KPIs, CMMI … und dann?

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SQM Congress 2006
Overview

• Short introduction of partners
• Short intro to KPIs, CMMI L4 & 5

• SISL: Quality Initiatives History -> Way to CMMI-L5
• Example for process improvement on L5 with quantitative evidence (effort estimation accuracy, effort estimation procedure, strategic decision for size input to effort estimation)

• Going beyond CMMI-L5
• The COMPAS Project
• Target COMPAS Models and their

• Conclusions
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Siemens Information Systems Ltd.

- Global HQ: Mumbai, India
- Global Operations: 32 Countries
- Founded in: 1992
- Employees: 4200
- FY05 Revenue: USD 171 Mio

#15/Top 20 India Software & Service Exporters (Criterion: Annual Turnover)
Goal: Reach Top10 next year!
Fraunhofer IESE  Kaiserslautern, Germany

- Fraunhofer Institute for Experimental Software Engineering
- Founded in 1996 (since 2000 permanent Institute)
- Mission: Applied Research & Technology Transfer with quantitative Evidence
  - Quantitative approach GQM & QIP (NASA)
  - Research projects (EU, German)
  - Industrial projects DE, EU, INT
- Leading European Organisation in applied research on Software Engineering (rank 4 worldwide)
- More than 100 scientific employees
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What is a KPI?

KPI = Key Performance Indicator

“A Key Performance Indicator (KPI) is an economic term. The term KPI denotes metrics using which the progress or fulfilment level of vital goals or critical success factors within an organisation can be measured and monitored.”

Typical KPIs in Software Business

• Process level
  – Ability to remove defects (early) -> Defect Containment Effectiveness
  – Cost of defect removal -> Cost of Quality
  – Process Capability & Maturity

• Project level
  – Effort accuracy -> e.g. Effort Relative Error
  – Schedule adherence

• Product level
  – Reliability (MTBF, MTTR, Availability)
  – Product size (ekLoC, FPs)
  – Defect Density
CMMI – Short Overview  (Staged Model)

1: Initial
- Process unpredictable, poorly controlled and reactive

2: Managed
- Process characterized for projects and is often reactive

3: Defined
- Process characterized for the organization and is proactive

4: Quantitatively Managed
- Process measured and controlled

5: Optimizing
- Focus on process improvement
MATURITY LEVEL 4: QUANTITATIVELY MANAGED

The maturity level 4 process areas are as follows:

**Organizational Process Performance**
- SG 1 Establish Performance Baselines and Models
  Baselines and models that characterize the expected process performance of the organization's set of standard processes are established and maintained.
- GG 3 Institutionalize a Defined Process
  The process is institutionalized as a defined process.

**Quantitative Project Management**
- SG 1 Quantitatively Manage the Project
  The project is quantitatively managed using quality and process-performance objectives.
- SG 2 Statistically Manage Subprocess Performance
  The performance of selected subprocesses within the project's defined process is statistically managed.
- GG 3 Institutionalize a Defined Process
  The process is institutionalized as a defined process.
MATURITY LEVEL 5: OPTIMIZING

The maturity level 5 process areas are as follows:

**Organizational Innovation and Deployment**

- **SG 1 Select Improvements:**
  Process and technology improvements that contribute to meeting quality and process-performance objectives are selected.

- **SG 2 Deploy Improvements:**
  Measurable improvements to the organization's processes and technologies are continually and systematically deployed.

- **GG 3 Institutionalize a Defined Process:**
  The process is institutionalized as a defined process.

**Causal Analysis and Resolution**

- **SG 1 Determine Causes of Defects:**
  Root causes of defects and other problems are systematically determined.

- **SG 2 Address Causes of Defects**
  Root causes of defects and other problems are systematically addressed to prevent their future occurrence.

- **GG 3 Institutionalize a Defined Process**
  The process is institutionalized as a defined process.
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SISL´s Quality Journey

Key Initiative
- ISO 9001
- CMM L5
- CMMI L5
- Six-Sigma

Focus Area
- Engineering Practices
- PM Practices
- Domain Knowledge
- Business Processes

Additional Initiatives
- HR (P-CMM)
- ISO 9001:2000 (F&A)
- BS 7799
- SAS 70
- ISO 13485

Comparison: Effort Estimation Procedure

94 - 99  99 - 01  01 - 04  04 - 06
SISL’s Quality Journey

Key Initiative

ISO 9001 → CMM L5 → CMMI L5 → Six-Sigma

SISL Good Practices

- Quality Policy and Quality System
- Quality Management as Early Warning System
- People Involvement and Integrated Process Improvement
- Balanced Scorecard and Metrics Program
- ExpertWEB and Technology Innovation
- Six-Sigma Programme and Process Optimization
- Process Automation through QMS Portal

| 94 - 99 | 99 - 01 | 01 - 04 | 04 - 06 |

Comparison: Effort Estimation Procedure
Effect of continuous process optimization

Example: Estimation procedure for project effort

Effort estimation
• Basic input: Size estimate (ekLOC)
• Further inputs
  – external risks (e.g. delay of LC documents, late change requests, global development sites)
  – internal risks (e.g. team fluctuation)

• Output: Effort (estimate in person hours)

• Evaluation of Effort estimates
  – Effort Accuracy / Effort Relative Error (Deviation from plan)
  – per phase and/or per project
Actual Size vs. Actual Total Effort – pre/at L5

Weak relationship between actual size and actual total effort.

Regression Model:
$R^2 = 17.4\%$
p-Value 12%
Actual Size vs. Actual Total Effort – going L5

Stable, significant relationship between actual size and actual total effort.

Regression Model:
$R^2 = 64.6\%$ (x 3.7)
p-Value $0.05\%$
Actual Size vs. Actual Eng. Effort – pre/at L5

Weak relationship between actual size and actual engineering effort.

Regression Model:
\[ R^2 = 21.8\% \]
p-Value 8%
Actual Size vs. Actual Eng. Effort – going L5

Stable, significant relationship between actual size and actual engineering effort.

Regression Model:
$R^2 = 72.5\%$ ($x$ 3.4)
p-Value 0.01%
**Engineering Effort Estimation RE/MRE – pre/at L5**

\[
RE = \frac{\text{Estimate} - \text{Actual}}{\text{Actual}} \times 100\%
\]

\[
MRE = |RE|
\]

**MeanRE = -5.05%**

**MedianRE = -1.64%**

**MeanMRE = 13.33%**

**MedianMRE = 10.04%**

**Interpretation RE**

- RE < 0: Effort was underestimated
- RE = 0: 100% hit!
- RE > 0: Effort was overestimated
Engineering Effort Estimation RE/MRE – going L5

Only projects finalized in FY 2005

MeanRE = -8.06%
MedianRE = -7.68%

MeanMRE = 8.43%
MedianMRE = 7.68%

MeanMRE: 36% lower
MedianMRE: 24% lower

Compare before values:
MeanMRE = 13.33%
MedianMRE = 10.04%
KPI Relations for Strategic Decisions (1/3)

Example: Make a strategic decision on size measurement approach
Which one is the right one in the scope of effort estimation? FP or LoC?

• Three KPIs
  - Size (actual)
  - Effort (actual)
  - Size-Effort-R-Square (Power of Size to explain variation in effort)

• Support of strategic decision
  - Conduct benchmark analysis on actual data on Size(LoC)/Effort from company data vs. Size(FP)/Effort from benchmark database
  - Selection of appropriate projects for the analyses
    • Similar/identical domain
    • Similar/identical system class
    • Comparable project sizes
KPI Relations for Strategic Decisions (2/3)

Stable, significant relationship between size (FP) and effort. Sample from: ISBSG Database; X-Org. data.

Regression Model:
\[ R^2 = 53.6\% \]
\[ p\text{-Value } 0.00\% \]
KPI Relations for Strategic Decisions (3/3)

Data Comparison

ISBSG (X-Org)
  Size-Effort-R-Square: 53.6%

SISL pre/at Level-5:
  Size-Effort-R-Square: 21.8%

SISL going Level-5:
  Size-Effort-R-Square: 72.5%

FP appears to be a meaningful alternative to eLoC for Size measurement and could be a basis for more reliable Effort estimation.

eLoC performs (in numbers) better than FP. Considering the X-Org context, both results may be compared in certain boundaries.

Expectation: eLoC and FP will perform equally well as basis for Effort estimation. Really change to FP?
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Going beyond L5 – The COMPAS Project

Situation
- Today’s SE processes are non-quantitative processes enriched with measures (easily measurable properties, e.g. productivity)
- Empirical research shows: uniform processes are not suitable, e.g. faults are not equally distributed over software units
- Domain plays an important role, e.g. safety-critical piece of SW in automotive vs. non safety-critical piece of SW in IS
- Establishing quantitatively controlled processes requires to understand underlying “rules” on a quantitative level

*COMPAS = Cooperation on Measurement-based quantified Processes for Activities in Software Engineering
**Going beyond L5 – The COMPAS Project**

**Project Goal**

- Identification and understanding of quantitative relationships of processes and products
- Exploitation of such relationships as rules for quantitatively controlling SE processes and projects
- E.g. models for predicting specific properties of SE products (along the process)
- E.g. models for predicting specific issues of SE processes
- Use of the results of the models to establish a quantitative control cycle on the process
- E.g. number of defects detected in a design (“is”); predict lower bound of overall number of defects in the design; compare “is” to lower bound and decide on how to proceed

```
current situation
      ↓
act & measure
      ↓
      ↓
      ↓
      ↓
decide
```

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Going beyond L5 – The COMPAS Project

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- E.g. number of defects detected in a design ("is"); predict lower bound of overall number of defects in the design; compare "is" to lower bound and decide on how to proceed

Current situation
After project situation (planned)

act & measure

analyze & predict

decide
Small Example for COMPAS Models

Standard procedure for review
- Act: Conduct review
- Measure: Collect data on detected defects

Example for quantitative control by a prediction model
- Two reviewers conduct a requirements review (100 pages RS)
- Usual quant. pass-criterion: 2-3 defects per 10 pages
- Review Findings:
  - Reviewer.1: 15; Reviewer.2: 17 Defects
  - Overlap: 5 Defects; Total: 27 different Defects
  - Result: 2.7 Defects/10 Seiten -> Pass
- Background: Early Defect Detection saves cost & time
Small Example for COMPAS Models

Standard procedure for review

- Act: Conduct review
- Measure: Collect data on detected defects

Example for quantitative control by a prediction model

Simple prediction model for defect content results in: Lower bound of defect content is approx. 51 Defects
Result: Probably more than 5.1 Defects/10 pages
Pass? Rework?

Usual Situation
Situation w/quant. control and prediction model

Diff. to real number of defects (est’d-real)
SISL Models in a Nutshell (selected ones)

- Defect Containment after Review
  - for controlling early QS processes
  - as input for predicting defects in tests
- Defect Containment/Density after Test
  - for controlling test processes
  - as input for defect density
- Corrective Size Prediction
  - for making Size prediction (ekLOC) more precise
  - as input for cost prediction
- Cost/Effort Prediction
  - for bringing cost accuracy towards RE < 10%
  - for controlling and revising spent effort
  - predict and control effort required to finish project under size, quality aspects (early warning system)
Processes, KPIs, quantitative Models

Prediction Model

Proc A → Proc B → Proc C → Proc D

Measure

Data

Predicted KPI X
(several predictions with increasing accuracy)

Control & Measure

Predicted KPI Y

near process

spanning several processes
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Conclusions

- Quantitative Prediction Models spanning processes can be used to gain high benefits

- COMPAS models will enable for quantitative insight into and across subprocesses
  - for stringent and proactive quantitative quality & process control
  - for understanding quantitative relationships along several subprocesses
  - as a subprocess spanning early warning system

- Enable for early as possible prediction (with decreasing uncertainty) of e.g. end product defect density as early as review phases
- Enable for re-estimation of project effort based on external triggers also accounting for quality issues