Estimating Software Reuse Costs

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Genesis

• An Attempt to Synthesize Current State of Art in Software Reuse Costs


• 30 Cost Models, All Talking about Reuse Costs, Cannot be All Saying Different Things.
Classification Schem

Cost Models can be Characterized by Seven Features

1. Investment Cycle
2. Economic Function
3. Cost Factors Involved
4. Reuse Organization
5. Scope
6. Hypothesis
7. Viewpoint

30 is not too many, but too few.
Synthetic Model

Model that recognizes these dimensions of variability, and provides for them, rather than unnecessarily restricting them.
Model Premises

• Four stakeholders in the software reuse lifecycle
• Each stakeholder is responsible for a key decision in the process
• All decisions are based on the economic rationale
• All decisions can be modeled as investment decisions
• All decisions can be quantified by means of investment analysis functions
Basis for Making Reuse Happen

Rather than Preaching, Lecturing, Finger-pointing,

Define a reward / incentive structure that integrates individual goals with reuse goals
Formulate Incentive / Reward Structure

• Four Stakeholders: Corporate, Domain, Application, Component
• For each Stakeholder: Formulate ROI Function
• Identify Controllable Factors in ROI Functions
• Fine Tune Controllable Factors to Make ROI Positive for All Stakeholders
• Measure Stakeholder Performance / Reward Stakeholders by Means of ROI
Optimal Incentive / Reward Structure

• Optimize Corporate ROI, under the Constraint that all Stakeholder’s ROI’s are Positive
Main Features of the Model

- Four Investment Cycles: Corporate, Domain, Application, Component

- Six Cost Factors:
  - Start Date, SD
  - Cycle Length, Y
  - Discount Rate, d
  - Investment Costs, IC
  - Episodic Benefits, B(y)
  - Episodic Costs, C(y)
Main Features of the Model

- Seven Economic Functions
  - NPV
  - ROI
  - PI
  - ARR
  - ARBV
  - IRR
  - PB
Hypotheses

• Non Linear Cost Effects
• Integration Costs
• Quantifying Gains (ACT differential)
• Code Inflation
• Quantifying Time-to-Market Gains
Classification of Existing Cost Models, Comparison to Proposed Model

- Development of an Automated Cost Estimation Tool, which has an Analytical function and an Archival Function
- Development of Sample Archival Data
- “Work in Progress” Website: http://www.csee.wvu.edu/reuseroi
Cost Structure

- Component Balance Sheet
- Domain Balance Sheet
- Application Balance Sheet
- Corporate Balance Sheet
### Component Balance Sheet

<table>
<thead>
<tr>
<th>year, $y$</th>
<th>Cost, $C_\gamma(y)$</th>
<th>Benefit, $B_\gamma(y)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y = SD$</td>
<td>Development for reuse</td>
<td></td>
</tr>
<tr>
<td>$y &gt; SD$</td>
<td>residence costs + maintenance</td>
<td>Sales to Projects</td>
</tr>
</tbody>
</table>

### Domain Balance Sheet

<table>
<thead>
<tr>
<th>year, $y$</th>
<th>Cost, $C_\delta(y)$</th>
<th>Benefit, $B_\delta(y)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y = SD$</td>
<td>Domain Analysis + Asset develop.</td>
<td></td>
</tr>
<tr>
<td>$y &gt; SD$</td>
<td>asset dev. + conc. domain analysis</td>
<td>Asset Sales to Projects</td>
</tr>
</tbody>
</table>

### Application Balance Sheet

<table>
<thead>
<tr>
<th>year, $y$</th>
<th>Cost, $C_\rho(y)$</th>
<th>Benefit, $B_\rho(y)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y = SD$</td>
<td>Purchase of reusable assets</td>
<td>savings of dev. costs</td>
</tr>
<tr>
<td>$y &gt; SD$</td>
<td></td>
<td>Quality gains</td>
</tr>
</tbody>
</table>

### Corporate Balance Sheet

<table>
<thead>
<tr>
<th>year, $y$</th>
<th>Cost, $C_\sigma(y)$</th>
<th>Benefit, $B_\sigma(y)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y = SD$</td>
<td>Infrastructure</td>
<td></td>
</tr>
<tr>
<td>$y &gt; SD$</td>
<td>Domain costs</td>
<td>Application benefits</td>
</tr>
</tbody>
</table>
## Corporate Cycle

**Investment Costs**
- Reuse Infrastructure

**Episodic Costs**

### Domain Engineering Cycle

**Investment Costs**
- Domain Analysis Costs

**Episodic Costs**

<table>
<thead>
<tr>
<th>Component Engineering Cycle</th>
<th>Investment Costs</th>
<th>Episodic Costs</th>
<th>Episodic Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Develop for Reuse</td>
<td>Library overhead</td>
<td>Sale of asset</td>
</tr>
</tbody>
</table>

**Episodic Benefits**
- Cost Transfers from Projects

### Application Engineering Cycle

<table>
<thead>
<tr>
<th>Investment Costs</th>
<th>Episodic Costs</th>
<th>Episodic Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>Reuse Overhead</td>
<td>Productivity gains</td>
</tr>
<tr>
<td>Process Impact</td>
<td>Reuse Risks</td>
<td>Quality gains</td>
</tr>
</tbody>
</table>
**IC**: upfront investment costs

**Y**: Investment cycle (in years)

**d**: Discount rate

**B(y)**: benefits at year *y*

**C(y)**: costs at year *y*
Corporate Cycle

Initiative Started in 1997,
SD=1997

IC = Infrastructure Costs + Reuse Institutionalization Costs
= 50 PM
Domain Cycle

Domain Initiative Started in 1997, SD=1997

5 Reusable Assets Developed in 1997

IC=Domain Engineering Costs + Asset Development Costs = DA + 5 x ER=175.66 PM

5 Reusable Assets Developed in 1998

=Asset Development Costs=5*ER=97.60 PM

Benefits: Will be Inferred from Application Engineering Activity
Application Engineering Cycle

- **CS98: Application Developed in 1998**
  - 10 Black Box Assets
  - 20 White Box Assets
  - 100 KLOC Custom Code

- **CS99: Application Developed in 1999**
  - 20 Black Box Assets
  - 10 White Box assets
  - 50 KLOC Custom Code
Component Engineering Cycle

- Reusable Asset size of 5 KLOC
- Residence Costs for Asset of .5 PM/yr
- Maintenance Costs of 0.1xE/yr

- $BP(y) = 0.6 \times E$
- $WP(y) = 0.2 \times E$

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Box</td>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>White Box</td>
<td></td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
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</tbody>
</table>
Estimating Component Engineering ROI

SD = 1997
IC = 29.12 PM

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(y)</td>
<td>29.12</td>
<td>2.32</td>
<td>2.32</td>
<td>2.32</td>
</tr>
<tr>
<td>B(y)</td>
<td>0</td>
<td>12.74</td>
<td>17.29</td>
<td>0</td>
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</tbody>
</table>
Estimating Domain Engineering ROI

SD = 1997
IC = 109.2 PM

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(y)</td>
<td>245.70</td>
<td>136.50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B(y)</td>
<td>0</td>
<td>127.40</td>
<td>172.90</td>
<td>0</td>
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</tbody>
</table>
Estimating Application Engineering ROI

CS98

SD = 1998
IC = 127.40 PM

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(y)</td>
<td>127.40</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B(y)</td>
<td>378.23</td>
<td>87.29</td>
<td>87.29</td>
<td>87.29</td>
</tr>
</tbody>
</table>
Estimating Application Engineering ROI

CS99

SD = 1999
IC = 172.90 PM

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(y)</td>
<td>172.90</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B(y)</td>
<td>423.53</td>
<td>67.99</td>
<td>67.99</td>
<td>67.99</td>
</tr>
</tbody>
</table>
Estimating Corporate Engineering ROI

SD = 1997
IC = 50 PM

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(y)</td>
<td>295.70</td>
<td>136.50</td>
<td>0</td>
<td>18.00</td>
</tr>
<tr>
<td>B(y)</td>
<td>0</td>
<td>378.23</td>
<td>510.82</td>
<td>155.28</td>
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</tbody>
</table>
### Results

<table>
<thead>
<tr>
<th>Cycle</th>
<th>NPV</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Engineering</td>
<td>-11.06 PM</td>
<td>.70</td>
</tr>
<tr>
<td>Application Engineering CS98</td>
<td>450.12 PM</td>
<td>4.53</td>
</tr>
<tr>
<td>Application Engineering CS99</td>
<td>405.86 PM</td>
<td>3.35</td>
</tr>
<tr>
<td>Domain Engineering</td>
<td>-122.87 PM</td>
<td>.66</td>
</tr>
<tr>
<td>Corporate Engineering</td>
<td>612.13 PM</td>
<td>1.97</td>
</tr>
</tbody>
</table>

**OOPS:**

Domain Engineering and Component Engineering NPV is Negative.

DE and CE will not Cooperate to Make this Work
Summary Results, Revisited

We Change the Controllable Factors in Favor of CE and DE:

- \( BP = 0.80 \times E \)
- \( WP = 0.25 \times E \)

<table>
<thead>
<tr>
<th>Cycle</th>
<th>NPV</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Engineering</td>
<td>10.83 PM</td>
<td>1.34</td>
</tr>
<tr>
<td>Application Engineering CS98</td>
<td>422.82 PM</td>
<td>3.73</td>
</tr>
<tr>
<td>Application Engineering CS99</td>
<td>242.06 PM</td>
<td>1.72</td>
</tr>
<tr>
<td>Domain Engineering</td>
<td>95.93 PM</td>
<td>1.26</td>
</tr>
<tr>
<td>Corporate Engineering</td>
<td>612.13 PM</td>
<td>1.97</td>
</tr>
</tbody>
</table>
Conclusion

• Classification Scheme for Existing Software Reuse Cost Models
• Generic Cost Model that Encompasses Many Features of Existing Models
• Used as a Basis for Controlling Reuse Deployment
• Illustrated by an Example, which Shows What it Means to Make Reuse Happen.