Apr 28th, 8:00 AM

Technical Paper Session II - Fast Conceptual Cost Estimating of Aerospace Projects Using Historical Information

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"FAST CONCEPTUAL COST ESTIMATING AEROSPACE PROJECTS USING HISTORICAL INFORMATION"

GLENN BUTTS

TECHNICAL PAPER
SESSION 2

SPACE VISIONS CONGRESS 2007
Fast Conceptual Cost Estimating of Aerospace Projects Using Historical Information

Accurate estimates can be quickly by applying powerful techniques and algorithms to create an Excel-based parametric cost model. In five easy steps you will learn how to normalize your company’s historical cost data to the new project parameters. This paper provides a complete, easy-to-understand, step by step how-to guide. Such a guide does not seem to currently exist.

Over 2,000 hours of research, data collection, and trial and error, and thousands of lines of Excel Visual Basic Application (VBA) code were invested in developing these methods. While VBA is not required to use this information, it increases the power and aesthetics of the model. Implementing all of the steps described, while not required, will increase the accuracy of the results.
Conceptual Estimating in Excel Using Historical Data

Accurate Estimates In Less Than A Minute

GLENN BUTTS
KSC NASA
CCC, CGC, CMC, CPC

Estimate Time Required for Typical $2M Building

Time is Money

If Plans Available

Estimate Accuracy

0 20 40 60 80 100 120

Hours

0 4% 6% 8% 10% 12% 14% 16% 18% 20%

- 10 - Minutes
- 1 - Hour
- 3 - Days
- 3 - Weeks
Time is Money

- Accurate estimates are essential
  - But only limited time given to prepare them

- This method is great for
  - Initial Budgets
  - “What If”
  - “How Much”

- Works on many types of projects
- Customizable to your requirements

What is the **LEAST** I can Build a New Office For?

- What the Customer Envisions
- What the Estimator Envisions
What is the LEAST I can Build a New Office For?

<table>
<thead>
<tr>
<th>Project Size</th>
<th>Unit Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>189,000 SF</td>
<td>$189,000</td>
</tr>
<tr>
<td>18,900 SF</td>
<td>$347,400</td>
</tr>
<tr>
<td>1,440 SF</td>
<td>$491,880</td>
</tr>
</tbody>
</table>

170% Difference

Basic Concept

- Historical data is adjusted and used to estimate new projects
- Data is
  - Collected
  - Filtered
  - Normalized
  - Averaged
  - Adjusted for specific project
# Data Collection

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Use</th>
<th>Scope</th>
<th>Type</th>
<th>Project Title</th>
<th>Unit Cost</th>
<th>UNR</th>
<th>Bid Date</th>
<th>Original Size</th>
<th>No. of Bids</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Processing</td>
<td>New</td>
<td>Platform</td>
<td>PCR Melodyb Unit (10.5 Tons structural steel) class 10,000 clean room located on the</td>
<td>1448.18 SF</td>
<td></td>
<td>Apr-77</td>
<td>10,000</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Specialty</td>
<td>New</td>
<td>Steel</td>
<td>MLP Tall Service Masts</td>
<td>515.96 SF</td>
<td></td>
<td>May-77</td>
<td>5,000</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Office</td>
<td>New</td>
<td>Steel</td>
<td>Fire Protection/Operative Support Building Bldg 270U 30 Heads</td>
<td>44 SF</td>
<td></td>
<td>Apr-77</td>
<td>4,000</td>
<td>8</td>
</tr>
<tr>
<td>11</td>
<td>Specialty</td>
<td>New</td>
<td>Crane</td>
<td>MLP Make/Design St/Long Crane S1 10 W Tonne 100 H</td>
<td>2607.50 Ton</td>
<td></td>
<td>Jan-77</td>
<td>50 00</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>Shop</td>
<td>New</td>
<td>Portal</td>
<td>Operational Support Building Tech. Support Bldg 9x11 SF metal bldg</td>
<td>9.56 SF</td>
<td></td>
<td>Aug-77</td>
<td>10,000</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>Utility</td>
<td>Mod</td>
<td>Pipeline</td>
<td>Operational Support Building Tech. Support Bldg 11x14 SF total Project</td>
<td>86.52 SF</td>
<td></td>
<td>May-77</td>
<td>10,000</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>Processing</td>
<td>R&amp;R Form</td>
<td>Roof</td>
<td>Building Costs in Phase 1</td>
<td>1180.50 EA</td>
<td></td>
<td>Max-76</td>
<td>32 37</td>
<td>7</td>
</tr>
<tr>
<td>15</td>
<td>Specialty</td>
<td>New</td>
<td>Steel</td>
<td>High Purity Oxygen Facility, LC-36</td>
<td>119.25 SF</td>
<td></td>
<td>Apr-76</td>
<td>1,295</td>
<td>7</td>
</tr>
<tr>
<td>16</td>
<td>Specialty</td>
<td>Mod</td>
<td>Clean-Room</td>
<td>High Bay Shuttle Payload Vertical Processing Facility (VPF) building addition</td>
<td>155.96 SF</td>
<td></td>
<td>Apr-77</td>
<td>20,000</td>
<td>5</td>
</tr>
<tr>
<td>17</td>
<td>Specialty</td>
<td>Mod</td>
<td>Elect</td>
<td>Utility MLP R Trimmer and Cutting, BLAST Ductal-System Host &amp; Sound Suppression</td>
<td>96.17 SF</td>
<td></td>
<td>May-77</td>
<td>21,014</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>Specialty</td>
<td>Mod</td>
<td>Elect</td>
<td>Utility MLP R Trimmer and Cutting, BLAST Ductal L&amp;M Summary</td>
<td>96.17 SF</td>
<td></td>
<td>May-77</td>
<td>21,014</td>
<td>5</td>
</tr>
<tr>
<td>19</td>
<td>Specialty</td>
<td>Mod</td>
<td>Elect</td>
<td>NIC, Summary</td>
<td>96.17 SF</td>
<td></td>
<td>May-77</td>
<td>21,014</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>Specialty</td>
<td>Mod</td>
<td>LC</td>
<td>LC 3”x 7” Hitch Mounted, Install 3000.00 Gal Water Tank, Water Pit, Sound Suppression,</td>
<td>4864.00 Ton</td>
<td></td>
<td>Jun-78</td>
<td>3,450</td>
<td>6</td>
</tr>
<tr>
<td>21</td>
<td>Specialty</td>
<td>New</td>
<td>Steel</td>
<td>PEMB Facility News Facility Bld 12R</td>
<td>38.88 SF</td>
<td></td>
<td>Mar-78</td>
<td>6,000</td>
<td>5</td>
</tr>
<tr>
<td>22</td>
<td>Office</td>
<td>Addition</td>
<td>Steel</td>
<td>PEMB Office Facilities for Security Patrol 19H</td>
<td>48.08 SF</td>
<td></td>
<td>Mar-78</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

## Filter Methods

- **Manual**
  - Slow
- **Excel Data Filter**
  - Easiest
- **VBA – Filter Copy**
  - Much more Powerful

  - Sub Copy_Filter()  
  - Action:=xlFilterCopy, _  
  - CriteriaRange:=Range("A13:AR14"),  
  - CopyToRange:=Range("A17:AR17"), Unique:=False  
  - End Sub

Filter = Hide unwanted data
Formulas

• Formulas are in Excel format
  – * = multiplication
  – / = division
  – ^ = exponent

Number of Bidders

• Adjust costs for the number of bidders
  – Corrects for market conditions
• Algorithm from historical bid data

  • Note: Bids by a 8(a) Set Aside, or HUBZone can result in higher costs than corrected for by algorithm
Number of Bidders

- Algorithm
  - $Y = 0.74 \times \text{number of bidders}^{0.14}$
    - $Y$ = percentage adjustment required for project

- Example
  - Project with two bidders, $126.50$ per SF:
    - $0.74 \times 2^{0.14} = 81.5\%$
    - $81.5\% \times 126.50 = 103.10$ per SF

Important Note:
This is data is based on bid prices, this effect may be dampened if used on final costs. Contractors may try harder to find change orders.

During periods of intense competition, companies may bid work at, or below cost, therefore the correct cost is higher than the bid price.

During periods of limited competition, (after hurricanes, etc) companies have more work than they can do. So they don’t sharpen their pencil, or even add a percentage to the estimate, therefore the correct cost is lower than the bid price.
Economies of Scale

- Small projects have higher unit costs than large projects
  - \( Y = 1.010001 \times \left( \frac{\text{new project size}}{\text{historical project size}} \right)^{-0.101} \)
    - Projects under 3,000 SF require additional adjustment, see paper for details
  - Example
    - Historical project 30,000 SF, New project 50,000 SF
      - $103.10 per SF Cost from Step 1
      - \( 1.010001 \times \left( \frac{50,000}{30,000} \right)^{-0.101} = .959 \)
      - .959 \times $103.10 per SF = $98.87 per SF

Important Note:
This is data is based on KBC Data, for a limited range of projects, formula may require adjustment for other projects.
Escalation

• Data must be escalated
• Excel VLookup function used
  =VLOOKUP($I$5,C2:C6,2,FALSE)-1
• Cost indexes used for escalation (averaged)
  – ENR – BCI
  – ENR – CCI
  – KSC – TR-1511
• Example
  • BCI November 2005 = 4352
  • BCI April 2002 = 3583
  • 4352 / 3583 = 121%
  • $98.87 * 121% = $119.63 per SF

Final Adjustments

• Other adjustments as required
  • Number of stories
  • Number of bidders anticipated
  • Anticipated overtime
  • Degree of finish
  • Site development required
  • Project location
  • LEED level
  • Difficulty
  • Escalation to mid point of construction
Final Adjustments

• Made with Algorithms or tables
  – Tables applied with Excel's Data Validation & VLookup functions
  – Conditional formatting used to identify other than normal items

<table>
<thead>
<tr>
<th>% of Total Project</th>
<th>100%</th>
<th>114.1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hrs Week</td>
<td>40</td>
<td>0.0%</td>
</tr>
<tr>
<td># of Stories</td>
<td>3</td>
<td>4.0%</td>
</tr>
<tr>
<td>Site Development</td>
<td>Average</td>
<td>0.0%</td>
</tr>
<tr>
<td>Finish</td>
<td>Average</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anticipated Number of Bidders</th>
<th>4</th>
<th>0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Date</td>
<td>Jun-07</td>
<td>12.4%</td>
</tr>
<tr>
<td>Project Location</td>
<td>KSC</td>
<td>0.0%</td>
</tr>
<tr>
<td>Lead Level</td>
<td>Silver</td>
<td>2.3%</td>
</tr>
<tr>
<td>Difficulty</td>
<td>Normal</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Final Adjustments

• Factors must be calculated correctly
  • (Factor 1 + 1) * (Factor 2 + 1) * (Factor 3 + 1) = markup percentage

• Method avoids compounding markups
Number of Bidders

- **Formula**: \( y = 1.2686 \times x^{-0.1218} \)
- **Note**: Corrects for anticipated market conditions at time of bid

Number of Stories

- **Formula**: \( y = 0.02 - (0.02 \times x) + 1 \)
- **Note**: Correction for new project
Early Decisions Affect Costs

- 200' Long * 75' Wide * 5 Stories = 75,000 SF

- 230' Long * 75' Wide * 5 Stories = 75,000 SF

Wall Areas
29,000 to 70,000+ SF Possible

33,000 SF Wall Area

63,000 SF Wall Area Requires more layout time, concrete, insulation, paint, windows, sitework, complicated roof & ~ 125% MORE MONEY!
General Rules of Thumb

- **Every time** facility change direction costs increase
  - Every corner added to an office building adds 0.1% to 0.4% to total project costs. **Average 0.25%**

<table>
<thead>
<tr>
<th>Corners</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Corners</td>
<td>100%</td>
</tr>
<tr>
<td>8 Corners</td>
<td>101%</td>
</tr>
<tr>
<td>12 Corners</td>
<td>102%</td>
</tr>
<tr>
<td>16 Corners</td>
<td>104%</td>
</tr>
</tbody>
</table>

1 Story Plain Buildings add ~0.17% Per Corner

Result of Adjustments

![Graphs showing the impact of adjustments on costs.](image)
This Method Appears Very Accurate

![Graph showing accuracy](image)

Low bid for each project

Testing

- Models must be tested after completion to verify means and methods
Model Output

<table>
<thead>
<tr>
<th>Average Cost</th>
<th>Average Standard Deviation</th>
<th>High Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$7,916,900</td>
<td>$ 158.34</td>
<td>$11,984,300</td>
</tr>
<tr>
<td>$ 5,396,200</td>
<td>$ 57.42</td>
<td>$ 8,369,500</td>
</tr>
</tbody>
</table>

- **Mode**: Median
- **Mode**: Median

### Todays Bid Price Probability Plot

<table>
<thead>
<tr>
<th>$115</th>
<th>$135</th>
<th>$155</th>
<th>$175</th>
<th>$195</th>
<th>$215</th>
<th>$235</th>
<th>$255</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Comparable Project**
- **Blue Dots Adjusted 1st Three Steps**
- **Trend** - Model - Example - Expon. (Trend)

### CSI Cost By Division

- CSI costs can be estimated from data

![CSI Cost By Division Chart]
Custom Functions

- Excel VBA allows custom functions

```vba
Function GBSize(Historical_Size, New_Size) As Double
    GBSize = 1.010001 * (New_Size / Historical_Size) ^ -0.101
End Function
```

Economies of Scale

<table>
<thead>
<tr>
<th>$</th>
<th>175</th>
<th>Cost Per SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>30,000</td>
<td>Historical SF</td>
<td></td>
</tr>
<tr>
<td>4,000</td>
<td>New Project SF</td>
<td></td>
</tr>
<tr>
<td>123.8%</td>
<td>Economies of Scale</td>
<td></td>
</tr>
<tr>
<td>$ 216.64</td>
<td>Adjusted SF Cost</td>
<td></td>
</tr>
</tbody>
</table>

CSI Cost By Division

- Model can used as sanity check of detailed engineering estimates
Estimate Summary

Automatic report, provides summary of estimate, and all assumptions to requester.

VBA - Wizard Interface
Monte Carlo Simulation

• Monte Carlo Simulation can be added
  – Crystal Ball, @Risk & others

Questions??

Questions and copy of presentation
Email – Glenn.C.Butts@NASA.Gov