Examining the Test Process: Predicting the Return on Investment of a Process Change

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Agenda
1. Motivation
2. What are Process Simulation Models
3. Benefits of Process Simulation
4. Examining the Testing Process
5. Goals, Questions, Performance Measures and Data
6. Model Results
7. Conclusion
Motivation

Competition within the U.S. and abroad is putting pressure on software firms to improve performance in terms of:

• Reducing costs
• Reducing cycle time
• Reducing defects

In order to compete, organizations need to incorporate new methods and tools into their development operations quickly.

Introducing - Process Simulation

One area that can help companies improve their processes is Process Simulation.

Process Simulation supports organizations at all levels of the CMMI
• Designing and defining processes
• Quantitative process management
• Continuous process improvement
What is Process Simulation?

- Simulation is a computerized model (not a maturity model) designed to display significant features of the dynamic system it represents.

- Process simulation models focus on the dynamics of software and systems development, maintenance and acquisition activities.

- Process Simulation models represent the process
  - as currently implemented (as-is), or
  - as planned for future implementation (to-be)

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**Company Strategy**

- Competitive Advantage
- Customer Value

**Improving Operations**

- Industry Standards
  - CMMI, Six Sigma, ISO

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Many choices. Which one(s) to choose?

Need to focus efforts to be successful.

Which change will provide the greatest improvement?

What is the financial impact?

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**Set of Potential Process Changes**

**Process Simulation**

Evaluate Impact on Process Performance

**Performance Measures**

- Cost, Quality, Schedule

**Financial Benefits - NPV, ROI**
General Approach

Software Development Process

Better Process Decisions

Process Performance
Cost, Quality, Schedule

Project Data
Process and Product

Model Parameters

Process Tradeoff Analysis Method (PTAM)

- Based on extensive research into Software Process Modeling conducted in academia, SEI and industry.
- Graphical user interface and models software processes
- Integrates SEI methods to define processes and to support CMMI PAs
- Integrates metrics related to cost, quality, and schedule into understandable project performance picture.
- Predicts project-level impacts of process improvements in terms of cost, quality and cycle time
- Support business case analysis of process decisions - ROI, NPV and quantitatively assessing risk.
Process Tradeoff Analysis Method (PTAM)

- **Reduces risk** associated with process changes by predicting the probability of improvement
- **Saves time, effort and expertise** over other methods

What are the Benefits of Process Simulation?

<table>
<thead>
<tr>
<th>Option</th>
<th>Project</th>
<th>Total Effort (PM)</th>
<th>Rework Effort Defects (PM)</th>
<th>Project Duration Calendar Month</th>
<th>Total Injected Defects</th>
<th>Corrected Defects</th>
<th>Escaped Defects</th>
<th>Rework Effort for Field Defects ($PM)</th>
<th>Implementation Costs ($)</th>
<th>NPV</th>
<th>ROI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Base Case</td>
<td></td>
<td>350</td>
<td>90</td>
<td>15</td>
<td>$0.00</td>
<td>1150</td>
<td>960</td>
<td>40</td>
<td>$0.00</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>1 Implement GFD</td>
<td></td>
<td>190</td>
<td>75</td>
<td>15</td>
<td>$0.00</td>
<td>1150</td>
<td>1020</td>
<td>100</td>
<td>$100,000</td>
<td>$165,145</td>
<td>15%</td>
</tr>
<tr>
<td>2 Implement VPC</td>
<td></td>
<td>185</td>
<td>75</td>
<td>15</td>
<td>$100,000</td>
<td>1150</td>
<td>1050</td>
<td>100</td>
<td>$120,000</td>
<td>$185,231</td>
<td>29%</td>
</tr>
<tr>
<td>3 Add Quality Test</td>
<td></td>
<td>175</td>
<td>85</td>
<td>15</td>
<td>$300,000</td>
<td>1150</td>
<td>1090</td>
<td>60</td>
<td>$80,000</td>
<td>$289,674</td>
<td>88%</td>
</tr>
<tr>
<td>4 Eliminate</td>
<td></td>
<td>230</td>
<td>130</td>
<td>22</td>
<td>$400,000</td>
<td>1150</td>
<td>900</td>
<td>250</td>
<td>$0.00</td>
<td>$378,043</td>
<td>-129%</td>
</tr>
<tr>
<td>5 Additional Process</td>
<td></td>
<td>295</td>
<td>190</td>
<td>25</td>
<td>$600,000</td>
<td>1150</td>
<td>850</td>
<td>200</td>
<td>$0.00</td>
<td>$570,043</td>
<td>-129%</td>
</tr>
</tbody>
</table>

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Benefits of Process Simulation

- Decision Support and Tradeoff Analysis
- Sensitivity Analysis – “What if”
- Supports Industry Certification and process improvement programs including CMMI, Six Sigma, and others
- Benchmarking
- Design and Define Processes
- Bring Lessons Learned Repositories Alive
- Can save cost, effort, and expertise
- Can be used to address project manager questions

Software Project Manager Concerns

- What development phases are essential?
- Which phases could be skipped or minimized to shorten cycle time and reduce costs without sacrificing quality?
- Are inspections worthwhile?
- What is the value of applying automated tools to support development activities?
- How do we predict the benefit associated with implementing a process change?
- How do we prioritize process changes?
- How to achieve higher levels of the CMMI?
- What is the level of Risk associated with a change?
NASA IV&V Questions

• What is the optimal IV&V strategy for a given NASA project or NASA project type?
• What combination(s) of IV&V techniques enable us to meet or exceed the quality assurance goals for the system? Which alternative is best?
• Given a budget of “X” dollars, what IV&V activities should be conducted?
• What if the complexity or defect profiles for a particular project were different than expected?
• How is the duration of the IV&V effort impacted by the overall staffing level for the project? How will this affect the total project duration?
• What would be the impact if selected V&V techniques are handled as IV&V services?

Potential Questions

• What would be the costs and benefits associated with implementing an IV&V technique on a selected software project?
• How would the IV&V technique contribute to the development process and quality assurance?
• How would IV&V activity “X” work in conjunction with other V&V or IV&V techniques?
• At what point in the process does this technique provide the greatest benefit (e.g. before or after testing)?
• What would be the impact if a IV&V technique “X” is applied at different portions of the process or applied multiple times?
Supports CMMI Based Process Improvement

CMMI Levels 4 and 5
- Process simulation helps to fulfill PAs (OID, CAR, OPP and QPM - Sub Goals and Generic Goals)

CMMI Levels 2 and 3
- Process simulation can be used to evaluate alternative process choices (RD, TS, PI, V&V, RM, SAM, PPQA, and CM)
- Process simulation helps to fulfill PAs (OPF, OPD, OT, IPM, Risk, DAR, PP, PMA, MA, PPQA – Multiple Sub Goals and Generic Goals)

Examining the Test Process: Organizational Setting
- Leading software development firm
- Peak staffing of 60 developers on project
- Assessed at strong Level 2 of CMM/CMMI
- Experienced development staff
- 5th release of commercial project
- Data available in electronic and paper form: quantitative and qualitative; professional estimates used to fill in gaps
- Active SEPG
CMMI Level 3 PAs: Validation and Verification

- Problem: Releasing defective products, had high schedule variance.
- Why? Unit Test was main defect removal stage. They did it unreliably.
- Built a model of Large-Scale commercial development process
- Based on actual project data
- Predicted project performance in terms of effort, task duration and delivered defects.
- Part of a full business case analysis - determined financial performance of the process change

Diagram of the Field Study Life Cycle AS-IS Process
Questions Investigated

- Will the process change improve project performance?
- What is the cost the firm is currently paying by conducting Unit Tests incorrectly?
- Is partial implementation of the proposed process change possible?
- How would potential learning curve effects affect the performance of the process change?
- Would alternative process changes offer a greater improvement?
- Can the project benefit from reusing process artifacts?
Performance Measures

Cost
• Person-Months of Development, Inspection, Testing and Rework effort
• Equivalent Manpower (Staffing levels)
• Implementation costs

Quality
• Number of delivered defects by type

Schedule
• Months of Effort

Input Data

• CMM/CMMI Level 2+ organization
• Process documents and assessments
• Project Size
• Productivity
• Earned Value by phase
• Total number of defects injected
• Defect injection, detection and correction rates
• Effort and schedule data
• Defect detection and rework costs
Graphical Model

Diagram of the Field Study Life Cycle AS-IS Process

Simplified Error Model

Verification Efficiency = \frac{Errors Detected}{Total Errors Present}

Undetected errors to next phase

Errors injected (and removed)

Errors detected in this phase

Undetected errors from previous phase

Perform Work

Verify Work

Rework Detected Errors
More Detailed Error Model

Unit Test Planning Process Change

**Estimate Localized Impacts**

- Effort and schedule to develop test plans
- Early detection and removal of defects while creating test plans
- Inspection effort for inspecting and reworking test plans
- Improved efficiency during Unit Test due to following the plans
## Key Parameters for the Process Change

<table>
<thead>
<tr>
<th>Model Parameters</th>
<th>AS-IS Observed</th>
<th>TO-BE Estimated</th>
<th>TO-BE (Observed) Pilot Study Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create Unit Test Plan Effort (Hours per KLOC)</td>
<td>0.0</td>
<td>Min=47.6 Mode=72.2 Max=144.3</td>
<td>Min=83.3 Mode=100.0 Max=190.0</td>
</tr>
<tr>
<td>Percentage of Current Errors Removed before Code Inspections while creating the Unit Test Plans</td>
<td>0.0%</td>
<td>Min = 9.0% Mode=15.7% Max = 22.5%</td>
<td>Min = 0.0% Mode=6.4% Max = 28.6%</td>
</tr>
<tr>
<td>Percent Unit Test Effort Decrease due to following the plan</td>
<td>0.0%</td>
<td>Min = 5% Mode=10% Max = 15%</td>
<td>Min = 5% Mode=15% Max = 20%</td>
</tr>
<tr>
<td>Percent Increase in Unit Test Error Detection Capability</td>
<td>0.0%</td>
<td>Min = 10% Mode=15% Max = 20%</td>
<td>Min = 5% Mode=15% Max = 20%</td>
</tr>
<tr>
<td>Effort to Prepare for the Inspection of the Unit Test Plan (hours per meeting)</td>
<td>0.0</td>
<td>Min=0.25 Mode=0.25 Max=0.25</td>
<td>Min=0.25 Mode=0.25 Max=0.40</td>
</tr>
<tr>
<td>Effort to Inspect the Unit Test Plan (hours per plan error)</td>
<td>0.0</td>
<td>0.0</td>
<td>Min=0.0 Mode=2.0 Max=3.0</td>
</tr>
</tbody>
</table>

---

## Unit Test Planning Process Change

### Model Predicts Project Level Impacts
- Cost, quality, and schedule impacts by phase for all phases of development
- Overall cost, quality, and schedule impacts for the project
- Implementation costs
- Post deployment quality
Baseline Results

- The process change offered significant reductions in remaining defects, staff effort to correct field detected defects, and project duration. The expected ROI was 56% for a typical 30 KLOC release.

- Pilot implementations indicated that the process change provided a 37% ROI even under worst case conditions.

Model Results

<table>
<thead>
<tr>
<th>PERFORMANCE MEASURE</th>
<th>AS-IS</th>
<th>TO-BE</th>
<th>MEAN DIFF</th>
<th>PCT CHG</th>
<th>CHG STD</th>
<th>P-VAL</th>
<th>PROB IMPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>REMAINING ERRORS</td>
<td>10.21</td>
<td>8.51</td>
<td>1.70</td>
<td>16.65%</td>
<td>0.93</td>
<td>0.000</td>
<td>97%</td>
</tr>
<tr>
<td>LIFE CYCLE EFFORT (PM)</td>
<td>52.42</td>
<td>52.49</td>
<td>-0.07</td>
<td>-0.12%</td>
<td>1.02</td>
<td>0.446</td>
<td>49%</td>
</tr>
<tr>
<td>TOTAL EFFORT (PM)</td>
<td>62.00</td>
<td>60.47</td>
<td>1.53</td>
<td>2.47%</td>
<td>1.43</td>
<td>0.000</td>
<td>85%</td>
</tr>
<tr>
<td>LIFE CYCLE DURATION (Mo)</td>
<td>18.05</td>
<td>16.44</td>
<td>1.61</td>
<td>8.92%</td>
<td>1.75</td>
<td>0.000</td>
<td>79%</td>
</tr>
</tbody>
</table>
Sensitivity Analysis Results

- Compressing Unit Test causes significant increases in schedule (+18%) and effort costs (+8%) during the later testing phases and reduces overall product quality (+48% increase in defects).

- Partial implementation of the process change is possible for complex portions of the code. Estimated ROI is 72%.

- Potential learning curve effects significantly enhance the performance of the process change. Expected ROI of 72% assuming only moderate improvements.

Mean Cost, Quality, and Schedule Impacts for Changes in Unit Test Error Detection Capability

<table>
<thead>
<tr>
<th>COST (Hours of Staff Effort)</th>
<th>MODE = 0.200</th>
<th>MODE = 0.351</th>
<th>TO-BE MODE = 0.403</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Effort</td>
<td>66.62</td>
<td>62.00</td>
<td>60.47</td>
</tr>
<tr>
<td>Life Cycle Eff</td>
<td>52.43</td>
<td>52.42</td>
<td>52.49</td>
</tr>
<tr>
<td>UT Effort</td>
<td>7.06</td>
<td>9.19</td>
<td>8.45</td>
</tr>
<tr>
<td>FVT Effort</td>
<td>8.22</td>
<td>6.55</td>
<td>6.01</td>
</tr>
<tr>
<td>SVT Effort</td>
<td>3.89</td>
<td>3.40</td>
<td>3.23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>QUALITY (Number of Remaining Errors)</th>
<th>MODE = 0.200</th>
<th>MODE = 0.351</th>
<th>TO-BE MODE = 0.403</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remaining Err</td>
<td>15.13</td>
<td>10.2133</td>
<td>8.51333</td>
</tr>
<tr>
<td>Corr E-UT</td>
<td>57.28</td>
<td>101.727</td>
<td>85.4867</td>
</tr>
<tr>
<td>Corr E-FVT</td>
<td>82.29</td>
<td>57.16</td>
<td>48.1333</td>
</tr>
<tr>
<td>Corr E-SVT</td>
<td>29.81</td>
<td>20.8267</td>
<td>17.5133</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCHEDULE (Hours of Task Duration)</th>
<th>MODE = 0.200</th>
<th>MODE = 0.351</th>
<th>TO-BE MODE = 0.403</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Cycle Dur</td>
<td>21.21</td>
<td>16.05</td>
<td>16.44</td>
</tr>
<tr>
<td>UT Duration</td>
<td>1.80</td>
<td>2.34</td>
<td>2.15</td>
</tr>
<tr>
<td>FVT Duration</td>
<td>16.71</td>
<td>12.73</td>
<td>10.47</td>
</tr>
<tr>
<td>SVT Duration</td>
<td>10.50</td>
<td>7.71</td>
<td>6.54</td>
</tr>
</tbody>
</table>
Sensitivity Analysis Results

• Improving inspections would be a more effective process improvement than the Creating Unit Test Plans process change.

• Reusing the Unit Test Plans on the next development cycle provided an overall ROI of 73% (compared to 56% expected improvement without reuse)

Impact on the Company

• Supports strategic process improvement goals of for higher CMMI levels
• Provides a framework and direction for metrics program (made improvements)
• Supports business case analysis of process changes
• Provides quantitative risk assessment prior to the introduction of process changes
• Obtains Management buy-in for process change and collection of further metrics
Rapidly Deployable Software Process Simulation Models

- **Goal:** To create a flexible decision support tool that can be easily used to support better project management, planning and tracking by quantitatively assessing the economic benefit of proposed process alternatives.

- **Motivation:** Companies need to get useful results from simulation models quickly.
Conclusions

Process simulation modeling has been used successfully to quantitatively address a variety of issues from strategic management to process understanding.

Key benefits include:
- Decision Support and Tradeoff Analysis
- Sensitivity Analysis – “What if”
- Supports Industry Certification and process improvement programs including CMMI, Six Sigma, and others
- Supports CMMI at all levels 2 through 5
- Design and Define Processes
- Benchmarking
- Can address project manager concerns
- Supports project management and control

Conclusions

This study provided turnkey analysis and recommendations for making a Go/No go decision on the process change:
- Expected benefit
- Partial Implementation
- Learning curve impacts
- Impact of bad behavior
- Alternative process changes
- Re-estimate based upon pilot study results

Not a silver bullet

Focus on RAPID DEPLOYMENT
- Reducing costs and making models easier to use – No simulation expert needed
The End

Questions?

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