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Using a Process Measurement Framework℠ to Successfully Achieve Measurable Results

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The Principle of Measurement

As Lord Kelvin said a century ago:

"When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of science."

Tutorial Objectives

Provide motivation for and describe the QIC Process Measurement Framework[SM].

Describe 4 real examples from industry:

1) Instrument a process
2) Instrument a project
3) Instrument an organization (e.g., Baldrige, CMM®, CMMI[SM], etc.)
4) Instrument a complex metric (e.g., ROI)

Answer any of your questions.

® CMM is registered in the U.S. Patent and Trademark Office by Carnegie Mellon University
SM CMMI is a service mark of Carnegie Mellon University

Tutorial Agenda

30 Minutes	**Introduction**
30 Minutes	**Measurement Framework Overview**
30 Minutes	**Example 1: Instrument a Process**
30 Minutes	**Break**
30 Minutes	**Example 2: Instrument a Project**
30 Minutes	**Example 3: Instrument an Organization**
30 Minutes	**Example 4: Instrument a Metric**
30 Minutes	**Questions and Answers**

Who is QIC?

The mission of Quality Improvement Consultants, Inc. (QIC) is to help organizations to measurably:

- **become "best-in-class" or "world-class" quality leaders in their respective markets (e.g., using benchmarking)**
- **improve quality and productivity (e.g., lower product defect rates, increased KSLOC per person month, etc.)**
- **reduce the cost of poor quality (e.g., rework, waste, scrap, etc.)**

Agenda

Introduction

Process Measurement Framework℠ Overview

Real Example 1: Instrument a Process

Real Example 2: Instrument a Project

Real Example 3: Instrument an Organization

Real Example 4: Instrument a Complex Metric

Some Lessons Learned

Questions and Answers

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Why Are You Here?

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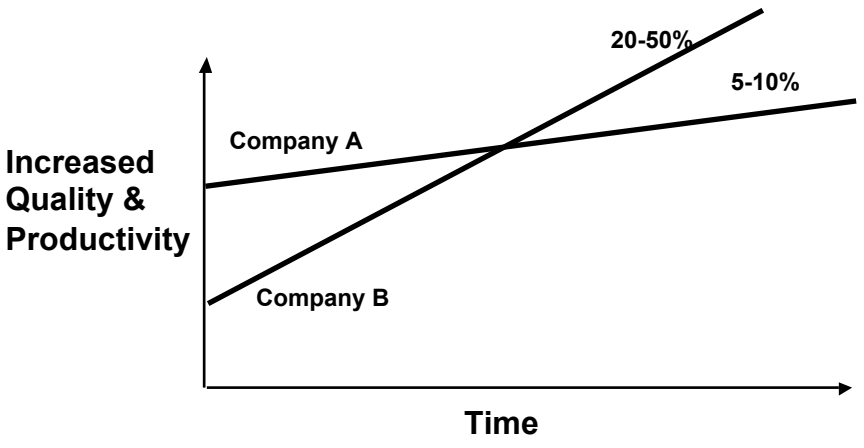
Evolutionary vs. Revolutionary Quality Improvement



• Adapted from *Juran on Leadership for Quality*, Juran, 1989

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Some Best-In-Class Benchmarks

METRIC	WORLD-CLASS BENCHMARK
Costs of Poor Quality	Reduced from 33% to under 10%
Defect Removal Efficiency	70-90% total defects removed before test
Post-Release Defect Rate	Six Sigma (i.e., 3.4 defects per million)
Productivity	Doubled (e.g., in 5 years)
Return on Investment	5:1 ROI (or higher)
Schedule / Cycle Time	Continually reducing (e.g., 10% annually)

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Goal/Question/Metric Paradigm

PART	DESCRIPTION
Goal	Every metric must be directed towards a measurable goal. The idea here is that there must be a good reason to be collecting the data.
Question	Every goal should be answered by one or more key questions. The question should be stated so that a metric(s) can clearly answer it.
Metric	The metric must be a quantitative entity that answers a specific question, which in turn addresses a goal or part of a goal.

- Adapted from "V. R. Basili and D. M. Weiss, "A Methodology for Collecting Valid Software Engineering Data", IEEE Transactions on Software Engineering, vol. SE-10, no. 3, November 1984, pp. 728-738.

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Goal/Question/Metric (G/Q/M)

A high level summary of the G/Q/M steps are:

1. Establish the goals of the data collection.
2. Develop a list of questions of interest.
3. Establish data categories.
4. Design and test data collection form.
5. Collect and validate data.
6. Analyze data

- Adapted from "V. R. Basili and D. M. Weiss, "A Methodology for Collecting Valid Software Engineering Data", IEEE Transactions on Software Engineering, vol. SE-10, no. 3, November 1984, pp. 728-738.

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Analogy: Managing for Finance

Managing for Finance	Managing for Quality
Financial Planning: Setting business goals; budgeting	**Quality Planning:** Setting quality goals; Estimating
Financial Control: Cost control; actual vs. planned	**Quality Control:** Planned vs. actual quality goals; taking action on difference
Financial Improvement: Cost reduction; mergers; acquisitions	**Quality Improvement:** Waste and rework reduction; eliminate & prevent defects

- Adapted from "Juran on Leadership for Quality: An Executive Handbook", Juran, 1989.

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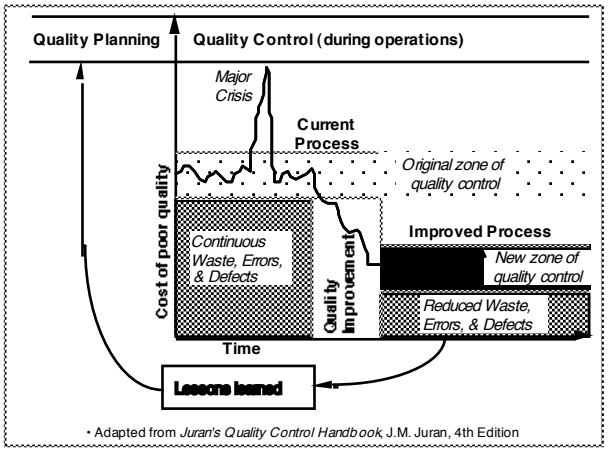
The Juran Trilogy for Quality Management



- Adapted from *Juran's Quality Control Handbook*, J.M. Juran, 4th Edition

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SEI Initial Core Measures

Unit of Measure	Characteristics
Counts of physical lines of code	Size, progress, reuse
Counts of staff hours expended	Effort, cost, resource allocations
Calendar dates	Schedule
Counts of software problems and defects	Quality, readiness for delivery, improvement trends

Reference: Carleton, et al., "Software Measurement for DoD Systems: Recommendations for Initial Core Measures", CMU/SEI-92-TR-19.

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Approaches: Pros and Cons

Approach	Advantages	Disadvantages
Goal/ Question/ Metric	• Powerful paradigm • Companies use it • Growing success stories • Practical approach	• Can struggle establishing meaningful goals • Hard to develop the right questions • Difficult to tailor metrics to organizational culture
Juran Quality Trilogy	• Powerful trilogy • Proven track record in quality • Good strategy	• Not tailored to Systems/SW • Not tailored to measurement in general • Big learning curve
SEI Recommended Core Measures	• Practical metrics • Based on applied research • Based on successful organizations	• Single report missing "big picture" or framework • Numerous SEI reports can be over whelming

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Tailoring The Juran Trilogy

PART	DESCRIPTION
Planning	Broadened to be planning in general (e.g., project planning). Estimating goals and measurements for processes and products.
Control	Measuring and comparing actual performance against planned performance (e.g., plans, goals, metrics, etc.), and taking corrective action on the major differences (e.g., special causes).
Improvement	Broadened to be improvement in general (e.g., improving quality, productivity, performance, and competitive position.

- **Adapted from** "Juran, Joseph. *Juran on Leadership for Quality: An Executive Handbook.* New York, NY: Macmillan, 1989.

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QIC Process Measurement Framework℠

GOALS	KEY QUESTIONS	METRICS	DC	DS
PLAN		Cost, defects, effort, size, schedule, etc.		
CONTROL		Cost, defects, effort, size, schedule, etc.		
IMPROVE		Cost, defects, effort, size, schedule, etc.		

- DC = Data Collection; DS = Data Storage

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What are In-Process Inspections?

The purpose of in-process inspections is to detect defects early in the process in order to reduce rework and costs, and to increase quality and productivity.

<u>In-process inspection:</u>
a formal process for verifying intellectual products (in-process) by manually examining a work product, a piece at a time, by small teams of trained peers to detect defects, to ensure that the product is correct and conforms to standards, product specifications, and requirements.

•Adapted from Ebenau, *Software Inspection Process*, McGraw Hill, 1994

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What's the Difference?

Characteristics	Inspections	Reviews	Walk-throughs
Goal	Identify defects	Reach consensus Raise issues	Reach consensus Raise issues
State of Work Product	Final draft	Work in progress	Work in progress
Process/ Measurements	Formal/ Required	Informal/ None required	Informal/ None required
Checklists/ Error Detection	Required/ Defects classified	Not required/ Not required	Not required/ Not required
Participants	Moderator;Reader; Recorder; Author; Inspectors	Author; Reviewers	Author; Reviewers
Process Owner	Moderator; Independent verification	Author	Author

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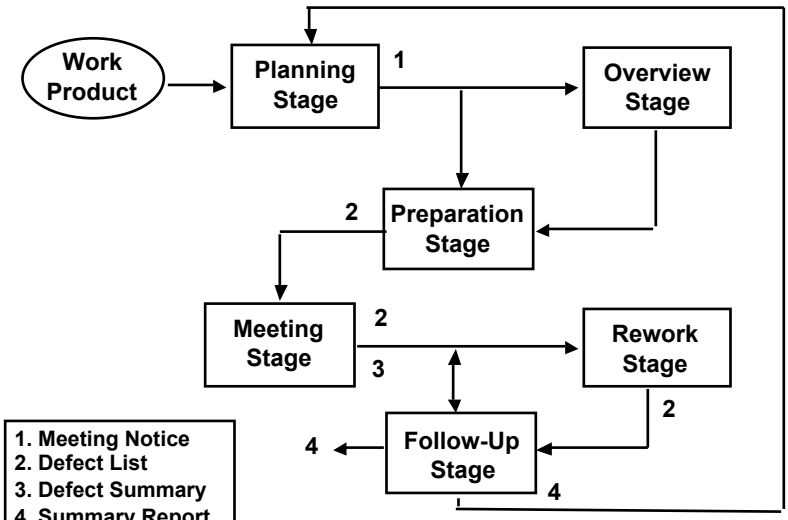
Inspection Process Model



•Adapted from Ebenau, *Software Inspection Process*, McGraw Hill, 1994

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Inspection Roles

Author - individual responsible for the work product, and for correcting any defects.

Moderator - ensures that the inspection process is followed, and that the other inspectors perform their responsibilities throughout the inspection process.

Recorder - records and classifies all the defects detected at the inspection meeting, and assists the moderator in preparing inspection reports.

Inspector - detects defects in the work product (all inspection team members are inspectors).

Reader - leads the team through the work product in a complete and logical fashion.

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Example: Inspection Metrics

Inspection Measurements	Example Estimates
Total Size	50 pages (Requirements Document)
Total Defects	50 Total Defects (50 pages * 1 defect per page)
Total Cost	• $2,500 to inspect document (50 pages * $50 a page) • $50 average cost per defect ($2,500/50 defects)
Total Effort	• 50 person hours of effort (1 hour per page * 50 pages) • 1 hour average effort per defect (50 hours/50 defects)
Schedule	• Average preparation rate of 10 pages per hour=5 hours • Average meeting rate of 10 pages per hour=5 hours • 5 hours/2 hour meetings is approximately 3 meetings • Schedule = 1 calendar week

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Example: Planning

Goal	Key Questions	Basic Metrics	Data Collection
	Per Work Product:	Based on Work Product Size:	
1. Plan and Estimate within 10% of Actuals • **Use historical data**	1a). How much will the inspections cost? How much will defects cost?	1a). Average **cost** per page (e.g., $50.00 per page). Average cost per defect (e.g., $50 per defect).	Inspection Database
	1b). How many defects will there be?	1b). **Defect** density (e.g., average 1 defect per page)	Inspection Database
	1c). How much effort will the inspection take? per defect?	1c). Average **effort** per page (e.g., 1 hour per page). Average effort per defect (e.g., 1 hour per defect).	Inspection Database
	1d). How long will the inspections take?	1d). Inspection **Schedule** (based on average preparation rate and average meeting rate and 2 hour limit duration per meeting)	Software Project Plan
	1e). How big is the work product?	1e). Total work product **size** in pages (e.g., 100 page design document).	Inspection Database

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Example: Control

Goal	Key Questions	Basic Metrics	Data Collection
2. Control • **Measure and track actual data against estimated data** • **Take action on major differences (Greater than 10%)**	What is the inspection status (per work product?	Measure actual data against estimated data:	Note: All metrics in database
	2a) What do the inspections cost? per defect?	2a) Actual average **cost** per page vs. estimated. Actual average **cost** per defect vs. estimated.	Derived
	2b) How many defects are there? What is the quality?	2b) Total number of **defects**. Actual **defect** density vs. estimated.	Summary Form
	2c) How much effort do the inspections take? per defect?	2c). Actual average **effort** per page vs. estimated. Actual average **effort** per defect vs. estimated.	Summary Form
	2d)What is the schedule status?	2d) **Schedule**: Percentage of actual inspections completed vs. estimated.	Summary Form
	2e) How many pages have been inspected?	2e) **Size**: Total pages inspected to date vs. estimated.	Summary Form

Example: Improvement

Goals	Key Questions	Basic Metrics	Data Collection
4. Improve Inspection Effectiveness	4a) How effective is the inspection process?	4a) **Defect**-removal efficiency; Average **cost** and **effort** per **defect**	All defect databases
• Improve inspection process based on data	4b) What defects did the inspections miss in the testing phase(s)?	4b) **Defects** in test and/or SCM databases	Test Database; SCM Database
	4c) What are the vital few defect categories that cause 80% of all defects?	4c) Pareto analysis of total **defects** in **defect** categories (per work product, by phase, etc.)	All defect databases
	4d) What is the 20% of the work product that causes 80% of the defects?	4d) **Defect** location (from Defect List). Advanced: also related to software complexity measures).	All defect databases

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Example: Planning

Goal	Key Questions	Basic Metrics	Data Collection
1. Plan and Estimate within 10% of Actuals • **Use historical data**	Per Project: 1a). How much will the project cost? 1b). How many defects will there be? 1c). How much effort will the project take? 1d). How long will the project take? 1e). How big is the project?	Based on Work Product Size: 1a). Project **cost** (e.g., derived from effort). 1b). **Defect** density (e.g., defects per KSLOC) 1c). **Effort** (total hours) for the project (e.g., based on hours per WBS). 1d). Project **Schedule** (e.g., based on project WBS). 1e). Total project **size** (e.g., LOC, FP, modules, objects, screens, reports, etc).	Organizational Cost Database Defect Database Time Tracking Database Project Plan Project Plan

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Example: Control

Goal	Key Questions	Basic Metrics	Data Collection
2. Control • **Measure and track actual data against estimated data** • **Take action on major differences (Greater than 10%)**	What is the project status? 2a) Is the project on budget? Per WBS? 2b) What is the quality of project? 2c) How much effort does the project take? Per WBS? 2d) What is the schedule status? 2e) How many pages have been inspected?	Measure actual data against estimated data: 2a) Actual **cost** vs. estimated. Actual **cost** (e.g., cost performance index or CPI). Also CPI per WBS element. 2b) Actual **defect**s vs. estimated. 2c). Actual average **effort** per page vs. estimated. Actual average **effort** per WBS vs. estimated. 2d) **Schedule**: Actual WBS completed vs. estimated (e.g., schedule performance index or SPI). 2e) **Size**: Total pages inspected to date vs. estimated.	Project Status Report (PSR) Defect DB; PSR PSR; Time Tracking DB PSR; MS Project; Excel Spreadsheet PSR

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Example: Improvement

Goals	Key Questions	Basic Metrics	Data Collection
4. Improve Project Quality • **Improve verification processes based on data**	4a) How effective are the verification processes? 4b) What defects did the verification processes miss? 4c) What are the vital few defect categories that cause 80% of all defects? 4d) What is the 20% of the defect categories that causes 80% of the defects?	4a) **Defect**-removal efficiency; Average **cost** and **effort** per **defect** 4b) **Defects** found late in the process: test, CM databases, or customer discovered deftecs 4c) Pareto analysis of total **defects** in **defect** categories (per work product, by phase, etc.) 4d) **Defect** location (from Defect List). Advanced: also related to complexity measures).	All defect databases Test Database; CM Database All defect databases All defect databases

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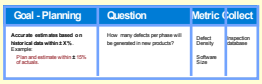
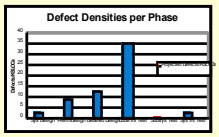
Example: Managing Quality

PLAN

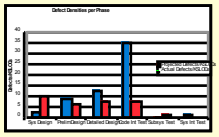


Quantitative Goals: Setting goals to Plan, Control, & Improve defect removal



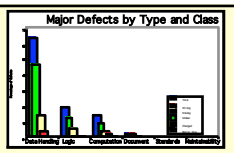
Defect Removal Curve: Setting defect removal curve per development phase

CONTROL



Defect Removal Curve: Actual vs planned; Taking action when set limits are exceeded

IMPROVE



Defect Prevention: Pareto and root cause analysis of common defects

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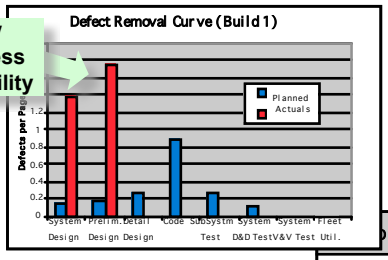
Control: Project Quality Tracking

New Process Capability



	Defect Removal (Pages) Planned	Actual	Control Limits Set	Within Limits?
Project Start-Up				
System Design	0.14	1.37	15%	978.5%
Preliminary Design	0.19	1.76	15%	926.3%
Detailed Design	0.26	0	15%	0%
Code	0.87	0	15%	0%
Sub-System Int. Test	0.112	0	15%	0%

Track defect removal taking corrective action when acceptable limits exceeded

- Adapted from Beeson, Dennis D. and Olson, Timothy G., "Instrumenting Software Projects: A Case Study of Real World Projects", SEPG 2001.

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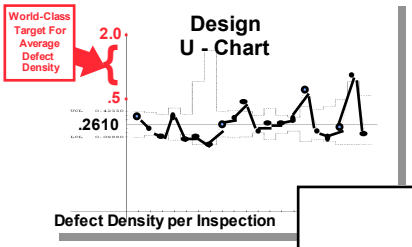
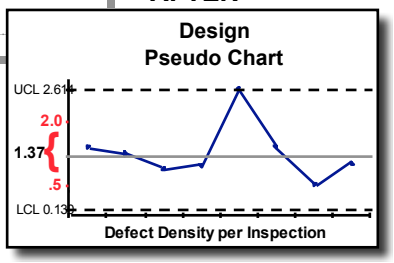
SPC of Product Defect Removal

BEFORE



AFTER



- Defect density average now within benchmark inspection data for embedded mission or life critical software
- Preparation rate and defect density analysis show rates are within benchmarked data
- Defect density still not in process control

Analysis indicates Quantitative Management & Inspection Processes have increased preparation rate and improved defect removal

- Adapted from Beeson, Dennis D. and Olson, Timothy G., "Instrumenting Software Projects: A Case Study of Real World Projects", SEPG 2001.

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Data Driven Project Management

Using data driven project management, projects should measure (at a minimum):

- Cost
- Defects
- Effort
- Schedule
- Size

Benefits include being able to measure:

- Performance
- Productivity
- Quality
- ROI

A data driven "project management dashboard" helps projects to ensure they are on track.

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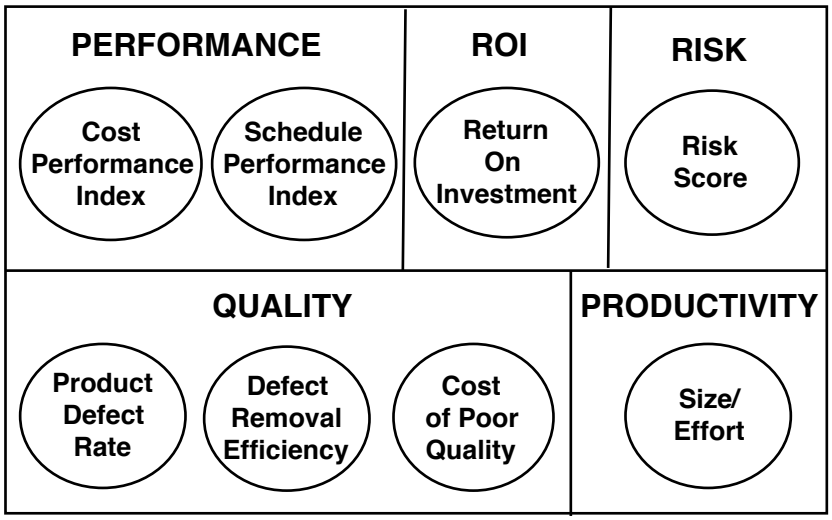
Example Metrics Dashboard



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Project Metrics

	Projects	Size	Effort	Cost	Schedule	Defects
Plate Full	1. 2. 3. . . . N					
Backlog	N+1 ...					

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Organizational Improvement

Strategic Action Planning should identify measurable organizational objectives. For example:

- **Compliance (e.g., Government requirements)**
- **Industry Standards (e.g., Baldrige, CMMI[SM], ISO, etc.)**
- **Market Share**
- **Performance (e.g., CPI, SPI)**
- **Productivity**
- **Quality**
- **ROI**
- **Time to market**

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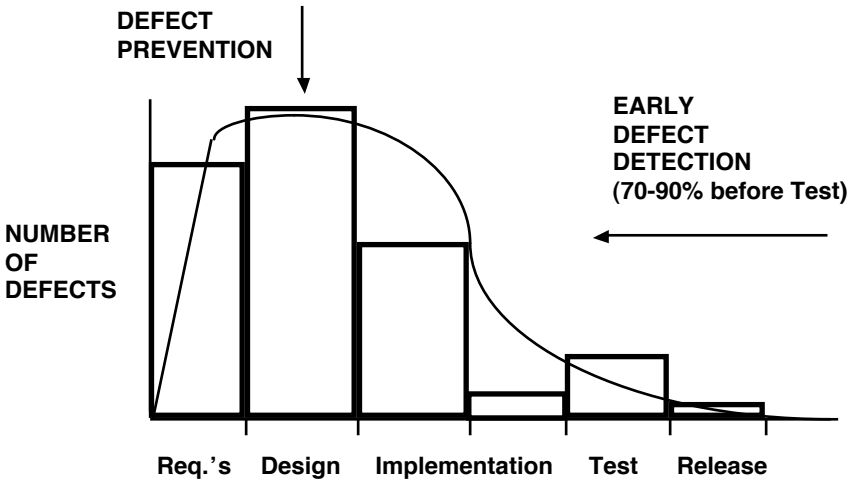
Best-in-Class Strategies



- **Slide adapted from Olson, "A Software Quality Strategy for Demonstrating Early ROI", SSQ Journal, May 1995.**

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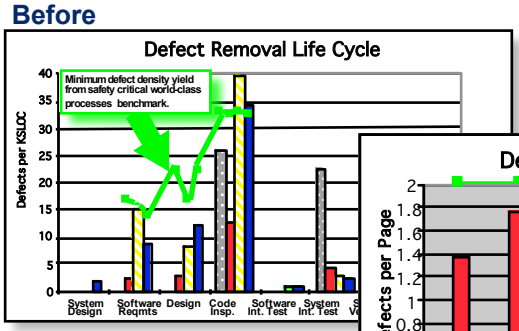
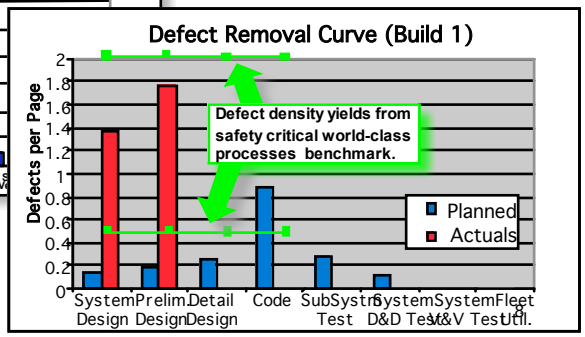
Improvement: Benchmarking

Before



After



Benchmarks indicated Requirements and Design inspections could yield highest ROI from process improvement

- Adapted from Beeson, Dennis D. and Olson, Timothy G., "Instrumenting Software Projects: A Case Study of Real World Projects", SEPG 2001.

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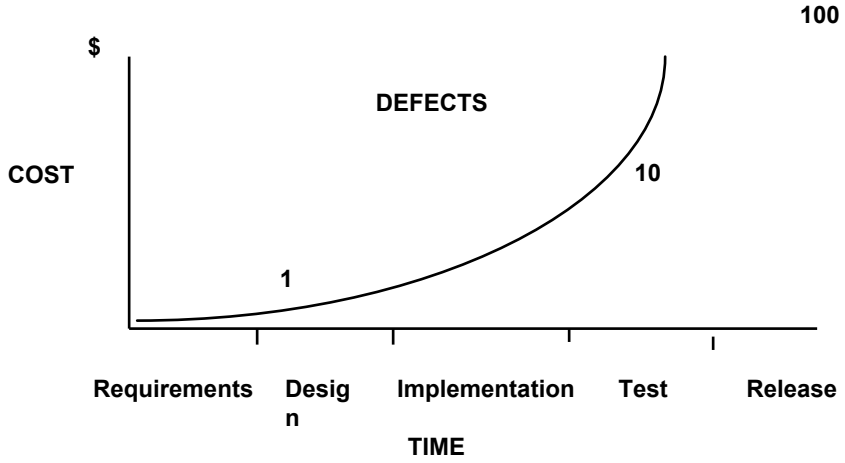
How Much Do Defects Cost?

Defects cost less to fix when detected earlier in the process



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Inspection ROI Assumptions

According to industry data, in-process inspections average about 3:1-12:1 ROI.

Historically, industry tests in quality (e.g., 80% of all defects are found in test).

According to industry data, defects cost 10-20 times more when found in test.

Once a defect is identified, testing processes can take about 5-20 hours to fix and verify per defect.

Once a defect is identified, in-process inspections take about 0.5-2 hours to fix and verify per defect.

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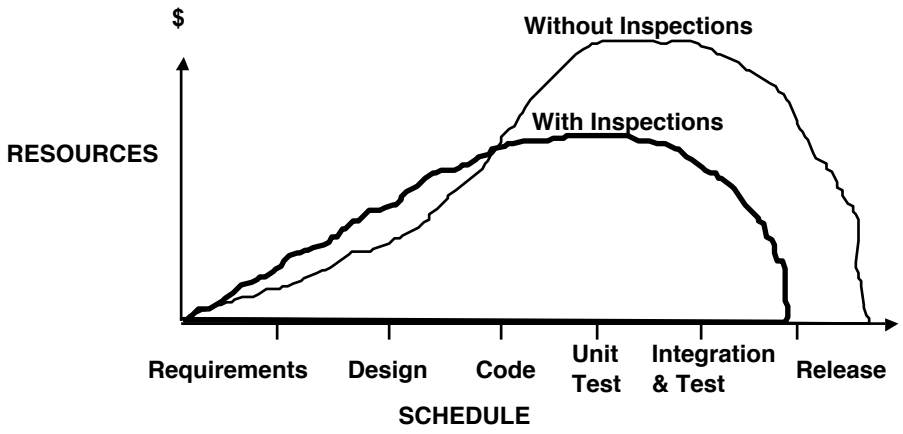
How is ROI Measured?



- Adapted from Fagan, M. "Advances in Software Inspections", IEEE Transactions on Software Engineering, July 1986

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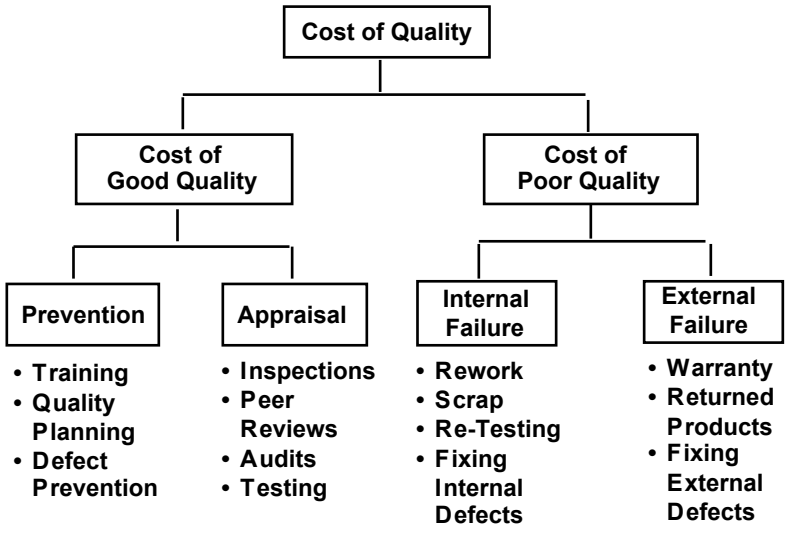
Major COQ Categories



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Key ROI Goal/Questions/Metrics

Goal: Measure ROI (both estimated and actual)

Key Questions:

1. **How much does a defect cost in each phase of the process (e.g., design vs. test vs. release)?**

2. **What is the defect removal rate of the verification processes for each phase (e.g., inspections, peer reviews, testing)?**

3. **For each project:**
   - **how many total defects (estimated and actual)?**
   - **how many total defects in each phase of the process (estimated and actual)?**

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ROI and Defect Dollarization

Goal	Key Questions	Metrics	Data Collection
Achieve 7:1 ROI **Measure old process against new process using Defect Dollarization** **NOTE: Old process is estimated based on actual data**	1. For Each Project: How much does a defect cost in each phase of the process?	1. Effort per defect per phase per project * hourly rate = cost per defect (for old process and new process)	Defect databases: Effort
	2. For each Project: a) How many total defects (estimated and actual)?	2a) Total Defects per Project (for old process and new process)	All defect databases
	b) How many total defects in each phase of the process?	2b) Total Defects per Phase per Project (for old process and new process)	All defect databases
	3. For Each Project: a) What is the defect removal rate of the verification processes?	3a) Defect Removal Efficiency per Project per verification process (for old process and new process)	All defect databases
	b) For each phase (e.g., inspections, peer reviews, testing)?	3b) Defect Removal Efficiency per Project per verification process per phase (for old process and new process)	All defect databases

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Some Lessons Learned - 1

Writing "good questions" in the G/Q/M paradigm is the hardest part.

The Process Measurement Framework[SM] adds more structure to the goals making the questions easier to write.

Operational definitions are required for each metric for repeatability.

There are many metrics that are derivable from the basic 5 metrics (e.g., defect density = total defects / total size).

World-Class Quality

Some Lessons Learned - 2

The Process Measurement Framework℠ is very powerful.

The Process Measurement Framework℠ should also be used with a measurement process.

Other more complex goals and metrics such as ROI or defect prevention may be also used with the Process Measurement Framework℠.

The Process Measurement Framework℠ should be tailored to each project and organization.

World-Class Quality

Summary

The Goal/Question/Metric paradigm, the Juran Quality Trilogy, and the SEI recommended initial core measures are best practices to build upon.

The Process Measurement Framework℠ is easy to use, very powerful, and scales up to handle complexity.

The Process Measurement Framework℠ can help:

- **Instrument individual processes**
- **Instrument projects**
- **Provide a measurement foundation for an organization**
- **Help define complex metrics**

Agenda

- Introduction
- Process Measurement Framework℠ Overview
- Real Example 1: Instrument a Process
- Real Example 2: Instrument a Project
- Real Example 3: Instrument an Organization
- Real Example 4: Instrument a Complex Metric
- Some Lessons Learned
- Questions and Answers

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