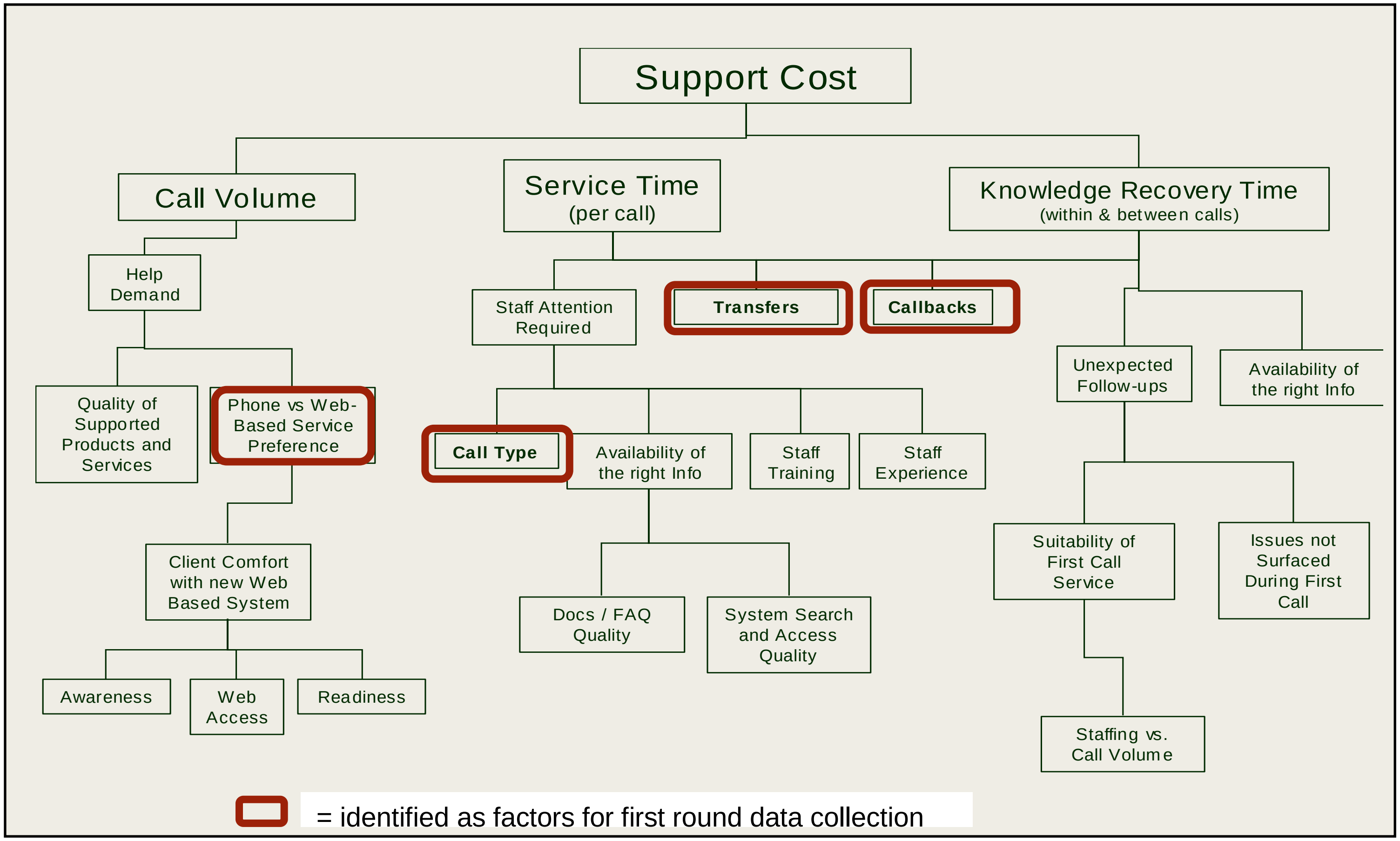


Does Wait Time impact C-Sat?

Do volume & staffing ratio impact Wait Time?

Does Days to Close impact C-Sat?

Example: Call Center Support Cost



Exercise: Segmentation & I/O Analysis

Earlier today, you answered the “define project scope” questions for a problem you are facing

1 Identify a key performance measure (a ‘big Y’)

2 Since that measure cannot be changed directly – begin to build a ‘Y to x’ tree to identify factors (x’s), groups, situations, or other categorical reasons that may be driving performance or variation?

3 For some key ‘x’s – classify whether they would be ‘controllable’ or ‘uncontrolled’ in the scope of the project at hand.

4 Think ahead about:
- Availability of data to study x-Y relationships
- Quality of the measurement system for x data

Measure Guidance Questions

Measure

- Does the measurement system yield accurate, precise, and reproducible data?
- Are urgently needed improvements revealed?
- Has the risk of proceeding in the absence of 100% valid data been articulated?

Identify needed data

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Obtain data set

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Evaluate data quality

Summarize & baseline data

- Is the needed measurement infrastructure in place?
- Are the data being collected and stored?

Measurement System Analysis (MSA)

Purpose

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

Indicators of data quality and reliability

- Validity
- Integrity
- Accuracy
- Repeatability
- Reproducibility
- Stability
- credibility

MSA Tools & Methods

Sometimes, a simple “eyeball” test reveals problems.

More frequently, a methodical approach is warranted.

Useful tools and methods include

- process mapping
- indicator templates
- operational definitions
- initial evaluation/exploration assessment using statistical tools
- checklists

Use common sense, basic tools, and good powers of observation.

MSA Practical Tips

Frequently encountered problems include the following:
- wrong data
- missing data
- skewed or biased data

Map the data collection process.
- Know the assumptions associated with the data.

Look at indicators as well as raw measures.
- ratios of bad data still equal bad data

Data systems to focus on include the following:
- manually collected or transferred data
- categorical data
- startup of automated systems

Exercise: What if I Skip MSA?

What if…

- All 0's in the inspection database are really missing data?
- "Unhappy" customers are not surveyed?
- Delphi estimates are done only by experienced engineers?
- A program adjusts the definition of "line of code" and doesn't mention it?
- Inspection data doesn't include time and defects prior to the inspection meeting?
- Most effort data are tagged to the first work breakdown structure item on the system dropdown menu?
- The data logger goes down for system maintenance in the first month of every fiscal year?
- A "logic error" to one engineer is a "___" to another

Which are issues of validity? Bias? Integrity? accuracy?
How might they affect your conclusions and decisions?

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Measure Guidance Questions

Define → **Measure**

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Baselining

What is baselining?

- establishing a snapshot of performance and/or the characteristics of a process

Why baseline performance?

- provides a basis by which to measure improvement

How is it done?

- map the process of interest
  - including scope (process boundaries) and timeframe
- gather data
  - sample appropriately
- summarize data using basic tools

The 7 Basic Tools

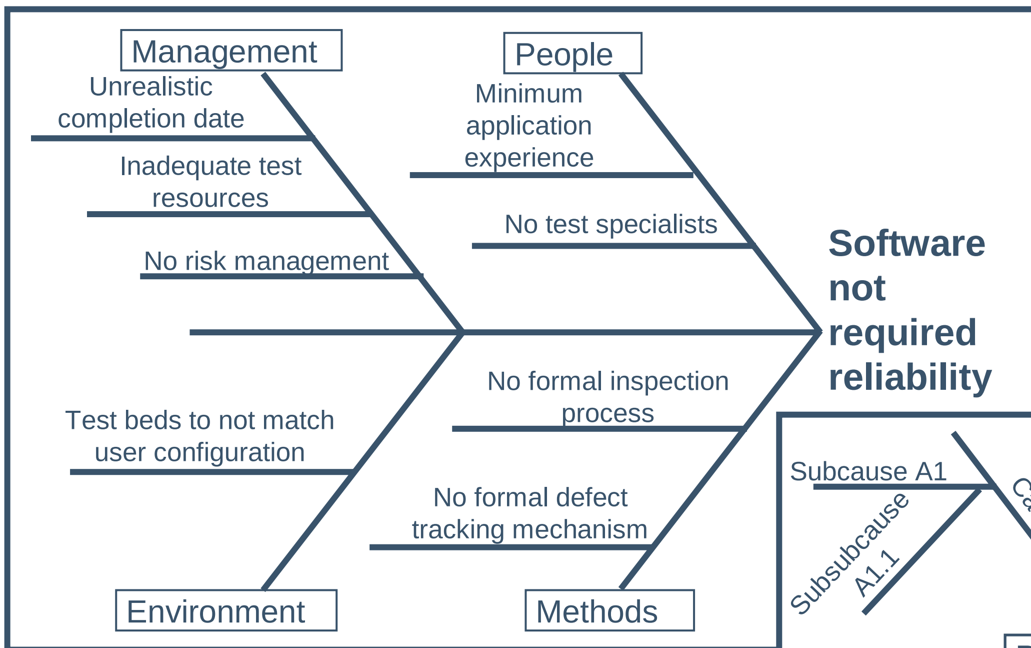
Description

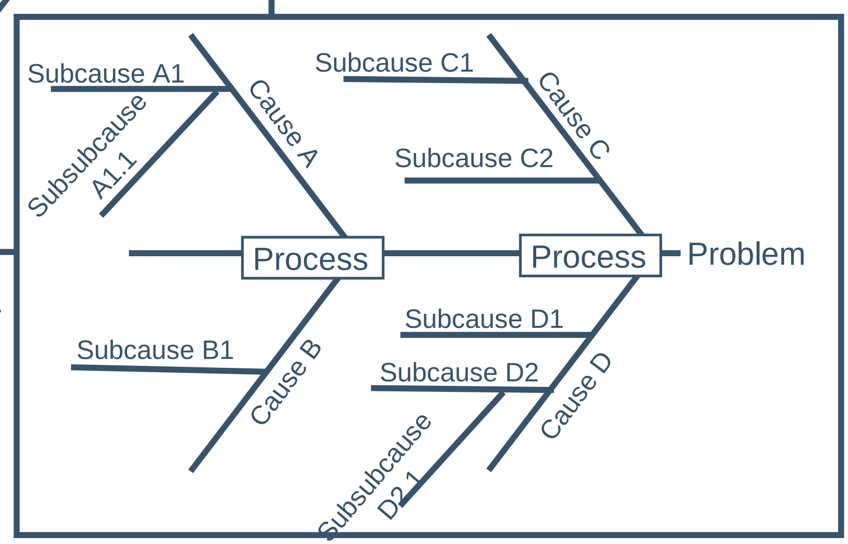
- Fundamental data plotting and diagramming tools
  - cause & effect diagram
  - histogram
  - scatter plot
  - run chart
  - flow chart
  - brainstorming
  - Pareto chart

- The list varies with source. Alternatives include the following:
  - statistical process control charts
  - descriptive statistics (mean, median, etc.)
  - check sheets

7 Basic Tools: Cause & Effect

Traditional diagram

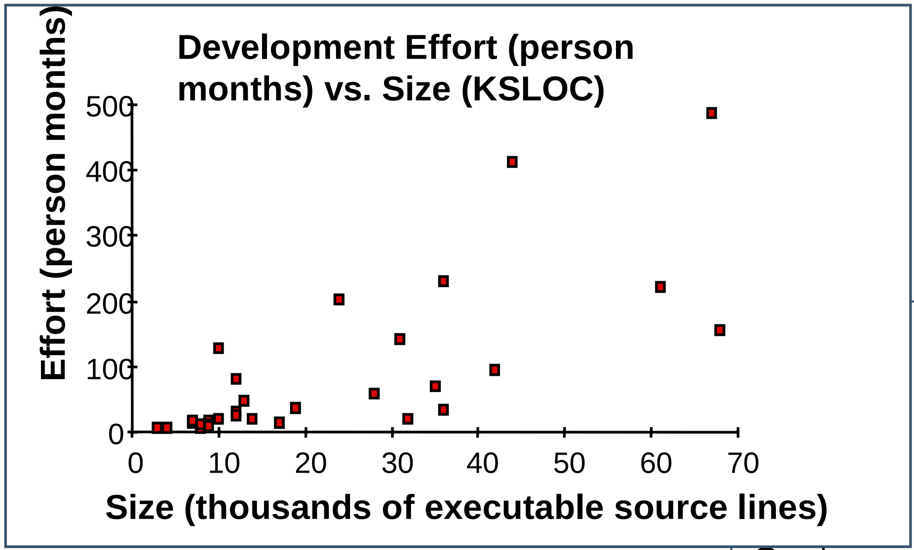




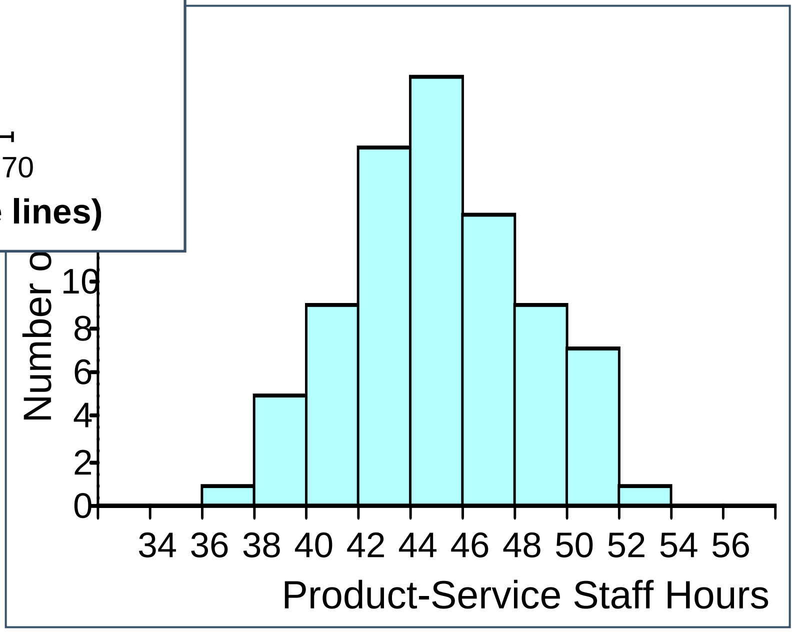
Variation

[Westfall]

7 Basic Tools: Chart Examples 2



Scatter Plot

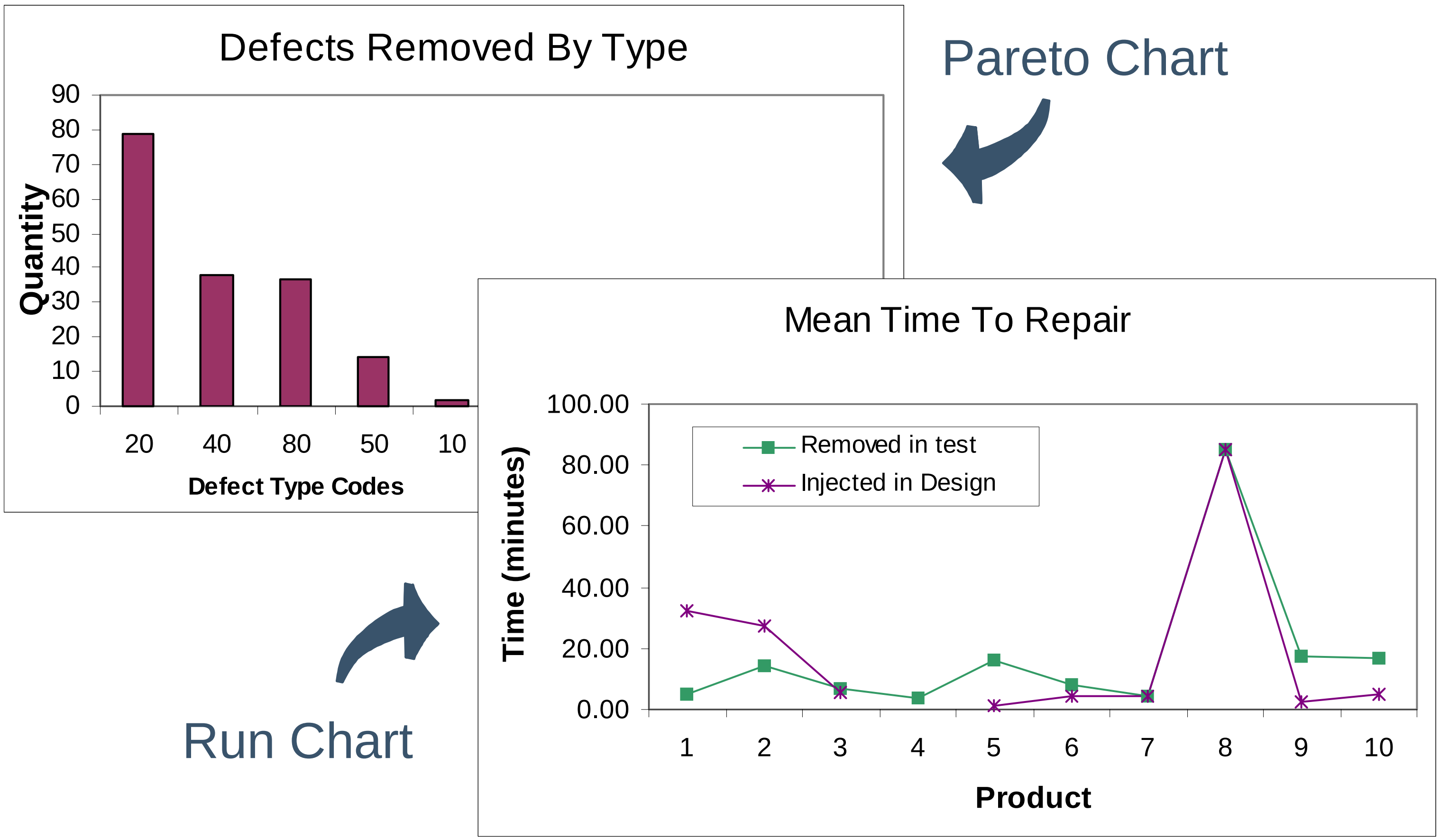


Histogram

7 Basic Tools: Chart Examples

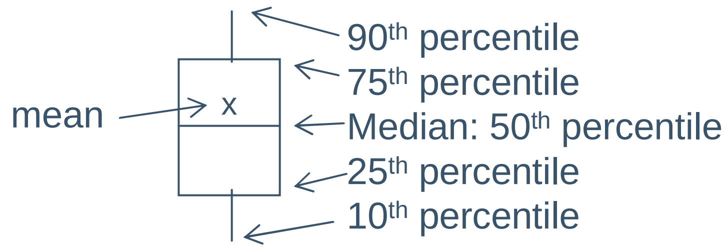
Pareto Chart

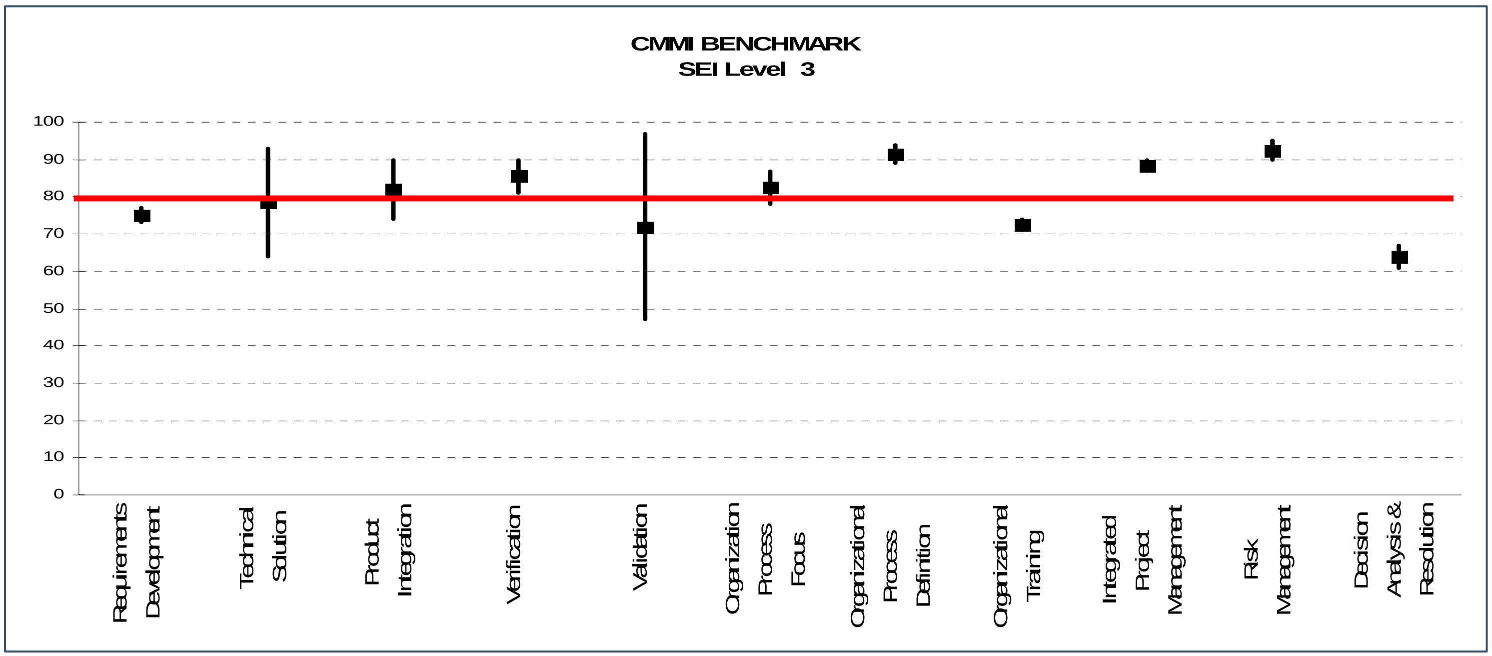
Run Chart



7 Basic Tools: Chart Examples

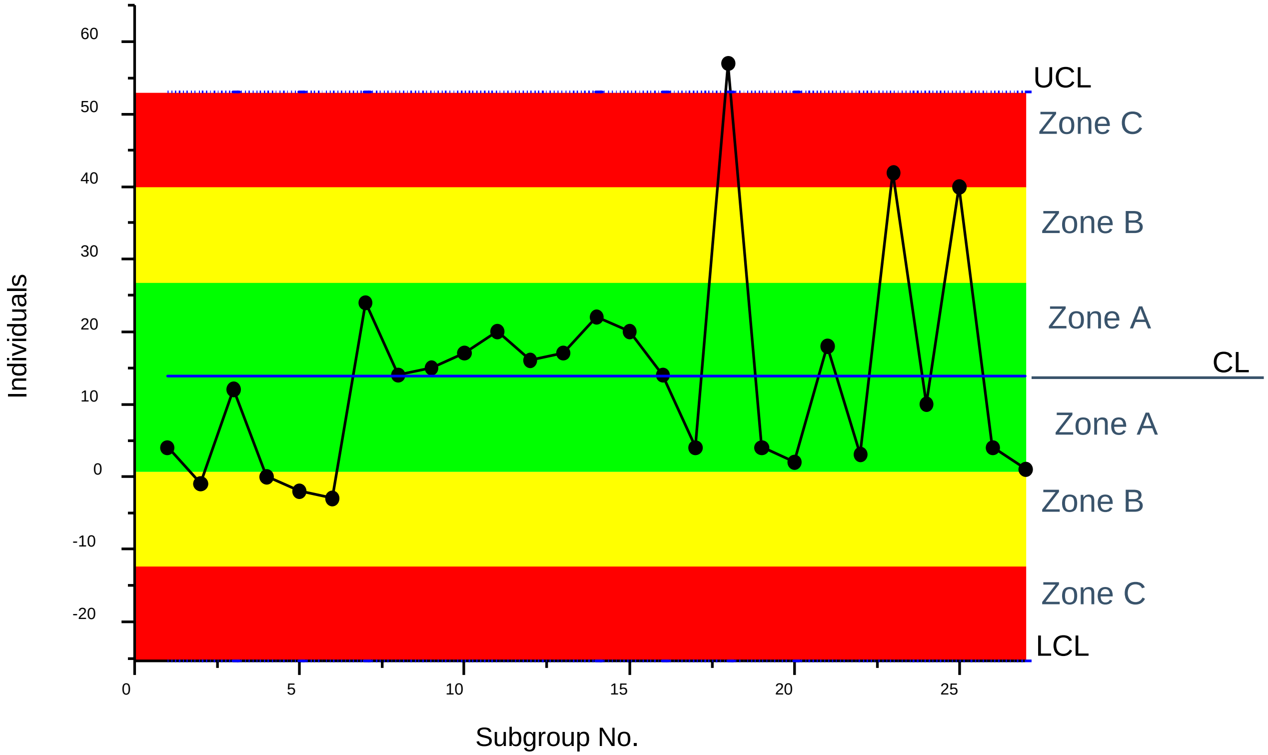
Box & whisker plot
for assessment data





7 Basic Tools: Chart Examples

SPC Chart: Individual, Moving Range



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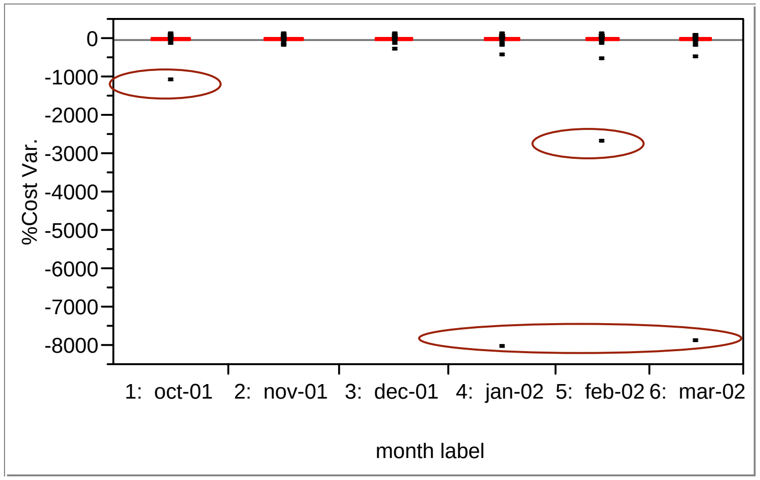
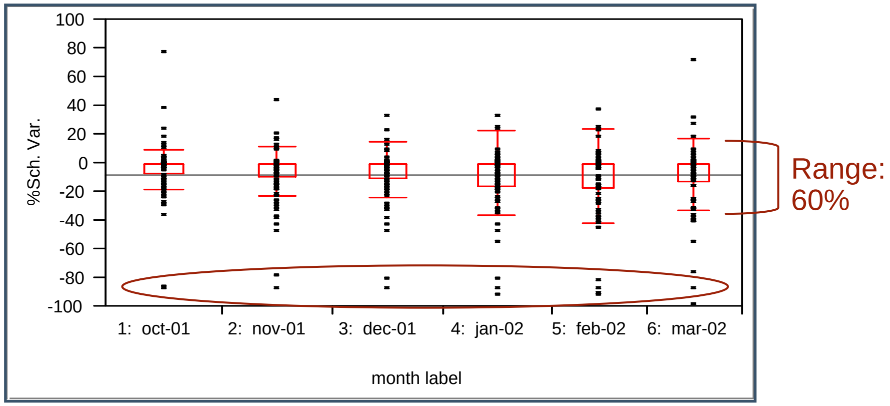
Example: Cost/Schedule Monthly Performance Baseline





All Org Units, all projects, October to March

- Reminder: This is (current actual – most recent estimate)
- Averages within spec, and close to 0
- Need to examine extreme values, especially for cost
- even if extreme values are outliers, it looks like we need to investigate variability

Exercise: Outliers

What is an outlier?

- a data point which does not appear to follow the characteristic distribution of the rest of the data
- an observation that lies an abnormal distance from other values in a random sample from a population

??

Consider this cost variance data:

- 13, 22, 16, 20, 16, 18, 27, 25, 30, 333, 40
- average = 50.9, standard deviation = 93.9

If "333" is a typo and should have been "33"

- corrected average = 23.6, corrected standard deviation = 8.3

But, what if it's a real value?

In groups of 3

- share your approach for deciding if and when to remove extreme values from data sets

[Frost 03], [stats-online]

Removing Outliers

There is not a widely-accepted automated approach to removing outliers.

Approaches

- Visual
  - examine distributions, trend charts, SPC charts, scatter plots, box plots
  - couple with knowledge of data and process
- Quantitative methods
  - interquartile range
  - Grubbs' test

Time is running short… So, we shall leave it to the student to look up the quantitative methods using the listed references as "homework." (We will display 1 slide on interquartile range during break)

[Frost 03], [stats-online]

When Not to Remove Outliers

When you don’t understand the process

Because you “don’t like the data points” or they make your analysis more complicated.

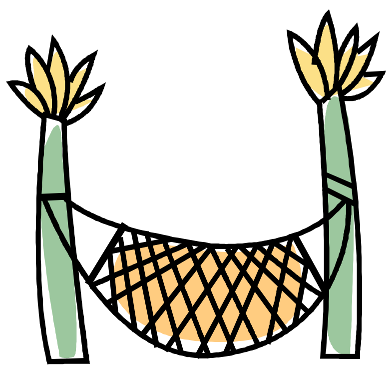
Because IQR or Grubbs method “says so”

When they indicate a “second population”
- identify the distinguishing factor and separate the data

When you have very few data points

Innocent until proven guilty

Copies of Slides



After break:
Exploring & Characterizing Data

If you would like copies of our slides,
add your name to our signup sheet, or
send an email to Debra Morrison, dtm@sei.cmu.edu.
- Put "SEPG Tutorial" in the subject line.

Interquartile Range: Example

1

333
40
Q2 → 30
27
25
22
20
18
Q1 → 16
16
13

2

Interquartile Range

30 – 16 = 14

4

Upper outlier boundary

30 + 1.5*14 = 51

3

Lower outlier boundary

16 – 1.5*14 = -5

Procedure

1. Determine 1st and 3rd quartiles of data set: Q1, Q3
2. Calculate the difference: interquartile range or IQR
3. Lower outlier boundary = Q1 – 1.5*IQR
4. Upper outlier boundary = Q3 + 1.5*IQR

Example adapted from “Metrics, Measurements, & Mathematical Mayhem,” Alison Frost, Raytheon, SEPG 2003

Analyze Guidance Questions

- Are there any hypotheses that need to be tested?
- What causal factors are driving or limiting the capability of this process?
- What process map updates are needed?
- Are there any immediate issues to address? Any urgent and obvious needs for problem containment?

Analyze

Explore data

Characterize process and problem

Update improvement project scope and scale

Evaluate data quality

Summarize, baseline data

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- What do the data look like?
- What is driving the variation?
- What is the new baseline?
- What are associated risks and assumptions associated with revised data set and baseline?

- Should the improvement goal be updated?
- Is additional data exploration, data decomposition, and/or process decomposition needed? Is additional data needed?
- Can I take action? Are there evident improvements and corrections to make?
- Have I updated the project tracking and communication mechanisms?

Exploring the Data

Considerations when answering the guidance questions

- What *should* the data look like? And, does it?
  - first principles, heuristics or relationships
  - mental model of process (refer to that black box)
  - what do we expect, in terms of cause & effect
- Are there yet-unexplained patterns or variation? If so,
  - conduct more Y to x analysis
  - plot, plot, plot using the basic tools
- Are there hypothesized x's that can be removed from the list?

The objective

- Go into "characterize" with as close as possible to the "right list" of Y's, y's, and x's to study/characterize in a detailed way.
- (At the end of characterize, the list is further narrowed and prioritized)

‘Lean’ Formulas for Data Exploration

Little’s Law

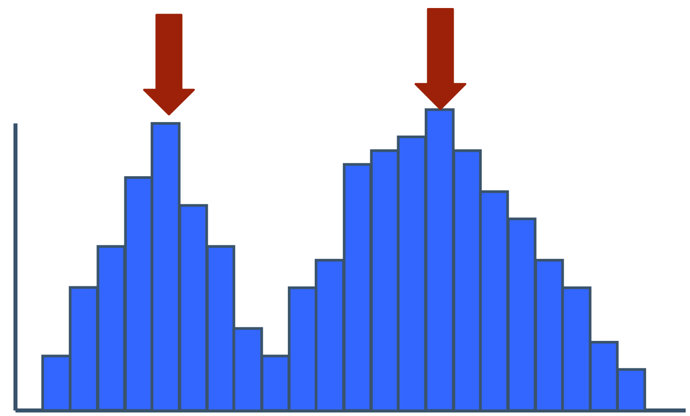
$$\text{Lead Time} = \frac{\text{Work ‘Units’ in Process}}{\text{Average Completion Rate}}$$

$$\text{Process Efficiency} = \frac{\text{Value-Added Process Time}}{\text{Total Process Time}}$$

$$\text{Cycle Time Performance Ratio} = \frac{\text{Actual Time}}{\text{Theoretical Time}}$$

A typical exploration question: Are There Multiple Populations?

Multimodal distributions point to multiple processes.



When there are multiple populations,

- Do we understand the causes based on work done in "measure"?
- Do we need to further explore Y to x relationships?
- Do we need to segment or stratify the data for further analysis?

Characterizing Your Process

What causal factors are driving or limiting the capability of this process?

- Which x's are or are not significant?
- Can plausible changes in x's deliver targeted/desired changes in y's and Y's?
- Do we need to find more x's?
- Do we need to refine goals?

To support the ability to answer these questions, are there any hypotheses that need to be tested?

- How do we test? (tests for significant difference, correlations, experiments)

What is the stability and capability of the process?

- What are assignable causes for "special cause" variation?
- What are root causes for "common cause" variation?

Testing for Differences

Comparing a process or product to “specification”

- Is the process on aim?
- Is the variability satisfactory?

Comparing two processes or products or populations

- Are the means (or medians) the same?
- Is the variation the same?

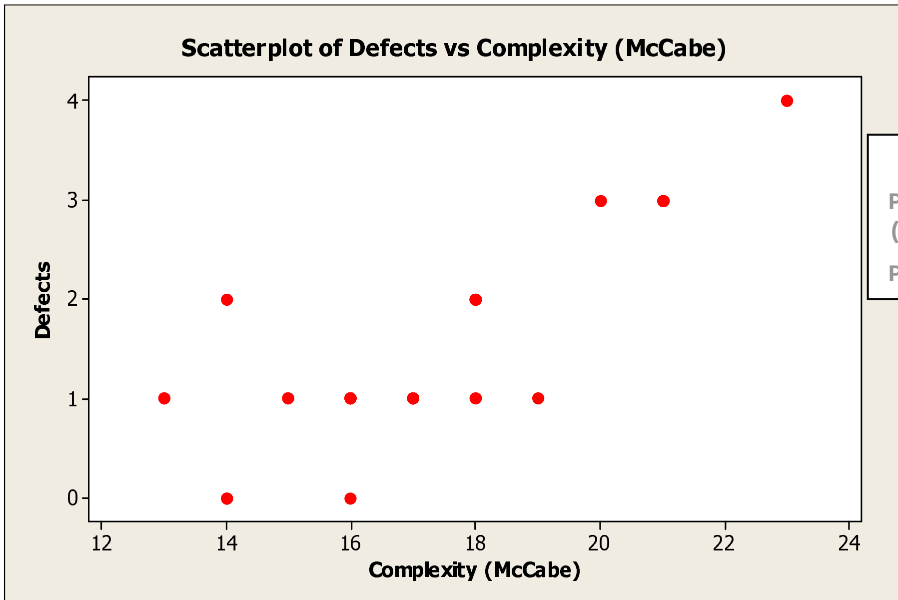
Approaches to determining if means/medians are the same

- one-way analysis of variance (ANOVA)
- means comparison tests
- confidence interval for the delta, $\mu_B - \mu_A$

More Advanced Tools that Support Characterization

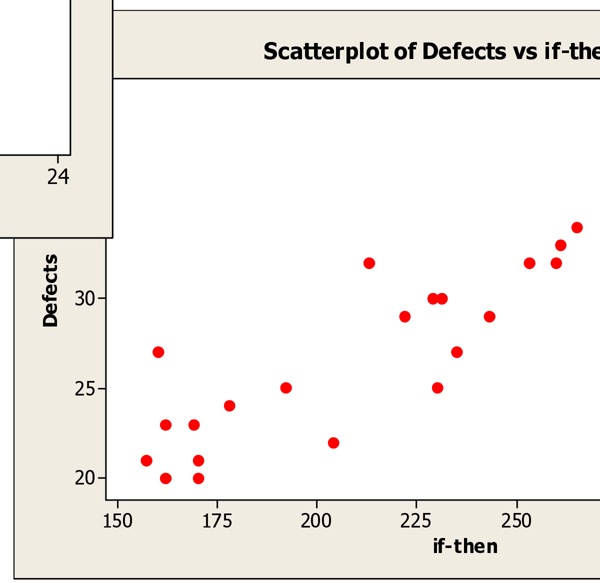
X \ Y	Attribute	Variable
Attribute	Pareto Chi-Square Contingency Table	Scatter Plot Time Series Analysis of Variance (ANOVA)
Variable	Logistic Regression	Scatter Plot Correlation Linear and Non-linear Regression F-test

X vs. Y Correlation



Pearson correlation of Complexity (McCabe) and Defects = 0.837

P-Value = 0.000



Pearson correlation of if-then and Defects = 0.930

P-Value = 0.000

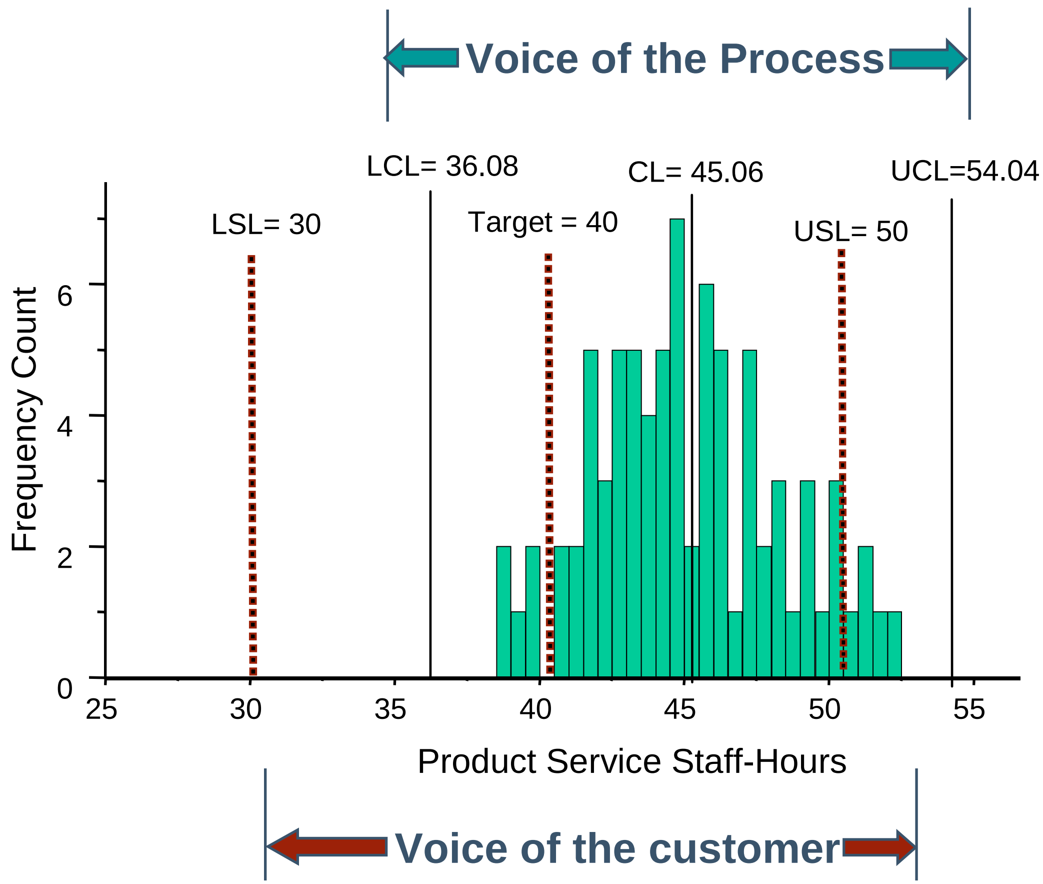
May ***indicate*** …
but not prove causation

Variability & Capability

Process
Capability

vs.

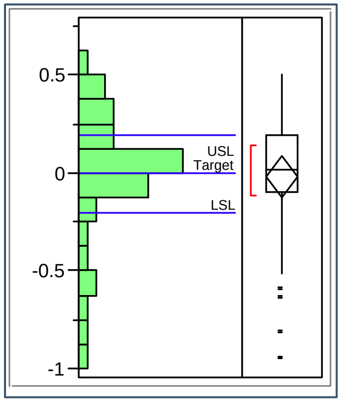
Capable
Process

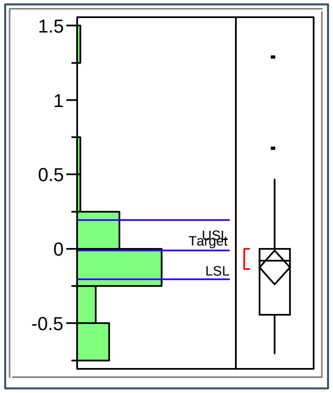


Example: Final Project Cost & Schedule

Cost/Schedule Performance Baseline, Outliers Removed

	% 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





Reminder: This is the total cumulative variance.

- (initial plan – final actual)
- customer-driven changes are included

Some extreme values still present

- there are no valid reasons to remove or segment the data

Large % of data outside specification

- process not capable

Analyze Guidance Questions

- Are there any hypotheses that need to be tested?
- What causal factors are driving or limiting the capability of this process?
- What process map updates are needed?
- Are there any immediate issues to address? Any urgent and obvious needs for problem containment?

GPs CAR

Analyze

Explore data

- What do the data look like?
- What is driving the variation?
- What is the new baseline?
- What are associated risks and assumptions associated with revised data set and baseline?

Characterize process and problem

Evaluate data quality

Summarize, baseline data

Update improvement project scope and scale

- Should the improvement goal be updated?
- Is additional data exploration, data decomposition, and/or process decomposition needed? Is additional data needed?
- Can I take action? Are there evident improvements and corrections to make?
- Have I updated the project tracking and communication mechanisms?

"Real" Process Characteristics

Real processes exist or occur only in execution/operation.[1]

Exactly stable conditions never exist with real processes.[1]

Real processes are never entirely free of perturbations or anomalies.[1]

Real processes are subject to entropy, requiring continual repair of its effects.

Variations in the "system of causes" results in process variation.

Process variation fluctuates over time.

[1] Deming, W.Edwards. *Out of the Crisis*. Cambridge, Mass.: Massachusetts Institute of Technology, Center for Advanced Engineering, 1986.

Process Analysis

Must take "real" process behavior into consideration before making statistical inferences about its performance.

- What is the normal or inherent process variation?
- What differentiates inherent from anomalous variation?
- What is causing the anomalous variation?
- Why is the anomalous variation occurring?

Methods and tools are needed to measure and analyze process behavior so that inductive inferences about the process performance can be supported.

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 this question:
"How is the process performing with respect to quality, quantity, effort (cost), and time?"

Process performance analysis answers this question:
"Why is the process behaving as it is?"

Process Variation

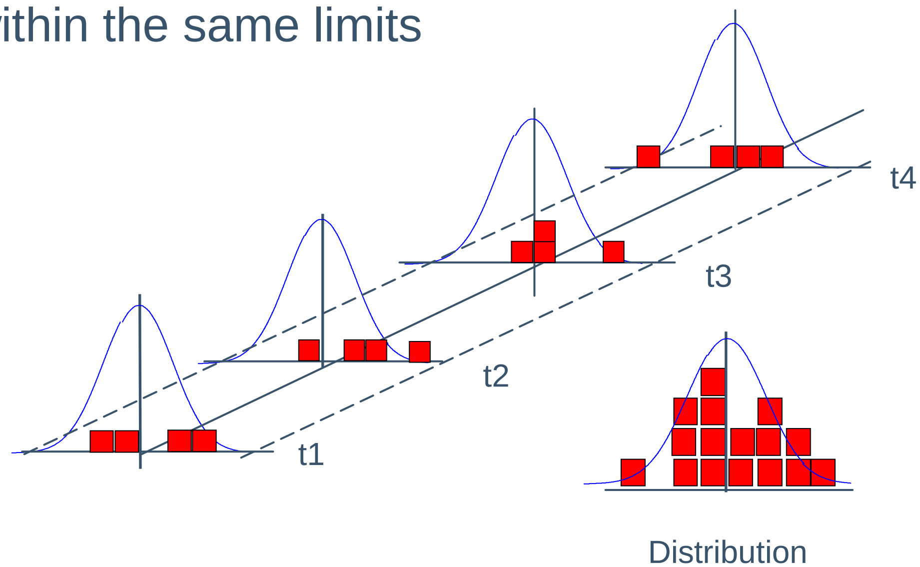
Shewhart's notion of dividing variation into two types:

1. Common cause variation
   - variation in process performance due to normal or inherent interaction among process components (people, machines, material, environment, and methods)
2. Assignable cause (special) 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

Controlled (Predictable) Variation

Process behavior measured at times t1, t2, t3, and t4

All measurements
• have same central tendency and dispersion
• fall within the same limits



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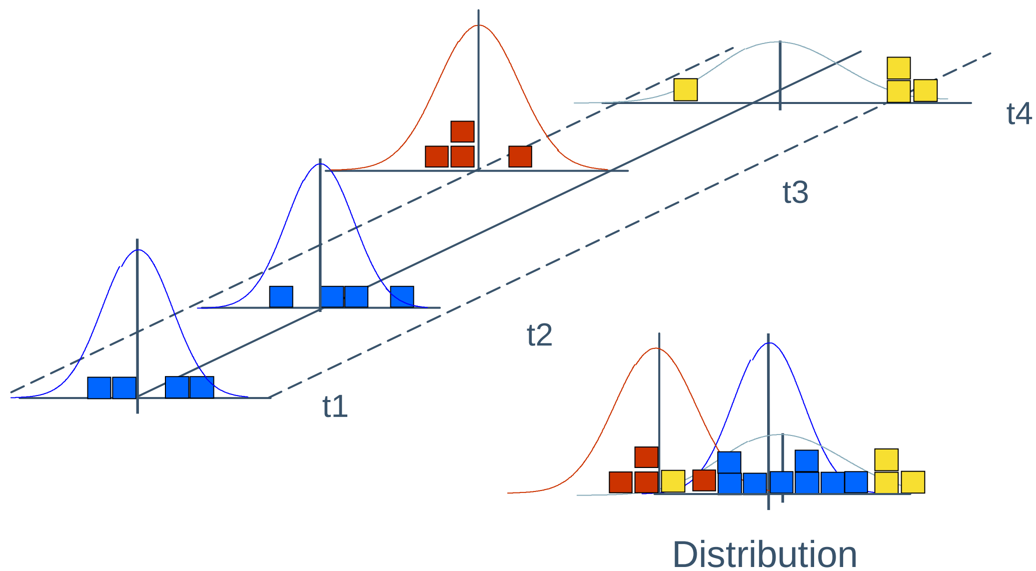
Uncontrolled (Unpredictable) Variation

Process behavior measured at times t1, t2, t3, and t4

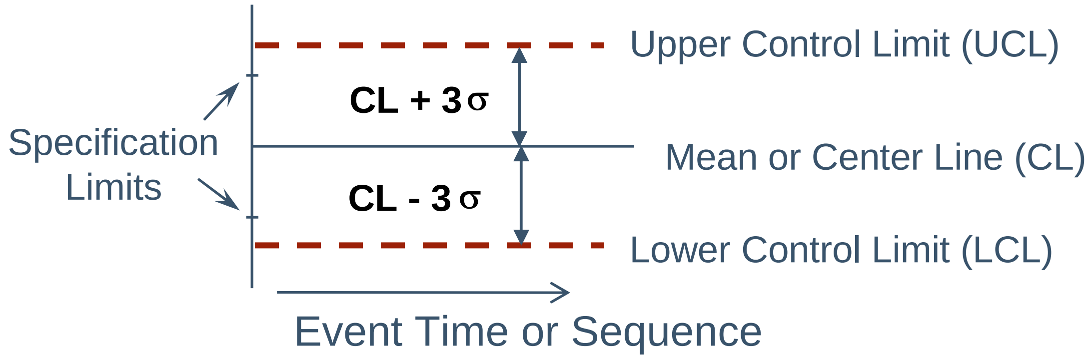
Not all measurements
- have same central tendency and dispersion
- fall within the same limits



Flagging Variation

Control charts

- a diagnostic mechanism to determine if a process is stable and to flag variation that requires causal analysis.
- when at desired performance, they are also a control mechanism



Other popular methods that flag variation and launch causal analysis

- distributions
- boxplots (also relative to time)

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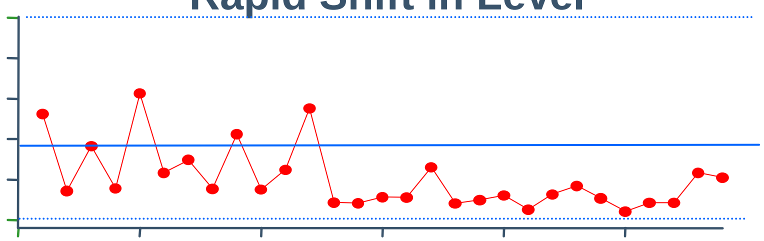
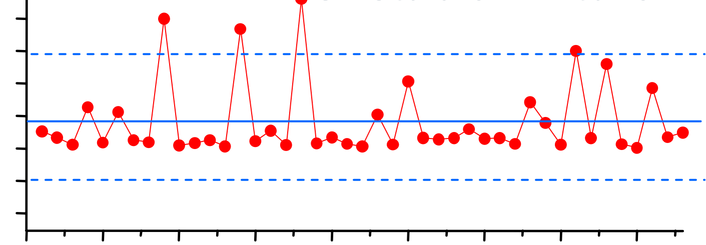
Patterns

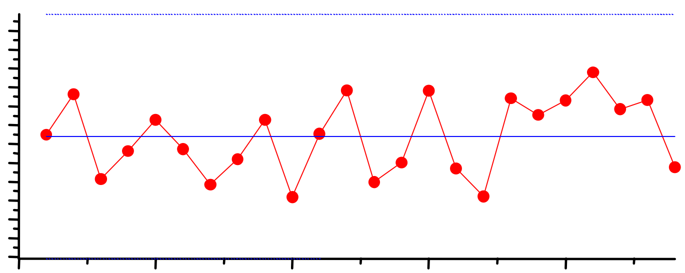
Rapid Shift in Level



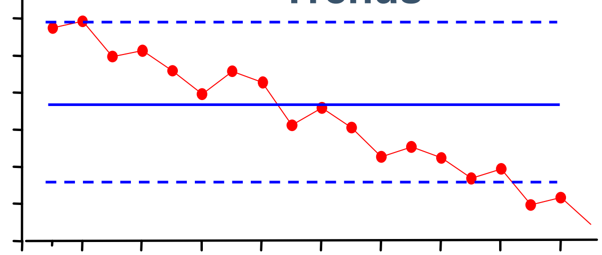
Unstable Mixture



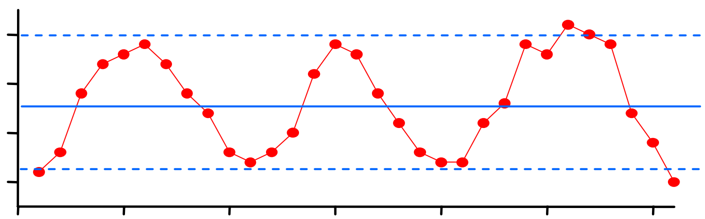
Stratification



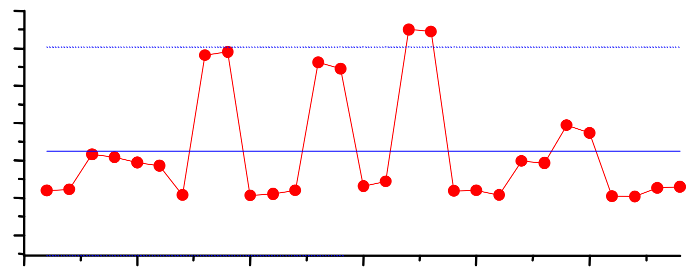
Trends



Cycles Pattern



Bunching or Grouping



Root Cause Terms

Problem
- any deviation from the standard, expected, or desired
- that which is outside the accepted tolerance, norm, benchmark

Symptom or direct cause
- observable indicator, cue, or event that flags the existence of a problem

Theory or hypothesis
- unproven assertion about reasons for the problems & symptoms

Cause
- event, factor, or circumstance that has been demonstrated to produce the problem or deviation

Root cause
- the cause that can be turned on & off to produce the problem, which is not itself an interim symptom resulting from another cause

Finding Root Cause: Why Care?

Applying corrective action or improvement to something other than root cause is unlikely to result in sustained improvement.

A brief scenario:
- A project is half complete and has overrun cost by 25%.
- The project team replans and negotiates an adjusted cost with the customer. No other actions are taken

?

What would you expect to happen if the root cause is
- constant rotation of team members on/off project
- increased cost of purchased materials
  - with all purchases now complete

What is the possible impact for future projects? For the business?

Diagnosing Root Cause

Key Steps

- generate and organize hypotheses
  - additional data exploration, characterization as needed
- select hypotheses to test
- test and evaluate

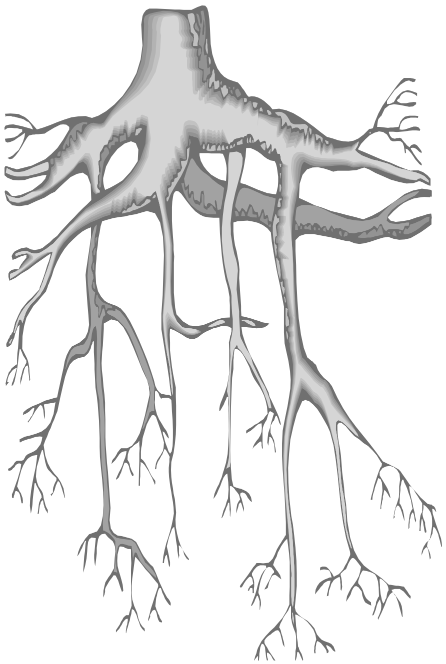
Generating and organizing lists of hypotheses

- 5 whys (just what it says: keep asking "why")
- Brainstorming
- PSM Performance Analysis Model
- diagrams: cause & effect, affinity, tree, interrelationship

Diagnosing Root Cause

Testing hypotheses

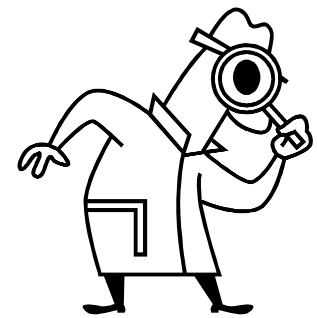
- historical review
- additional data collection
- process decomposition
- experiments



Evaluating tests

- 7 basic tools
- capability analysis
- means-comparison tests
- diagramming techniques
- failure modes and effects analysis

Root Cause Tips



Play detective. Suspect everything!

Evaluate paired comparisons
- characteristics of a “good data point” vs.
- characteristics of a “bad data point”

Or stratify the data into “good” and “bad” subsets and evaluate.

For sporadic problems, troubleshoot in real time if possible.
- memories fade quickly

Frequently used indicators for symptoms
- frequency
- severity or impact

If you can turn the problem on and off,
you probably have found root cause!

Outline

Context: The Value Proposition

Approach to building integrated training

A roadmap for performance-driven improvement

Roadmap connections to CMMI

The roadmap in practice: case example

The roadmap in practice: mini lectures & practice

Summary
- Illustrative summary
- Key points

Composite Project Illustration

Problem and goal statement (Y):
- maximum latent defects released
- minimum mean time between failure in the field

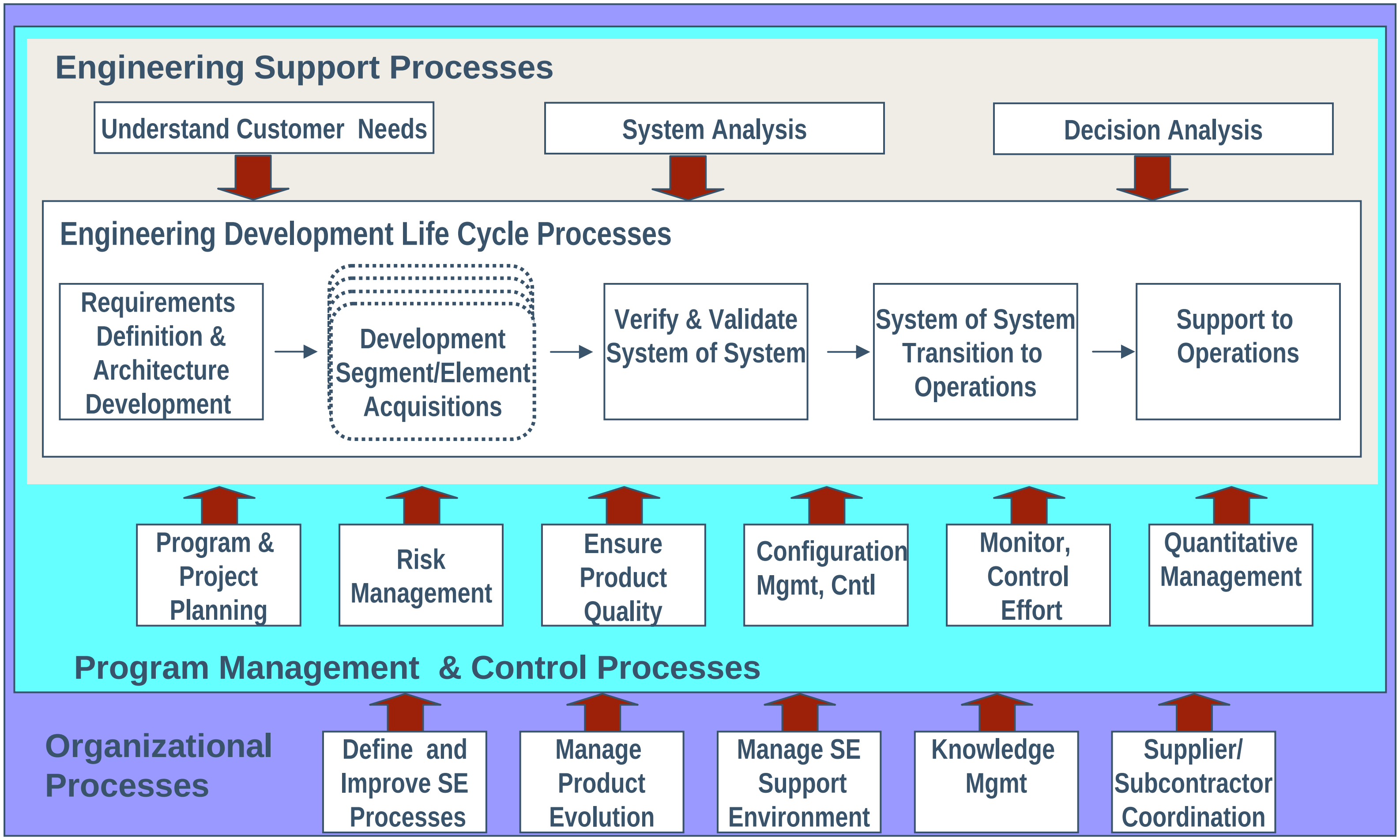
Define → **Measure** → **Analyze** → **Improve** → **Control**

Define:
- Problem & goal statements
- Define boundaries
- Process maps
- "Management by fact"

Measure, Analyze, Improve, Control:
- 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……)

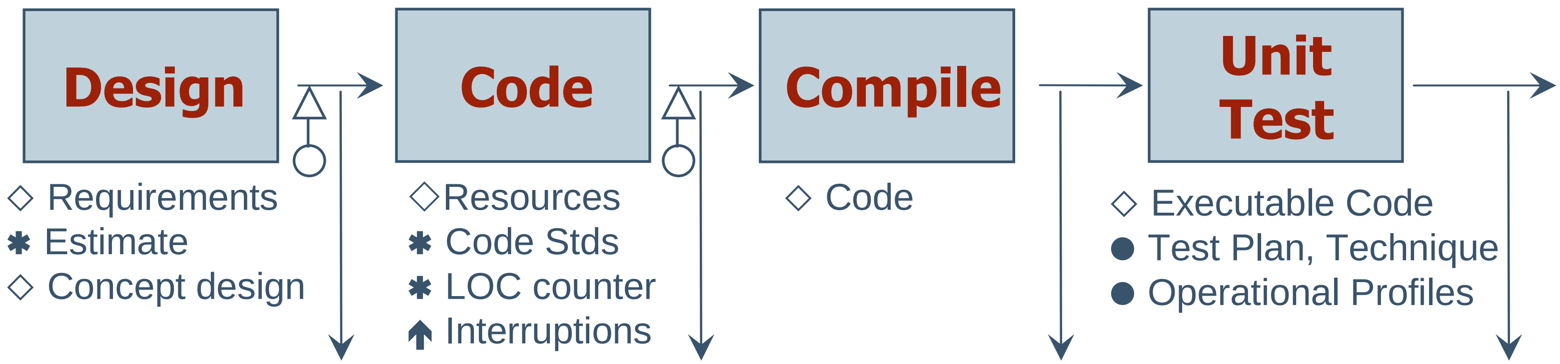
Defined Processes



[LMCO 02]

Project Boundaries

Process Map



- **Detailed Design**
- **Test cases**
- **Complexity**
- **Data:** Design Review defects, Fix time, 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	◇ Critical Inputs	✱ Standard Procedure
○ Rework	🡅 Noise	● Control Knobs

Drilldown to Inspection Process

What are the sources of variation? The control knobs?

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

Trouble-shoot

What would you list?

Correct Defects

What would you list?

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

→ **Data feed DMAIC project process**

◇	Critical Inputs
🡅	Noise
✱	Standard Procedure
●	Control Knobs

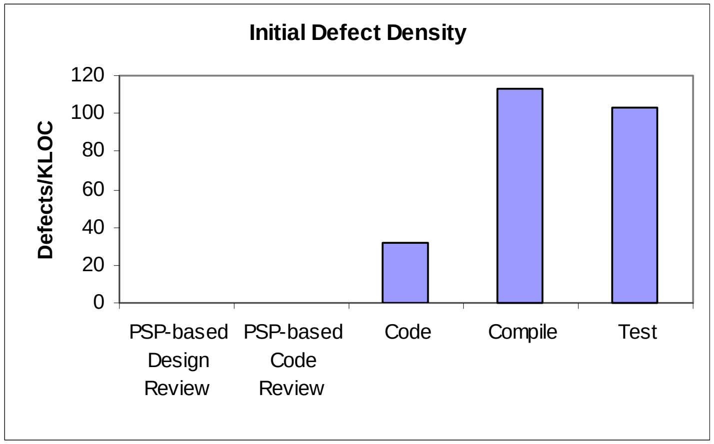
DMAI Iterations

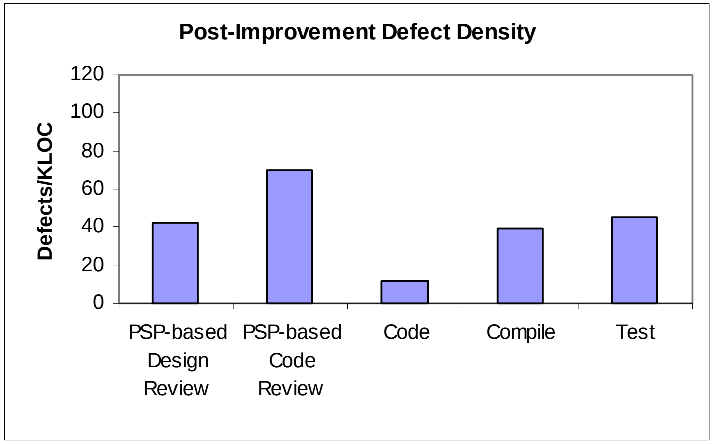
Collecting basic data

Refining processes
• inspections

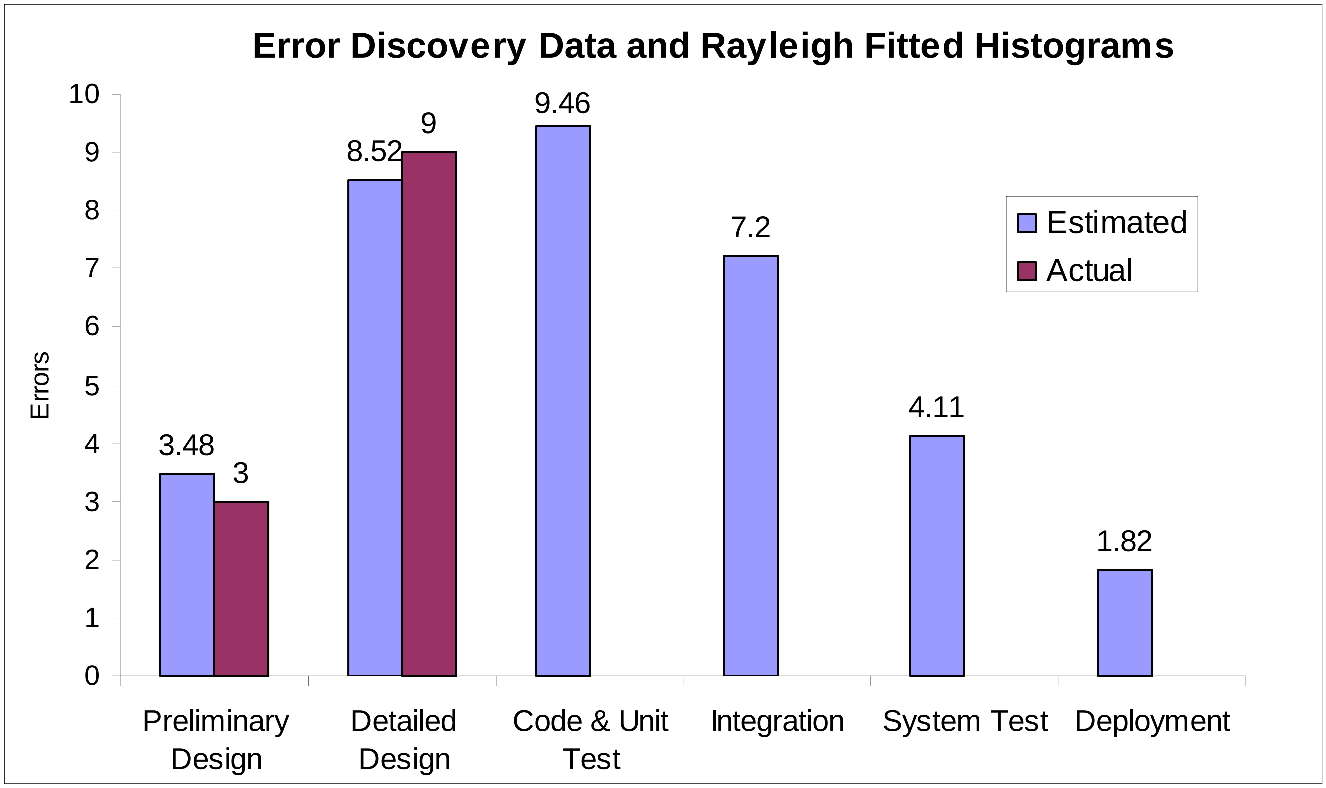
Improving using
• cause & effect matrix
• pareto analysis

Leads to
• injecting fewer defects
• detecting defects earlier
• removing them efficiently
• process stability





Rayleigh Distribution as Control Mechanism



Forecasting Defects and Repair Costs by Phase

Pre-release and post-release defect counts can drive further models to forecast defects and their repair costs over time, by development phase:

Size and Defect Count Estimates
(From Forecast Model)

Defect Analysis Scorecard
To-Be Prediction

Title:

Date:

Team Leader:

Notes

Enter the yellow fields:
- Size
- Size units (e.g. SLOC, KLOC, Fpts)
- Total Defects
- Defect Source Insertion %s
- Phase Containment Effectiveness (errors)
- Defect Containment Effectiveness (upstream defects)
- Hours to fix one defect
- Hourly labor rate (loaded)

Defect Source Distribution

Code size	Size units
1,000	FP

Total Defects> **1,050**

Found-in Phase

Origin Phase	Insertion %	Count	Reqts	Design	Code	Test	Post-Release	Total Containment Effectivenes (TCE) per phase	
Reqts	22%	231	127	52	29	15	8	96%	Reqts
Design	35%	368		221	81	43	23	94%	Design
Code	43%	452			262	123	66	85%	Code
Test		0				0	0		Test
Totals	100%	1050	127	272	371	181	98	90.7%	<TCE

	Reqts	Design	Code	Test
PCE (errors)	55%	60%	58%	
DCE (defects)		50%	55%	65%

Enter **Hours to Fix One Defect** for each insertion and find category

Hours to Fix One Defect	Reqts	Design	Code	Test	Post-Release
Reqt	1.19	2.28	6.19	13.53	71.86
Design		0.92	2.75	6.49	18.84
Code			1.10	2.58	12.87
Test					

Total Fix Hours	Reqts	Design	Code	Test	Post-Release
Reqt	151	119	177	206	588
Design		203	222	279	436
Code			288	318	854
Test					

Loaded Defect Fix Costs	Reqts	Design	Code	Test	Post-Release	Totals	
Reqt	$ 15,119	$ 11,850	$ 17,695	$ 20,569	$ 58,825	$ 124,058	Reqt
Design		$ 20,286	$ 22,234	$ 27,905	$ 43,619	$ 114,044	Design
Code			$ 28,806	$ 31,801	$ 85,419	$ 146,025	Code
Test						$ -	Test
Totals	$ 15,119	$ 32,136	$ 68,734	$ 80,276	$ 187,863	$ 384,128	

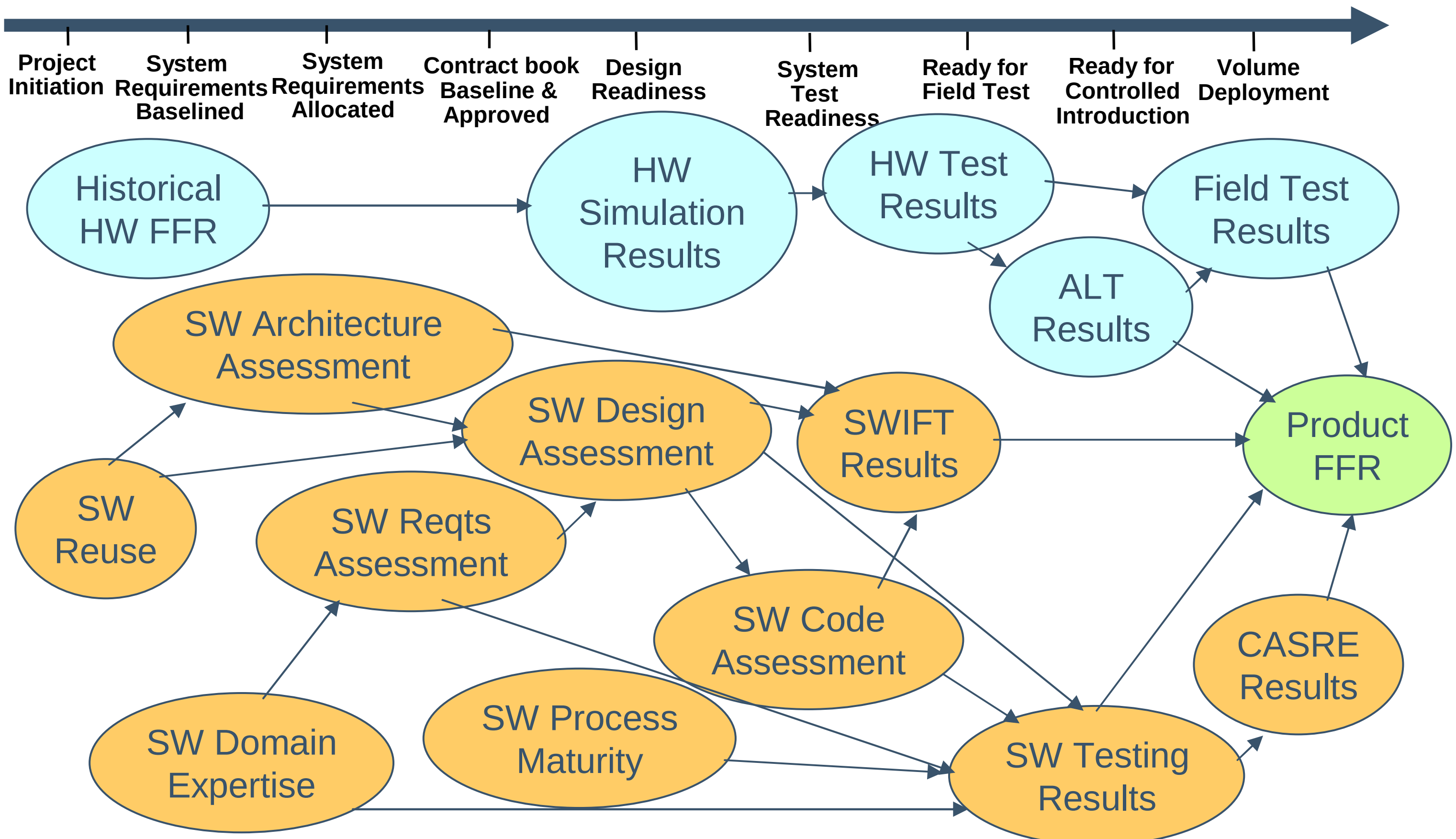
Project Cost Rollup	Hourly labor rate (loaded)	Person-months	Cost of Effort		
				Cost per FP :	$ 384.13
				Cost per Released Defect	$ 1,922.68
	$ 100.00	84.3	$ 1,317,188	Fix Cost %	29%

Predicted Defects by Phase

Defect Repair Costs

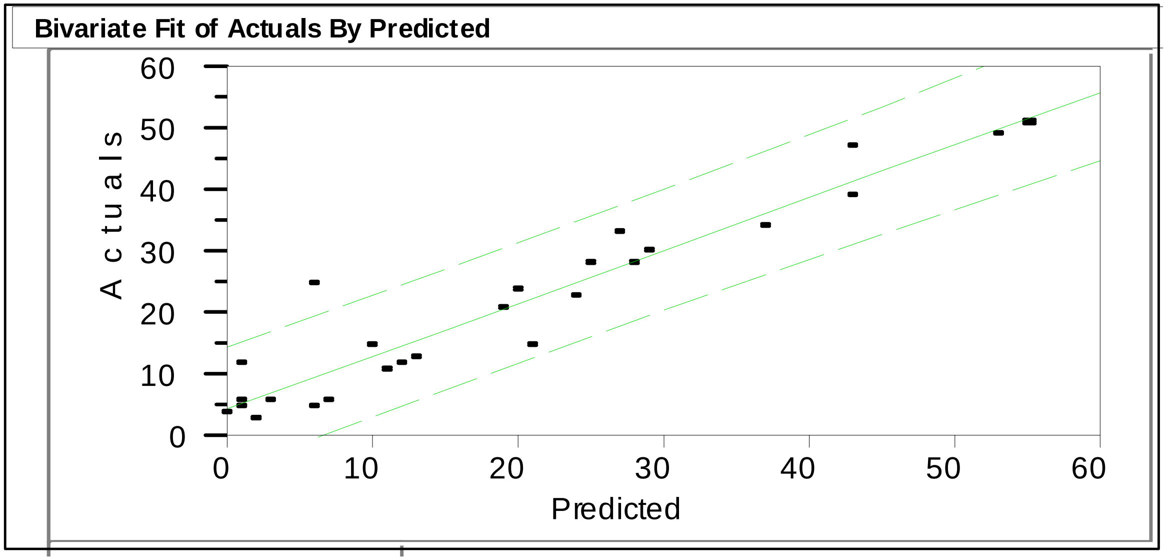
Rework cost is 29% high ?

From single process to systemic view: Cause-Effect Model Using Bayesian Modeling



[Stoddard 02]

Beyond Control Charts: Prediction Models



Actual field defects = f(CASRE predicted defects)

CASRE predicted defects = f(weekly arrival rate of SW failures, weekly test intensity measures)

$3M/year savings from premature SW releases

[Stoddard 02], *CASRE = Computer Aided Software Reliability Estimation

Summary – Key Points

Value Proposition
- It is a multi-initiative world
- Measurement & analysis is a common root and an integrating platform

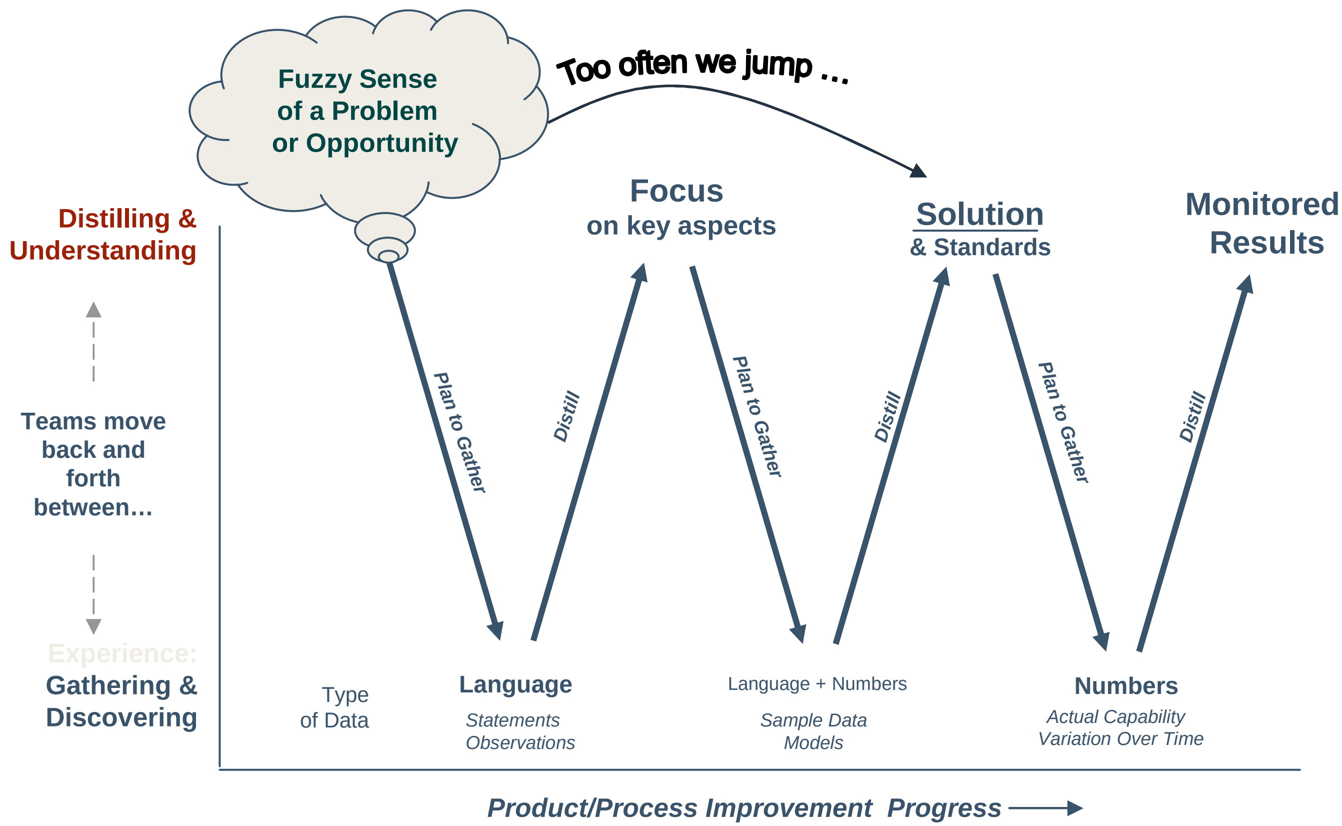
Approaches to Integration
- Training courses are a mechanism to make connections

DMAIC & CMMI relationships
- DMAIC and CMMI are different and synergistic
- Relationships exist at the PA, goal, practice and toolkit level

DMAIC Execution
- Performance driven improvement
- Enables CMMI subprocess selection to be informed by business priorities, baselines, problem statements and causal analysis
- Propels you to high maturity and/or high capability

A Base Architecture

- Connecting all the Improvement Models



[Kawakita], [Shiba]

Contact Information

If you would like copies of our slides

- Add your name to our signup sheet, or
- Send an email to Debra Morrison, dtm@sei.cmu.edu.
  - Put "SEPG Tutorial" in the subject line.

For questions or other information:

Jeannine Siviy
Software Engineering Institute
jmsiviy@sei.cmu.edu

Dave Hallowell
Six Sigma Advantage
dhallowell@SixSigma-Advantage.com

Dave Zubrow
Software Engineering Institute
dz@sei.cmu.edu

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