Maintenance Cost Estimation

1. Classifying Maintenance Activities
2. Product Versions = Maintenance Projects
3. Types of Maintenance Costs
4. Calculating Maintenance Project Costs
5. Estimating Correction Costs
6. Calculating the Error Correction Effort
7. Estimating Effort for Error Correction
8. Predicting the Number of Errors
9. Estimating Error Correction Costs
10. Estimating Evolution Costs
11. Measuring System Size
12. Adjusting System Size through Complexity
13. Adjusting System Size through Quality
15. Code-based Change Estimation
16. Measuring previous Productivity
17. Impact Analysis of new Requirements
18. Estimating Evolution Costs
19. Costs of Software Maintenance Management
20. Maintenance Management Activities
22. Calculating Overall Maintenance Costs
Classifying Maintenance Activities

Software Maintenance

- Maintenance of the last Version
  - Corrective Maintenance
  - Emergency Fixes
- Development of the new Version
  - Enhancive Maintenance
  - Adaptive Maintenance
  - Perfective Maintenance
- Management
  - Collecting & Tracking of Error Reports
  - Collecting & Filtering of Change Requests
  - Product & Project Planning
  - Product & Project Monitoring
# Product Versions = Maintenance Projects

<table>
<thead>
<tr>
<th>Year</th>
<th>Management</th>
<th>Maintenance Effort</th>
<th>Development Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>2000</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>2001</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>2002</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>

- Version 3
- Version 4
- Version 5
- Version 6
Types of Maintenance Costs

- Development of next Version
  - Appreciable because of Impact Analysis
  - Adaptive Maintenance
  - Enhancive Maint.
  - Perfective Maint.

- Correction of last Version
  - Hardly predictable
  - Corrective Maintenance

- Maintenance Management

- Overhead Costs relative to Operational Costs
Calculating Maintenance Project Costs

Calculation of Maintenance Project Costs requires combining several different costs.

Maintenance Project Costs = Costs of Development of the new Version + Costs of Correction of the last Version + Costs of Maintenance Management

Costs of new Version are computed based on the size of the added functions and data.

Costs of correction are based on the number of errors to correct.
Estimating Correction Costs

1. Counting of Error Reports so far
   - Version_1 = 16 Error Reports
   - Version_2 = 12 Error Reports

2. Calculating Efforts of Error Correction so far
   - Version_1 = 30 Person Days = 1.4 PD per Error
   - Version_2 = 20 Person Days = 1.6 PD per Error

3. Estimation of Error Reports for the next Version
   - Version_3 = Number of Errors

4. Estimation of Error Correction Efforts for the next Version
   - Version_3 = ? Person Days = PD per Error x Number of Errors
Calculating Error Correction Effort

- Effort per Error so far
- Size of last Version in Lines of Code or Statements or Function Points or Data Points or Object Points
- Complexity of last Version in Interface Complexity, Control Flow Complexity, Condition Complexity, Inheritance Complexity, Data Flow Complexity, Language Complexity etc.
- Quality of last Version in Modularity, Flexibility, Testability, Conformity etc.
- Size, Complexity and Quality of current Version
Estimating Effort for Error Correction

**Estimation of Effort for Error Correction**

Effort per Error so far = 1.6 PD

Differences between the last and the current Version

<table>
<thead>
<tr>
<th>Version</th>
<th>Size</th>
<th>x Complexity</th>
<th>adjusted Size</th>
<th>x Quality</th>
<th>adjusted Size</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Last:</td>
<td>20,000</td>
<td>0.7</td>
<td>29,000</td>
<td>0.6</td>
<td>22,400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.7/0.5</td>
<td>= 1.4</td>
<td>0.5/0.6</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current:</td>
<td>22,000</td>
<td>0.75</td>
<td>33,000</td>
<td>0.55</td>
<td>29,700</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.75/0.5</td>
<td>= 1.5</td>
<td>0.5/0.55</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff:</td>
<td>2,000</td>
<td>0.05</td>
<td>5,000</td>
<td>0.05</td>
<td>7,300</td>
<td>= 1.3</td>
</tr>
</tbody>
</table>

Effort per Error = 1.6 x 1.3 = 2.0 PD per Error Correction
## Projecting the Number of Errors

### Estimation of Number of Errors

<table>
<thead>
<tr>
<th>Last Error Number</th>
<th>= 52</th>
</tr>
</thead>
<tbody>
<tr>
<td>Last System Size</td>
<td>= 20,000</td>
</tr>
<tr>
<td>Last Error Density</td>
<td>= (52 / 20,000 = 0.0026)</td>
</tr>
<tr>
<td>Last Test Coverage</td>
<td>= 0.82</td>
</tr>
<tr>
<td>Last uncovered Portion</td>
<td>= (20,000 \times (1.00 - 0.82) = 3,600)</td>
</tr>
<tr>
<td>Last uncovered Error Density per uncovered Portion</td>
<td>= (3,600 / 52 = 69) [1 pro 69]</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Current System Size</td>
<td>= 22,000</td>
</tr>
<tr>
<td>Current Test Coverage</td>
<td>= 0.85</td>
</tr>
<tr>
<td>Current uncovered Portion</td>
<td>= (22,000 \times (1.00 - 0.85) = 3,300)</td>
</tr>
<tr>
<td>Estimated Number of Errors</td>
<td>= (3300 / 69 = 48)</td>
</tr>
<tr>
<td>Estimated Error Density</td>
<td>= (48 / 22,000 = 0.0022)</td>
</tr>
</tbody>
</table>
Estimating Error Correction Costs

<table>
<thead>
<tr>
<th>Version</th>
<th>Size</th>
<th>Coverage</th>
<th>Effort per Error</th>
<th>Error</th>
<th>Effort over all</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version_1</td>
<td>17,000</td>
<td>0.75</td>
<td>1.4</td>
<td>56</td>
<td>78.4</td>
</tr>
<tr>
<td>Version_2</td>
<td>20,000</td>
<td>0.82</td>
<td>1.6</td>
<td>52</td>
<td>83.2</td>
</tr>
<tr>
<td>Version_3</td>
<td>22,000</td>
<td>0.85</td>
<td>2.0</td>
<td>48</td>
<td>96.0</td>
</tr>
</tbody>
</table>

Version_3 = (22,000 x (1 - 0.85) / 69) = 48 x 2 = 96

Correction Effort = 96 Person Days
Estimating Evolution Costs

1. Measure Size, Complexity and Quality of the last Version
   \[ \text{Justified Size} = \text{Bare Size} \times \text{Complexity} \times \text{Quality} \]

   (Enhancements, Adaptations, Perfections)
   \[ \% \text{ Change} = \% \text{ Enhancement} + \% \text{ Adaptation} + \% \text{ Perfection} \]

3. Measure Productivity so far
   \[ \text{Productivity} = \frac{\text{Adjusted Impact Area}}{\text{Person Days}} \]

4. Estimate Effort for new Version
   \[ \text{Version}_4 = \frac{\text{Person Days}}{\text{Productivity}} = \frac{\text{Change Portion}}{\text{Productivity}} \]
Measuring the System Size

Lines of Code = Lines over all – Comment Lines – Empty Lines

Statements = Declarations + Procedural Statements

Data Points = Data Entities x 8 (Tables, Structures, Classes) + Data Keys x 4 + Data Relations x 2 + Data Attributes x 1

Object Points = Classes x 4 + Methods x 3 + Associations x 2 + Variables x 1

Function Points = Inputs x (3:6) + Outputs x (4:7) + Interfaces x (5:10) + Data Entities x (7:15)
Adjusting System Size through Complexity

Complexity = Median of Data Complexity (0.720)
Data Flow Complexity (0.760)
Interface Complexity (0.920)
Control Flow Complexity (0.600)
Condition Complexity (0.480)
Branching Complexity (0.640)
Language Complexity (0.780)

Complexity Factor = Complexity / Median Complexity
(1.4) = (0.7) / (0.5)

Adjusted Size = Raw Size x Complexity Factor
(28.000) x (20.000) x (1.4)
Adjusting System Size through Quality

Quality = Median of
- Maintainability (0.500)
- Testability (0.600)
- Reusability (0.420)
- Conformity (0.720)
- Modularity (0.640)
- Flexibility (0.560)
- Readability (0.800)
- Portability (0.480)

Quality Factor = Median Quality / Quality
= (0.5) / (0.6) = 0.83

Justified Size = Bare Size x Quality Factor
= (22.400) x (0.8) = 28.000
### Specification based Change Request Cost Estimation

<table>
<thead>
<tr>
<th>Product</th>
<th>GEOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>NOSTRO</td>
</tr>
<tr>
<td>Project</td>
<td>Harry</td>
</tr>
<tr>
<td>Repository</td>
<td>d:\tools\maintain\softanal\cmfanal\output\METRICS</td>
</tr>
</tbody>
</table>

**Change Adjusted Monthly Person**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Quantity</th>
<th>Rate</th>
<th>Complexity</th>
<th>Quality</th>
<th>Quantity</th>
<th>Product</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stmnts</td>
<td>1680</td>
<td>0.500</td>
<td>1.528</td>
<td>0.917</td>
<td>1176</td>
<td>480</td>
<td>2.45</td>
</tr>
<tr>
<td>Dat_Pt</td>
<td>773</td>
<td>0.500</td>
<td>1.528</td>
<td>0.917</td>
<td>541</td>
<td>152</td>
<td>3.56</td>
</tr>
<tr>
<td>Obj_Pt</td>
<td>1116</td>
<td>0.500</td>
<td>1.528</td>
<td>0.917</td>
<td>781</td>
<td>152</td>
<td>5.14</td>
</tr>
<tr>
<td>Fct_Pt</td>
<td>161</td>
<td>0.500</td>
<td>1.528</td>
<td>0.917</td>
<td>112</td>
<td>36</td>
<td>3.13</td>
</tr>
<tr>
<td>Median</td>
<td>0</td>
<td>0.500</td>
<td>1.528</td>
<td>0.917</td>
<td>0</td>
<td>0</td>
<td>3.57</td>
</tr>
</tbody>
</table>
### Code based Change Request Cost Estimation

<table>
<thead>
<tr>
<th>Change</th>
<th>Adjusted Monthly Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Quantity</td>
</tr>
<tr>
<td>Stmnts:</td>
<td>333 X 0.500 X 1.028 X 0.595 = 101 / 500 = 0.20</td>
</tr>
<tr>
<td>Dat_Pt:</td>
<td>65 X 0.500 X 1.028 X 0.595 = 19 / 150 = 0.13</td>
</tr>
<tr>
<td>Obj_Pt:</td>
<td>425 X 0.500 X 1.028 X 0.595 = 129 / 140 = 0.93</td>
</tr>
<tr>
<td>Fct_Pt:</td>
<td>108 X 0.500 X 1.028 X 0.595 = 33 / 32 = 1.03</td>
</tr>
<tr>
<td>Median:</td>
<td>0 X 0.500 X 1.028 X 0.595 = 0 / 00 = 0.57</td>
</tr>
</tbody>
</table>

**Product:** GEOS  
**System:** NOSTRO  
**Project:** CR2  
**Repository:** d:\maintain\softrepo\tables  
**Date:** 11.09.01
Measuring previous Productivity

Measurement of previous Productivity

Adjusted Size of Version\(i\) = 22,400  
Impact Domain of Version\(i\) = 0.15  
Change Portion of Version\(i\) = 3,360  
Effort over all of Version\(i\) = 360 Person Days  
Productivity\(i\) = \(\frac{\text{Change Portion}(i)}{\text{Effort}(i)}\)  
9.3 Stmts per PT = \(\frac{3,360}{360}\)  
Productivity so far = Average (Version 1:n)  
that means 10 Productivity Units per Person Day
Impact Analysis of new Requirements

<table>
<thead>
<tr>
<th>Type of Impact</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhancement Impact</td>
<td>(Enhancement_1 = 0.030) + (Enhancement_2 = 0.010) + (Enhancement_3 = 0.020)</td>
</tr>
<tr>
<td>Change Impact</td>
<td>(Change_1 = 0.005) + (Change_2 = 0.005) + (Change_3 = 0.010)</td>
</tr>
<tr>
<td>Perfection Impact</td>
<td>(Perfection_1 = 0.008) + (Perfection_2 = 0.012)</td>
</tr>
<tr>
<td>Impact over all</td>
<td>Enhancement Impact(0.06) + Change Impact (0.02) + Perfection Impact (0.02)</td>
</tr>
</tbody>
</table>
Estimating Evolution Costs of the new Version

Change Proportion = 10% von 22,400 = 2,240 Productivity units
Productivity so far = 10 pro Person Days
New Effort = Change Proportion / Productivity so far
New Effort = (2,240 / 10)
New Effort = 224 Person Days
**Costs of Software Maintenance Management**

Two Levels of Software Maintenance

Management Overhead = 1/3 of operational costs

- Maintenance Process (administrative)
- Planning, Organization and Controlling of Maintenance Tasks

old Version

- Performance of Maintenance Tasks

new Version

new Measures
Estimating Management Overhead Costs

According to the Experience in the Maintenance Process:

Management = 33% of the Over All Effort

Execution Effort = Correction Effort + Evolution Effort
= (96 PD’s) + (224 PD’s) = 320 PD’s

Management Costs = Execution Effort x 0.5
= (320) x 0.5 = 160 PD’s
Calculating Overall Maintenance Costs

Calculation of Overall Maintenance & Evolution Costs

Over All Maintenance Effort = Correction Effort + Evolution Effort + Management Costs

<table>
<thead>
<tr>
<th>Effort</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correction Effort</td>
<td>96 Person Days</td>
</tr>
<tr>
<td>Evolution Effort</td>
<td>224 Person Days</td>
</tr>
<tr>
<td>Management Costs</td>
<td>160 Person Days</td>
</tr>
<tr>
<td>Over All Effort</td>
<td>480 Person Days</td>
</tr>
</tbody>
</table>

Costs per Person Day = Euro 750
Costs of Maintenance Project = Euro 360 000
(Next Pass through the Life Cycle)