USC Center for Software Engineering

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USC-CSE Seven Step Modeling Methodology

1. Analyze Existing Literature
2. Perform Behavioral Analysis
3. Identify Relative Significance
4. A-PRIORI MODEL + SAMPLING DATA = A-POSTERIORI MODEL
5. Perform Expert-Judgment, Delphi Assessment
6. Gather Project Data
7. Determine Bayesian A-Posteriori Update
8. Gather more data; refine model
### COTS Advantages and Disadvantages

**Advantages**
- Available now; earlier payback
- Avoids expensive development & maintenance
- Predictable license costs & performance
- Rich in functionality
- Broadly used, mature technology
- Frequent upgrades often anticipate organization’s needs
- Dedicated support organization
- Hardware/software independence
- Tracks technology trends

**Disadvantages**
- Licensing and intellectual property procurement delays
- Up front license fees
- Recurring maintenance fees
- Reliability often unknown/inadequate; scale often difficult to change
- Unnecessary features compromise usability, performance
- Functionality, efficiency constraints
- No control over upgrades/maintenance
- Dependency on vendor
- Efficiency sacrifices
- Integration not always trivial; incompatibilities among vendors
- Synchronizing multiple-vendor upgrades
COTS Definition

• “Commercial Off the Shelf” Software
• Commercial Software Products
  – sold, leased, licensed at advertised prices
• Source Code Unavailable
  – generally an application program interface (API)
  – frequently tailoring options
• Usually periodic releases with feature growth, obsolescence
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COTS Integration Sources of Effort

1) COTS Assessment
   Of functionality, performance, interoperability, etc.
   (pre- and post- commitment)
2) COTS Tailoring and Tuning
   Effects of platform, other COTS products
   - includes added Application V&V (System) Effort
3) Glue Code Development
   Similar to other COCOMO II software effort estimation
   - also includes added Application V&V (System) Effort
4) Application Volatility Due to COTS
   COTS volatility, shortfalls, learning curve
COCOMO vs. COCOTS Cost Sources
(COTS in System)

- LCO (reqs review)
- LCA (PDR)
- IOC

Application Code Development Integration and Test Separate from COTS Effects

- LCO - Life Cycle Objectives
- LCA - Life Cycle Architecture
- IOC - Initial Operational Capability

COCOMO Effort Estimate
COCOTS Effort Estimate Components

Beta Test, Field Test

TIME

STAFFING
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**COTS Integration Cost Sources:**

3) **Glue Code Development and Test - Glue Code Cost Drivers**

**Personnel Drivers**

1) ACIEP - COTS Integrator Experience with Product
2) ACIPC - COTS Integrator Personnel Capability
3) AXCIP - Integrator Experience with COTS Integration Processes
4) APCON - Integrator Personnel Continuity

**COTS Component Drivers**

5) ACPMT - COTS Product Maturity
6) ACSEW - COTS Supplier Product Extension Willingness
7) APCPX - COTS Product Interface Complexity
8) ACPPS - COTS Supplier Product Support
9) ACPTD - COTS Supplier Provided Training and Documentation

**Application/System Drivers**

10) ACREL - Constraints on Application System/Subsystem Reliability
11) AACPX - Application Interface Complexity
12) ACPER - Constraints on COTS Technical Performance
13) ASPRT - Application System Portability

**Nonlinear Scale Factor**

1) AAREN - Application Architectural Engineering
**COTS Integration Cost Sources:**

3) **Glue Code Development and Test - Glue Code Cost Drivers**

8.1 ACIEP - COTS/NDI Integrator Experience with Product

How much experience did/does the development staff have with running, integrating, and maintaining the COTS/NDI products?

*Metric: months/years of experience with product.*

**UNKNOWN**

<table>
<thead>
<tr>
<th>y Low</th>
<th>Low</th>
<th>Nominal</th>
<th>High</th>
<th>Very High</th>
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<td>average has no experience with the products.</td>
<td>Staff on average has less than 6 month’s experience with the products.</td>
<td>Staff on average has between 6 month’s and 1 year’s experience with the products.</td>
<td>Staff on average has between 1 and 2 years’ experience with the products.</td>
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<table>
<thead>
<tr>
<th>VL</th>
<th>L</th>
<th>N</th>
<th>H</th>
<th>VH</th>
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</table>

Explain rationale for your rating:
COTS Integration Cost Sources:
3) Glue Code Development and Test

Total Effort = \( A \cdot [(\text{size})(1+\text{breakage})]^B \cdot \prod \) (effort multipliers)

- \( A \) - a linear scaling constant
- \( \text{Size} \) - of the glue code in SLOC or FP
- \( \text{Breakage} \) - of the glue code due to change in requirements and/or COTS volatility
- \( \text{Effort Multipliers} \) - 13 parameters, each with settings ranging VL to VH
- \( B \) - an architectural scale factor with settings VL to VH
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## Delphi Results

### FAA Delphi Round 2 Results

9/1997 (n=7)

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<th>ACIEP</th>
<th>ACIPC</th>
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| mean | 1.77  | 2.63  | 1.65  | 2.45  | 2.05  | 1.35  | 2.20  | 1.78  | 1.50  | 2.08  | 1.69  | 2.07  | 1.57  | 1.43  |
| median | 1.80  | 2.57  | 1.60  | 2.50  | 2.10  | 1.30  | 2.20  | 1.70  | 1.43  | 2.00  | 1.70  | 2.02  | 1.50  | 1.30  |
| mode  | 1.80  | 2.53  | 1.60  | 2.50  | 2.05  | 1.30  | 2.02  | 1.70  | 1.43  | 2.00  | 1.58  | 2.02  | 1.50  | 1.30  |
| range | 1.50-1.90 | 2.53-2.80 | 1.50-2.00 | 1.80-2.75 | 1.80-2.30 | 1.20-1.55 | 2.02-2.57 | 1.70-2.20 | 1.40-1.75 | 1.75-2.50 | 1.58-1.85 | 1.70-2.30 | 1.50-1.77 | 1.30-2.00 |
Delphi Results (cont’d)

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<td>2.07</td>
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<td>1.43</td>
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<td>1.58-1.85</td>
<td>1.70-2.30</td>
<td>1.50-1.77</td>
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</tbody>
</table>

CA 6/25/99
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### Experience with Library Projects

#### Raw Effort Data

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
<th>Total Pers-hrs</th>
<th>% Total Pers-hrs</th>
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<td><strong>General Activity</strong></td>
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<tr>
<td>Determine Requirements:</td>
<td>16.00</td>
<td>49.50</td>
<td>86.50</td>
<td>26.50</td>
<td>5.50</td>
<td>38.50</td>
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<td><strong>COTS Related Activity</strong></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Understand and qualify COTS:</td>
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<td>98.50</td>
<td>10.00</td>
<td>61.00</td>
<td>19.50</td>
<td>197.00</td>
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</tr>
<tr>
<td>Design COTS glue code:</td>
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<td>7.50</td>
<td>0.00</td>
<td>0.30</td>
<td>9.00</td>
<td>16.80</td>
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<td>16.80</td>
<td>30.50</td>
<td>51.30</td>
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<td>477.60</td>
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Table VIII.1- Effort hours by activity for graduate software engineering class projects incorporating COTS products.

**Key:**
- Group 1 - EDGAR Corporate Data
- Group 2 - Medieval Manuscripts
- Group 3 - Technical Reports
- Group 4 - Latin American Pamphlets
- Group 5 - CNTV Moving Image Archive
- Group 6 - Hancock Photo Archive
# Experiences with Library Project Data

## Initial Model

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<tr>
<th>Project</th>
<th>A</th>
<th>Size</th>
<th>B</th>
<th>xEAFs</th>
<th>Estimate (P-hr)</th>
<th>Actual (P-hr)</th>
<th>Relative Error</th>
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<td>3</td>
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<td>12</td>
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<td>8.16</td>
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<td>1.00</td>
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<td>4.35</td>
<td>13.05</td>
<td>14.54</td>
<td>10%</td>
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</table>

\[ A = 1.00 \Rightarrow \text{one UFP/P-hr} \]
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Experiences with Library Project Data
Revised Glue Code Submodel

<table>
<thead>
<tr>
<th>Project</th>
<th>A</th>
<th>Size (SLOC)</th>
<th>B</th>
<th>xEAFs</th>
<th>Estimate (P-hr)</th>
<th>Actual (P-hr)</th>
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<th>Original Error</th>
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<td>-87%</td>
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<td>48.38</td>
<td>39.50</td>
<td>22%</td>
<td>10%</td>
</tr>
</tbody>
</table>

A = .009 => 111 SLOC/P-hr
COTS Integration Cost Sources:

1) Assessment

Initial Filtering Effort

Total Effort = \( \left( \# \text{ COTS Candidates} \right) \left( \frac{\text{Average Filtering Effort}}{\text{Candidate}} \right) \)

Final Selection Effort

Total Effort = \( \sum \left( \# \text{ COTS Candidates} \right) \left( \frac{\text{Average Assessment Effort}}{\text{Candidate}} \right) \)

- List of attributes refined in collaboration with Dr. Elizabeth Bailey
- Effort/candidate is project-dependent, within domain guidelines
## COTS Integration Cost Sources:
### 1) Assessment - Assessment Attributes

<table>
<thead>
<tr>
<th>Correctness</th>
<th>Understandability</th>
<th>Portability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>Documentation quality</td>
<td>Portability</td>
</tr>
<tr>
<td>Correctness</td>
<td>Simplicity</td>
<td></td>
</tr>
<tr>
<td>Testability</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Availability/Robustness</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td>Functionality</td>
</tr>
<tr>
<td>Fail safe</td>
<td>Ease of use</td>
</tr>
<tr>
<td>Fail soft</td>
<td>Usability/Human Factors</td>
</tr>
<tr>
<td>Fault tolerance</td>
<td>Version Compatibility</td>
</tr>
<tr>
<td>Input error tolerance</td>
<td>Downward compatibility</td>
</tr>
<tr>
<td>Redundancy</td>
<td>Upward compatibility</td>
</tr>
<tr>
<td>Reliability</td>
<td>Maturity</td>
</tr>
<tr>
<td>Robustness</td>
<td>Product Maturity</td>
</tr>
<tr>
<td>Safety</td>
<td>Inter-component Compatibility</td>
</tr>
<tr>
<td></td>
<td>Vendor Maturity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Security</th>
<th>Flexibility</th>
<th>Extendability</th>
<th>Warranty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security (Access related)</td>
<td>Flexibility</td>
<td>Extendability</td>
<td>Vendor Support</td>
</tr>
<tr>
<td>Security (sabotage related)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product Performance</th>
<th>User Training</th>
<th>User training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Execution performance</td>
<td>Installation/Upgrade Ease</td>
<td>User training</td>
</tr>
<tr>
<td>Information/data capacity</td>
<td>Installation Ease</td>
<td></td>
</tr>
<tr>
<td>Precision</td>
<td>Upgrade/Refresh ease</td>
<td>Vendor Concessions</td>
</tr>
<tr>
<td>Memory performance</td>
<td></td>
<td>Willingness to escrow source code</td>
</tr>
<tr>
<td>Response time</td>
<td></td>
<td>Willingness to make modifications</td>
</tr>
<tr>
<td>Throughput</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Two Models, Differing Fidelity in Development
(Parallels COCOMO II modeling)

Early Design COCOTS model

- roll up of parameters in Assessment, Glue code submodels into fewer, more aggregated factors; inclusion of only the approximate Volatility model.

- less fidelity but requires fewer data points to calibrate.

- intended for more “what if” kind of estimating, earlier in the development process.

Post-architecture COCOTS model

- the full model with all parameters
COTS Integration Cost Sources:

2) Tailoring

\[
\text{Total Effort} = \sum_{\text{Tailoring Complexity Levels}} \left( \frac{\# \text{ COTS Candidates Tailored at Complexity Level } i}{\text{Average Effort at Tailoring Complexity Level in Domain } i} \right)
\]

-Five tailoring effort complexity levels:

- Very Low, Low, Nominal, High, Very High

Differentiated based on number tailored parameters, difficulty of needed scripts, API iterations, etc.
### COTS Integration Cost Sources:

#### 2) Tailoring - Dimensions of Tailoring Difficulty

<table>
<thead>
<tr>
<th>Tailoring Activities &amp; Aids</th>
<th>Very Low (point value = 1)</th>
<th>Low (point value = 2)</th>
<th>Nominal (point value = 3)</th>
<th>High (point value = 4)</th>
<th>Very High (point value = 5)</th>
<th>Corresponding Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameter Specification</strong></td>
<td>Zero to 50 parms to be initialized.</td>
<td>51 to 100 parms to be initialized.</td>
<td>101 to 500 parms to be initialized.</td>
<td>501 to 1000 parms to be initialized.</td>
<td>1001 or more parms to be initialized.</td>
<td>________</td>
</tr>
<tr>
<td><strong>Script Writing</strong></td>
<td>Menu driven; 1 to 5 line scripts; 1 to 5 scripts needed.</td>
<td>Menu driven; 6 to 10 line scripts; 6 to 15 scripts needed.</td>
<td>Hand written; 11 to 25 line scripts; 16 to 30 scripts needed.</td>
<td>Hand written; 26 to 50 line scripts; 31 to 50 scripts needed.</td>
<td>Hand written; 51 or more line scripts; 51 or more scripts needed.</td>
<td>________</td>
</tr>
<tr>
<td><strong>I/O Report &amp; GUI Screen Specification &amp; Layout</strong></td>
<td>Automated or standard templates used; 1 to 5 reports/screens needed.</td>
<td>Automated or standard templates used; 6 to 15 reports/screens needed.</td>
<td>Automated or standard templates used; 16 to 25 reports/screens needed.</td>
<td>Hand written or custom designed; 26 to 50 reports/screens needed.</td>
<td>Hand written or custom designed; 51 or more reports/screens needed.</td>
<td>________</td>
</tr>
<tr>
<td><strong>Security/Access Protocol Initialization &amp; Set-up</strong></td>
<td>1 security level; 1 to 20 user profiles; 1 input screen/user.</td>
<td>2 security levels 21 to 50 user profiles; 2 input screens/user.</td>
<td>3 security levels 51 to 75 user profiles; 3 input screens/user.</td>
<td>4 security levels 76 to 100 user profiles; 4 input screens/user.</td>
<td>5 or more security levels 101 or more user profiles; 5 or more input screens/user.</td>
<td>________</td>
</tr>
<tr>
<td><strong>Availability of COTS Tailoring Tools</strong></td>
<td>No tools available.</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Tools are available.</td>
<td>________</td>
</tr>
</tbody>
</table>

**Total Point Score = ________**
COTS Integration Cost Sources:
4) Increased Application Effort Due to COTS Volatility

Approximate Model:

Total Effort = (Application Effort) • \left[ \frac{\text{BRAK COTS}}{100} \right] • (\text{EAF})^\text{COTS}

Detailed Model with COCOMO II Parameters:

Total Effort = (Application Effort) • \left[ \left( \frac{1 + \frac{\text{BRAK COTS}}{1+\text{BRAK}}}{1 + \frac{\Sigma}{1+\text{BRAK}}} \right)^{1.01 + \Sigma} - 1 \right] • (\text{EAF})^\text{COTS}

BRAK COTS: \% application code breakage due to COTS volatility
BRAK : \% application code breakage otherwise
\Sigma : COCOMO II scale factor
EAF : Effort Adjustment Factor (product of effort multipliers)
### COTS Integration Cost Sources:
#### 4) Increased Application Effort Due to COTS Volatility
- **COCOMO II Scale Factors**

<table>
<thead>
<tr>
<th>Scale Factor</th>
<th>Very Low</th>
<th>Low</th>
<th>Nominal</th>
<th>High</th>
<th>Very High</th>
<th>Extra High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Precedentedness</strong></td>
<td>thoroughly unprecedented</td>
<td>Largely unprecedented</td>
<td>somewhat unprecedented</td>
<td>generally familiar</td>
<td>largely familiar</td>
<td>thoroughly familiar</td>
</tr>
<tr>
<td><strong>Development Flexibility</strong></td>
<td>rigorous</td>
<td>Occasional Relaxation</td>
<td>some relaxation</td>
<td>general conformity</td>
<td>some conformity</td>
<td>general goals</td>
</tr>
<tr>
<td><strong>Architecture/Risk Resolution</strong></td>
<td>little (20%)</td>
<td>some (40%)</td>
<td>often (60%)</td>
<td>generally (75%)</td>
<td>mostly (90%)</td>
<td>full (100%)</td>
</tr>
<tr>
<td><strong>Team Cohesion</strong></td>
<td>some difficult interactions</td>
<td>Basically cooperative interactions</td>
<td>largely cooperative</td>
<td>highly cooperative</td>
<td>seamless interactions</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Process Maturity</strong></td>
<td>Chaos</td>
<td>CMM Level 1</td>
<td>CMM Level 2</td>
<td>CMM Level 3</td>
<td>CMM Level 4</td>
<td>CMM Level 5</td>
</tr>
</tbody>
</table>

*percentage of module interfaces specified, percentage of significant risks eliminated.*
Total COTS Integration Cost Estimate

Total Integration Effort (in Person-Months) = 
Assessment Effort + Tailoring Effort + Glue Code Effort + Volatility Effort

where
Assessment Effort = Filtering Effort + Final Selection Effort

Total integration Cost = 
(Total Integration Effort) • ($$/Person-Month)
USC-CSE Seven Step Modeling Methodology

1. Analyze Existing literature
2. Perform Behavioral Analysis
3. Identify Relative Significance
4. Perform Expert-Judgment, Delphi Assessment
5. Gather Project Data
6. Determine Bayesian A-Posteriori Update
7. Gather more data; refine model

A-PRIORI MODEL + SAMPLING DATA = A-POSTERIORI MODEL
Calibration Data Collection Status

• 6 Student Digital Library Projects
  – 4 more by end Spring ‘99 semester

• 16 Industrial Projects
  – FAA & aerospace contractors
  – 4+ additional projects anticipated by mid ‘99
  – will allow calibration of Early Design version

• Other Sources Being Explored
  – NASA, DoD, Commercial, foreign
  – USC-CSE Affiliates, professional conferences
Immediate COCOTS Follow-ons

• Modeling of schedule estimation & activity distribution
• Complete COTS software lifecycle modeling
• Integration with COCOMO II estimation model
• More extensive tool implementation
In Conclusion: COCOTS’ Most Important Aspect

- COCOTS is completely open:
  - highlights most important factors of concern in using COTS s/w.

- COCOTS is a "constructive" cost model:
  - helps understand the complexities of a given software job.
  - Shows exactly why it gives the estimates it does.