A Measurement & Analysis Training Solution Supporting CMMI & Six Sigma Transition

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SM Architecture Tradeoff Analysis Method; ATAM; CMM Integration; CURE; IDEAL; Interim Profile; OCTAVE; Operationally Critical Threat, Asset, and Vulnerability Evaluation; Personal Software Process; PSP; SCAMPI; SCAMPI Lead Assessor; SCAMPI Lead Appraiser; SCE; SEI; SEPG; Team Software Process; and TSP are service marks of Carnegie Mellon University.
Objectives

Primary
• Trace the design and development of a measurement & analysis course that integrates CMMI and Six Sigma
• Show why such integration is important

Secondary
• Highlight the complexities of process improvement in a “multi-technology world”
• Share issues related to technology transition
• Describe instructional design choices
• Illustrate a course case study in Six Sigma project form
Outline

Motivations for process improvement

Process improvement solutions
- Roots, evolutions, and integrations
- Transitioning your solution

Training as part of your “whole product”
- Designing an integrated training solution
- Illustration(s)
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.
More Solutions: SPC Frameworks Quagmire
And Yet More Solutions
CIO Magazine: “Quality Model Mania”

[CIO 04]
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And There Are Still More…

In addition to the traditional list of “process improvement” models, methods, and standards, there are life-cycle, business-sector-specific, and other types of relevant technologies.

For instance:
- Rational Unified Process (RUP)
- Agile
- Architecture Tradeoff Analysis Method (ATAM)
- TL9000
- People CMM
Do You Have a Headache Yet?
Observations

Organizations are implementing one or more of these solutions simultaneously.

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.

Before we discuss our project, let’s unfold the story…
Evolutions (examples)

Six Sigma
- Evolved at Motorola in the 1980s from TQM
- First focused on reducing process defects and cycle time in manufacturing
- Later expanded to address design (DFSS)
- Spread to services and is in early stages in software

CMMI
- Released in 2000
- Evolved from several Capability Maturity Models, reflects Crosby’s 5 maturity levels
- Focuses on infrastructure and process maturity
- Intended for software and systems engineering

Common roots and common improvement intent
A Technology Adoption Process

Establish Business Drivers

Select Technology

Implement Solution

Measure impact

Project Team

Implement/Integrate tech.

Execute project life cycle phases, steps

Organization’s Process Improvement Groups: SEPGs, Six Sigma Practitioners, et. al.

SEI (or other institution)

develop technology

transition technology

Level Rating,
Business Results

Proj Results,
Designing Your Approach

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.

Your Six Sigma skills can play a role in the design.
Transitioning Your Solution

*Technology transition* is the process of creating or maturing a technology, introducing it to its intended adopters, and facilitating its acceptance and use.

*Technology* is

- Any tool, technique, physical equipment or method of doing or making, by which human capability is extended.”
- “The means or capacity to perform a particular activity.”

Do you use the words maturation, introduction, adoption, implementation, dissemination, rollout, deployment, or fielding in your improvement approach? Each indicates transition.

[Forrester], [Schon], [Gruber]
Effective Transition Planning

Features include:
- Precision about the problem, clarity about the solution
- Transition goals & 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 transition

[Forrester]
The “Whole Product” Concept

- Standards
- Software
- Training
- Support
- Introduction
- Debugging
- Etc.

[Moore]

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Outline

Motivations for process improvement

Process Improvement Solutions
• Roots, evolutions, and integrations
• Transitioning your solution

Training as part of your “whole product”
• Designing an integrated training solution
• Illustration(s)
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, 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

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

Highlights of our course design and content follow.
Scope of New Analysis Courses

Our task is to build new courses that

- Focus on analysis
  - But more than just SPC
- Focus on skills-building
- 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
Approach

• Leverage other technologies and initiatives.
  - Reuse demonstrated frameworks and toolkits
  - Build explicit connections to models
  - Define “certification” boundaries and options
  - Return to common roots but don’t reinvent the wheel
• Assemble a cross-organizational, cross-functional development team
• Use Gagne’s Model for Instructional Design
• Use Kirkpatrick’s Four-Level Evaluation Model
• Design for extensibility: case study approach
  - Allows easy swap-in of other domains, technologies
  - Allows easy updates as core technologies evolve
Considerations

- Integrate product, process, project analysis
  - Focus on process
  - Reuse SEI “Analysis Dynamics”
- Use aspects of Six Sigma
  - DMAIC problem solving framework
  - Toolkit
  - Training philosophy (hands on, practitioner focus)
- Make CMMI links explicit
- Determine fit with existing measurement courses
- Couple with an annual Measurement Practices Workshop (future)
A Base Architecture
- Connecting all the Improvement Models

Distilling & Understanding

Too often we jump ...

Fuzzy Sense of a Problem or Opportunity

Focus on key aspects

Solution & Standards

Monitored Results

Experience: Gathering & Discovering

Teams move back and forth between..

Distilling & Understanding

Language

Type of Data

Language Statements
Observations

Language + Numbers
Sample Data Models

Numbers

Actual Capability
Variation Over Time

Solution Plan to Gather

Plan to Gather

Plan to Gather

Design

Distill

Monitor Results

Product/Process Improvement Progress

[Kawakita], [Shiba]

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Version 1.0

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Design & Development Process

- Identify needs, requirements
- Update overall measurement curriculum design
  - Integrate with “certificate programs”
- Establish learning objectives
- High-level design of measurement & analysis courses
  - Course themes and storyboards
  - Desired student capability level in specific methods
- Detailed design of measurement & analysis courses
  - Including case study storylines
- Module development, including reviews
- Pilot
Curriculum

Measurement and Analysis Course Curriculum

- Managing Software Projects with Metrics
  Additional training (as desired)
- Goal-Driven Software Measurement
- Process Measurement & Analysis I
- Process Measurement & Analysis II

Tutorials
- Estimating Acquisition
- CMMI & Six Sigma

Enterprise Measurement & Analysis (future)
- Acquisition Measurement & Analysis (future)

apply toward Six Sigma training
apply toward SEI Analyst Certification (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
Learning Objectives

Students should be able to

• Describe the methodology (DMAIC + thoughtmap), incl
  - improved process behavior for business benefit
  - how this methodology “plays” in the CMMI world

• Decide how, when and why to use selected key tools and interpret their outputs.

• Demonstrate how effective measurement & analysis contributes to a paradigm shift from a compliance-driven to performance-driven improvement.

• Analyze, interpret, and report data using “x” tools.

• Explain statistical thinking, central tendency, uncertainty and risk.
# Design Highlights: Course Themes

<table>
<thead>
<tr>
<th>CMMI Relationship</th>
<th>Process Measurement &amp; Analysis I</th>
<th>Process Measurement &amp; Analysis II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement Orientation</td>
<td><strong>Reduce</strong> defects, waste (effort, resources, etc), and cycle time by correcting special cause variation, repairing, and/or improving processes.</td>
<td><strong>Prevent</strong> defects, ensure cost/schedule performance by using real-time data and optimizing front-end planning, requirements, and design processes.</td>
</tr>
<tr>
<td>Maps to GP2.8 and GP3.2 at any maturity level. Maps to Level 4 thinking.</td>
<td>Maps to GP3.2 and GP4.2 at any maturity level. Maps to Level 5 thinking.</td>
<td></td>
</tr>
</tbody>
</table>
Design Highlights: Course Outline

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
- Recap DMAIC
- Project Simulation: Organization and Project Baseline
- Defect Containment Case:
  - Optimize inspections and improve design
- Cost & Schedule Case:
  - Optimize estimating and improve requirements
## Skills Capability Matrix (excerpt)

<table>
<thead>
<tr>
<th>Analytical Methods</th>
<th>desired student capability</th>
<th>addressed in course</th>
</tr>
</thead>
<tbody>
<tr>
<td>7+ basic tools (histogram, scatterplot, pareto, etc.)</td>
<td>skill</td>
<td>1</td>
</tr>
<tr>
<td>process mapping / SIPOC</td>
<td>skill</td>
<td>1</td>
</tr>
<tr>
<td>systems thinking - current/future reality trees, causal loop diagrams</td>
<td>tbd</td>
<td>tbd</td>
</tr>
<tr>
<td>sampling, grouping, alpha/beta risk</td>
<td>understand</td>
<td></td>
</tr>
<tr>
<td>FMEA</td>
<td>skill</td>
<td>1</td>
</tr>
<tr>
<td>Orthogonal decomposition</td>
<td>knowledge</td>
<td>tbd</td>
</tr>
<tr>
<td>multivariate analysis (principle components)</td>
<td>awareness</td>
<td>tbd</td>
</tr>
<tr>
<td>Confidence and prediction intervals</td>
<td>understand</td>
<td>2</td>
</tr>
<tr>
<td>hypothesis tests, Means comparison tests</td>
<td>skill</td>
<td>1</td>
</tr>
<tr>
<td>Variance comparison tests</td>
<td>knowledge</td>
<td>tbd</td>
</tr>
<tr>
<td>design of experiments (DOE)</td>
<td>understand</td>
<td>2</td>
</tr>
<tr>
<td>analysis of variance, incl analysis of error</td>
<td>knowledge</td>
<td>2</td>
</tr>
<tr>
<td>modeling - regression, residual analysis, response surface</td>
<td>knowledge</td>
<td>2</td>
</tr>
<tr>
<td>Rayleigh distributions</td>
<td>understand</td>
<td>2</td>
</tr>
<tr>
<td>chi square distributions</td>
<td>understand</td>
<td>tbd</td>
</tr>
<tr>
<td>capability analysis</td>
<td>understand</td>
<td>2</td>
</tr>
<tr>
<td>KJ</td>
<td>skill</td>
<td>2</td>
</tr>
<tr>
<td>VOC</td>
<td>skill</td>
<td>2</td>
</tr>
<tr>
<td>QFD</td>
<td>awareness</td>
<td>2</td>
</tr>
<tr>
<td>pugh's concept selection</td>
<td>skill</td>
<td>2</td>
</tr>
<tr>
<td>process simulation</td>
<td>awareness</td>
<td>2</td>
</tr>
</tbody>
</table>

**Awareness = on the radar**  
**Knowledge = knows basic information**  
**Skill = can do it**  
**Understand = can do, interpret, explain**
Case 1 Storyline 1

Define

- organization project portfolio includes both new development and maintenance
- project size and complexity varies significantly
- project schedules vary from <1 month to >18 months
- Primary focus: customer satisfaction as proxied by field defects and effort & schedule variance
- Organization is transitioning from CMM to CMMI, working toward high maturity
- Organization is not a Six Sigma adopter (yet)

Measure

- Earned value data
- Defect data
- Customer satisfaction survey (new)
Case 1 Storyline

Analyze

- Iteration 1: baseline and problem/goal identification
  - Reduce cost and schedule variance (in process and closed project)
  - Improve data quality (presence, accuracy, etc.)
- Subsequent iterations:
  - baseline updates
  - problem/goal refinement
  - process understanding
- Tools used: boxplots, distributions, time series, pareto charts, capability analysis, basic descriptive statistics, indicator templates, survey analysis, SMART* goals, root cause analysis

Specific, Measurable, Attainable, Realistic, Timely
Case 1 Storyline

Improve
- Measurement infrastructure
- Cost and schedule variance cause code taxonomy
- Estimating (training, minor process adjustments)
- Adoption of “management by fact” (MBF) format
- Homogeneous samples for in-process charts

Control
- Organization: dashboards with charts for cost, schedule, defects, data quality, customer satisfaction
- Projects: Earned Value (EV) prediction model
Case 1 Sample Artifacts

Sample artifacts on following slides include:
- Baseline charts: boxplots, capability analysis
- Co-optimized pareto analysis
- SMART goals and root cause analysis
- Homogeneous sampling
- Earned Value prediction model
- Management by Fact

The full case storyline demonstrates the usage of an improvement process:
- consistent with DMAIC, incl gates
- meeting CMMI specific practices
- leveraging measurement best practices
Case 1 Artifacts: Goal Structure

Consonant with GQIM and Six Sigma CTQs

Customer Satisfaction

Success Indicators, Management Indicators

- other factors

Deliver high quality product

- other factors

Track/chart field defects

Analysis Indicators, Progress Indicators

- other factors

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

- scatter plots

Track/chart cost & schedule deviation

Analysis Indicators, Progress Indicators

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

- scatter plots

SPI Task Plans
In-Process Schedule Variance Boxplot

Data reported monthly for all projects, cycle phases

Conclusion: need to address variability
Completed Project Data Baseline

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

It is the total cumulative variance
  • customer-requested/approved changes are included
  • one way or another, this is what the customer sees

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

Direct Cause vs. Root Cause

Causes resolved in-process vs. causes that affect final performance
## Co-Optimized Pareto Analysis

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

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

Reduce the impact of external causes by 50%.

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

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

Cause Code: Underestimated tasks
Process: Project Management
Subprocesses: Planning
• Establish requirements
• Define project process
• Perform detailed planning

As subprocesses are explored, process mapping may be used with (or based on) ETVX diagrams

CMMI Friendly
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
Improving Sampling Homogeneity

Overall rollup:
- group data by project milestones

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

![Diagram showing project cost index with wider limits for projects in planning phase and narrower limits for projects in execution phase.](chart)
EV Estimate-At-Completion Model

Calculated Estimate at Completion

Internal Spec Limits. 20% and 10%

Baseline Estimate at Completion

Process UCL, Effort and Schedule

Process LCL, Effort and Schedule
Reduce the total schedule variance by decreasing the variance of the top 3 internal causes by 50% in 1 year.

**Total variance w/ mean comparison**

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

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

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

**Impact, Capability**
In total, these countermeasures will remove 15% of typical variance.
(as possible, list impact of each countermeasure)
Case Study 1: The Connections

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
Case Study: Skills-Building

In class practice: statistical skills-building
  • Boxplots
  • Tukey Kramer
  • Adapted FMEA

In class discussions and other exercises
  • Risks of using historical data
  • Small sample sizes and homogeneous sampling
  • Corrective action guidance (as part of indicator template, esp. for SPC charts)
  • Evaluate and rewrite goals for SMARTness
Key Points

Effective training is a critical part of your process improvement approach.

Training can and should be “integrated” (as appropriate).

*Measurement & Analysis* is an effective platform for integration.
  - It is a common root!

Integrated approaches to training are win-win propositions.
  - If you are a Six Sigma adopter, you get exposure to domain specific technologies that will help solve your problems.
  - If you are a CMMI adopter, you learn to better leverage the most current body of knowledge for problem-solving.
  - If you are adopting both, you spend less time making the connections and more time making progress!
Contact Information

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References

All URLs subject to change

[BPD] Process Maturity / Capability Maturity, http://www.betterproductdesign.net/maturity.htm (a resource site for the Good Design Practice program, a joint initiative between the Institute for Manufacturing and the Engineering Design Centre at the University of Cambridge, and the Department of Industrial Design Engineering at the Royal College of Art (RCA) in London)


[Forrester] Forrester, Eileen, Transition Basics (reference information)


Addenda

CMMI Process Areas and Structure
# CMMI Process Areas

<table>
<thead>
<tr>
<th>Category</th>
<th>Process Areas</th>
</tr>
</thead>
</table>
| **Process Management** | Organizational Process Focus  
                      Organizational Process Definition  
                      Organizational Training  
                      Organizational Process Performance  
                      Organizational Innovation and Deployment |
| **Project Management** | Project Planning (PP)            
                      Project Monitoring and Control (PMC)  
                      Supplier Agreement Management (SAM)  
                      Integrated Project Management  
                      Risk Management  
                      Quantitative Project Management (QPM) |
| **Engineering**   | Requirements Management  
                      Requirements Development  
                      Technical Solution  
                      Product Integration  
                      Verification  
                      Validation |
| **Support**       | Configuration Management  
                      Process and Product Quality Assurance  
                      Measurement and Analysis (MA)  
                      Causal Analysis and Resolution  
                      Decision Analysis and Resolution |