Risk-Based, Probabilistic Cost Estimating Methods

Dubrovnik, May 27, 2015
Overview

1. Target – What will you learn here & today?

2. Current Status – Cost & Time Overruns dominate the news ...

3. Overview of existing Cost Estimating Methods

4. Comparison of existing Cost Estimating Methods

5. Include Your Risks

6. How do you do this?

7. Your Lessons Learned

8. Questions / Answers
Section 1
Target – What will you learn here & today?
What You Will Learn Here & Today

Here & now, you will learn, how to ...

1. Avoid **under estimating** your cost (& time)
   => No wrong promises

2. Include your Risks
   (= Effects of Uncertainties on your Goals) transparently,

3. Deliver Cost Estimates with **probability information**

=> Deliver reliable Cost Estimates ...
=> And communicate your results accordingly!

This will change your approach to cost estimates for the rest of your life.

Welcome - great to have you all here!
Section 2

Current Status - Endless Cost & Time

Overruns dominate the news ...
Do You Have Similar Projects ... Experience?

Sydney Opera House, NSW, Australia
Started: 1957
Completed: 1971 (14 years)
Budget: AUS 7 Million (= 100 %)
Cost @ Completion: AUS 102 Mio (1’457 %)

Elbe Philharmony, Hamburg, HH, Germany
Started: 2007 (- 2010)
Completed: ... ? (Expected for 2017)
Budget: EUR 241 Million (= 100 %)
Cost @ Completion: ... ? (Expected in 2015: EUR 865 Million = 359 %)
Source: NZZ, May 21, 295

Berlin-Brandenburg Airport (BER), Berlin, Germany
Started: 2006 (- 2008)
Completed: ... ? (Maybe in 2017 ...)
Budget: EUR 2 Billion (= 100 %)
Cost @ Completion: ... ? (Expected in 2015: EUR > 5.4 Billion = 270 %)
Source: NZZ, May 21, 295
Why ... What May Be the Root Causes for Project Management Desasters?

Potential Root Causes – Author’s Usual Suspects ...

1. Politics ...?

“... We must not create false expectations ...”
(German Chancellor Angela Merkel, speaking in front of the Berlin parliament before leaving for the Eastern Partnership Summit in Riga last Thursday, May 21 – Author’s quote)

“... You must not make promises you cannot keep up with ...”
(Werner Fayman, Austrian Federal Chancellor, recently speaking, Author’s quote)

2. Loss of communication

3. Other? – Yes, for sure ...

4. Our current, existing Cost Estimating Methods ...?
   => Optimistically biased ...
   => No Value at Risk (VaR) information available
Value at Risk (VaR) Definition

Value at Risk (VaR) = A certain amount, within a distribution, that will not be exceeded according to the corresponding probability.

VaR 70 means that a $5M budget would not be exceeded in 70% of all simulated scenarios (there remains a 30% probability that the $5M budget will be exceeded).
Section 3
Overview of existing
Cost Estimating Methods
Overview of Well-Known, Established Cost Estimating Methods

Basically there **4 types** of existing, well-known Cost Estimating Methods:

1. **Deterministic:**
   Aggregated unit quantities multiplied by unit prices.
   Usually with some degree of conservatism built in.
   **Plus an added reserve or contingency**

2. **Bandwidth:**
   Range approach with minimum, most likely, and maximum cost.
   The total cost is obtained by simply adding these parameters for all line items.

3. **Square Root:**
   Delivers **one single figure** which is the sum of all base costs plus the square root of the sum of the squares of the risk contingencies.

4. **Probabilistic:**
   Range approach which characterizes cost information with **probability distributions**
### Bandwidth Approach

**Input:**
3-Point-Estimate

**Process:**
Simply adding up the minimum, most likely and maximum values from each item

→ **Suggests that the extreme scenarios will have the same occurrence rate as scenarios around the most likely value.**
→ **This will lead to scenarios which will not occur in reality**

![Bandwidth Approach Diagram](image)

### Probabilistic Approach

**Input:**
3-Point-Estimate modelling a distribution density

**Process:**
Simulation (e.g. Monte Carlo Simulation) to cover most of real risk combinations

→ **Will lead to a realistic result where best and worst case scenarios are adequately considered**

![Probabilistic Approach Diagram](image)
Bandwidth (Method 2) versus Probabilistic (Method 4) Approach: E.g. Rolling 20 Dice

Input: One Die

- Same probability of every value between 1 and 6
- Same input for both methods
- Simple 2-Point-Estimate

Rolling 20 dice – Consider this to be 20 risks in a project

Bandwidth Approach

Result

- Bandwidth from 20 to 120
- Same probability for every scenario

Probabilistic Approach

Result (Reality)

- Maximum around 95 instead of 120.
- 120 will not occur even using 100'000 iterations
- Same for minimum
- The most likely scenario will be around 70

Many more combinations than rolling 1 die

- Not a realistic scenario: 120 (20 x 6 -only one possible combination) is equal rated to e.g. 70 where many combinations will lead to the same result
- Even higher effect when using 3-Point-Estimates
- No probability information
- Not applicable for cost prediction
Square Root Approach (Method 3)

Standard Cost Estimation Items

<table>
<thead>
<tr>
<th>Subsection</th>
<th>Base Cost</th>
<th>Risk Surcharge</th>
<th>Risk Contingency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Painter</td>
<td>$10,000.00</td>
<td>10%</td>
<td>$1,000.00</td>
</tr>
<tr>
<td>Roofer</td>
<td>$30,000.00</td>
<td>12%</td>
<td>$3,600.00</td>
</tr>
<tr>
<td>Floor tiler</td>
<td>$15,000.00</td>
<td>8%</td>
<td>$1,200.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$55,000.00</strong></td>
<td></td>
<td><strong>$5,800.00</strong></td>
</tr>
</tbody>
</table>

Square Root Method is used to adapt the risk contingency in order to consider that all risks won't occur at the same time.

\[ \sqrt{\sum Risk^2} \]

- Delivers no realistic result
- Simple **deterministic (one figure)** surcharge
- Information on the individual item is lost (not valid in comparison to overall result)
- No probability information
- **No Value at Risk (VaR)** information, e.g. how much is risk covered by budget

\[ \sqrt{1,000^2 + 3,600^2 + 1,200^2} = 3,924 \]
Square Root Approach (Method 3) for Quantitative Risk Assessment

Risk Assessment Using Bandwidths

<table>
<thead>
<tr>
<th>Item</th>
<th>Min Impact</th>
<th>Max Impact</th>
<th>Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk 1</td>
<td>$10,000.00</td>
<td>$30,000.00</td>
<td>$20,000.00</td>
</tr>
<tr>
<td>Risk 2</td>
<td>$20,000.00</td>
<td>$35,000.00</td>
<td>$15,000.00</td>
</tr>
<tr>
<td>Risk 3</td>
<td>$5,000.00</td>
<td>$12,000.00</td>
<td>$7,000.00</td>
</tr>
</tbody>
</table>

\[
\sqrt{\sum (\text{max} - \text{min})^2} = \sqrt{20,000^2 + 15,000^2 + 7,000^2} = 25,962
\]

Result

\[
\sum_{\text{min}} = 35,000
\]

\[
\sum_{\text{max}} = 77,000
\]

New overall contingency: $60,962 = 35,000 + 25,962

Bandwidth information is lost

Again ... keep in mind that not all risks will occur at the same time
Section 4
Comparison of Existing Cost Estimating Methods
All Four Cost Estimating Methods in Comparison: Tunnel Excavation Category (Base Cost only)

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Distribution</th>
<th>min</th>
<th>ml</th>
<th>max</th>
<th>unit</th>
<th>Distribution</th>
<th>min</th>
<th>ml</th>
<th>max</th>
<th>Price [USD]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shotcrete 10 cm - Top Heading</td>
<td>Triangular</td>
<td>13.83</td>
<td>15.37</td>
<td>17.68</td>
<td>m²</td>
<td>Triangular</td>
<td>9.696</td>
<td>12.12</td>
<td>15.756</td>
<td>186.28</td>
</tr>
<tr>
<td>Steel Mesh AQ50, outer layer- Top Heading</td>
<td>Triangular</td>
<td>13.83</td>
<td>15.37</td>
<td>16.91</td>
<td>m²</td>
<td>Triangular</td>
<td>0.976</td>
<td>1.22</td>
<td>1.586</td>
<td>18.75</td>
</tr>
<tr>
<td>Swellex 3.0 m - Top Heading</td>
<td>Triangular</td>
<td>1.73</td>
<td>1.82</td>
<td>2.00</td>
<td>pc</td>
<td>Triangular</td>
<td>20.712</td>
<td>25.89</td>
<td>33.657</td>
<td>47.12</td>
</tr>
<tr>
<td>Shotcrete 5 cm - Bench</td>
<td>Triangular</td>
<td>5.18</td>
<td>5.76</td>
<td>6.62</td>
<td>m²</td>
<td>Triangular</td>
<td>5.992</td>
<td>7.49</td>
<td>9.737</td>
<td>43.14</td>
</tr>
<tr>
<td>Swellex 3.0 m - Bench</td>
<td>Triangular</td>
<td>0.43</td>
<td>0.45</td>
<td>0.50</td>
<td>pc</td>
<td>Triangular</td>
<td>20.712</td>
<td>25.89</td>
<td>33.657</td>
<td>11.65</td>
</tr>
</tbody>
</table>

1. Deterministic Approach

Most likely quantity x most likely price

306.95 USD

2. Bandwidth Approach

\[
\sum CostItem(\text{min } Q \times \text{min } P) = 223.36 \text{ USD}
\]

\[
\sum CostItem(\text{ml } Q \times \text{ml } P) = 306.95 \text{ USD}
\]

\[
\sum CostItem(\text{max } Q \times \text{max } P) = 453.86 \text{ USD}
\]

3. Square Root Approach

\[
\sqrt{\sum CostItem(\text{max } - \text{min })^2} + \sum \text{min} = 375.67 \text{ USD}
\]

4. Probabilistic Approach

![Distribution Function](image)

Risk-Based, Probabilistic Cost Estimating Methods
All Four Cost Estimating Methods in Comparison: Visualized

Deterministic Approach

Bandwidth Approach

Square Root Approach

Probabilistic Approach

Min. 223

Bandwidth Approach 307

Square Root Approach 321

Probabilistic Approach 362

VaR5 286

VaR50 307

VaR95 376

Max 454
<table>
<thead>
<tr>
<th>Estimating Method</th>
<th>Pro</th>
<th>Con</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Deterministic</td>
<td>One single figure</td>
<td>No probability information for single value</td>
</tr>
<tr>
<td></td>
<td>Well-known &amp; accepted</td>
<td>No VaR information</td>
</tr>
<tr>
<td></td>
<td>Quick</td>
<td>More often than not on the unsafe side</td>
</tr>
<tr>
<td></td>
<td>Can be performed “manually”</td>
<td>(high, unknown probability of cost overruns)</td>
</tr>
<tr>
<td>2. Bandwidth</td>
<td>Three values (minimum, most likely and</td>
<td>No probability information for range values</td>
</tr>
<tr>
<td></td>
<td>maximum) in a range</td>
<td>No VaR information</td>
</tr>
<tr>
<td></td>
<td>Quick</td>
<td>More often than not on the unsafe side</td>
</tr>
<tr>
<td></td>
<td>Can be performed “manually”</td>
<td>(high, unknown probability of cost overruns)</td>
</tr>
<tr>
<td></td>
<td>Range maximum and minimum very unlikely</td>
<td></td>
</tr>
<tr>
<td>3. Square Root</td>
<td>One single value</td>
<td>No probability information for single value</td>
</tr>
<tr>
<td></td>
<td>Quick</td>
<td>Bandwidth information is lost</td>
</tr>
<tr>
<td></td>
<td>Can be performed “manually”</td>
<td>No VaR information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Range limits are extreme values and very</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unlikely</td>
</tr>
<tr>
<td>4. Probabilistic</td>
<td>Full probability information</td>
<td>Needs probabilistic thinking &amp; understanding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Needs (a little bit) more time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Needs software support</td>
</tr>
</tbody>
</table>
Section 5
Include Your Risks
Control Your Uncertainty – Distinguish Between Basic Elements and Risks

Uncertainty in predictions

Basic Elements (Cost, Time, etc.)

→ Will always occur (e.g. elements in a cost estimation)
→ Exact price or time is uncertain

Risk

→ Has a probability of occurrence
→ Consequences (costs, time, etc.) are uncertain
Basic Travel Time from Your Home to Dubrovnik

Estimation of the basic driving time from your City to Dubrovnik
Premise: Normal traffic and weather conditions

Best case: 3.5 h  
Most likely: 4 h  
Worst case: 5 h
**Risk: Bad weather in ...**

- Snow and icy roads / Thunderstorms / ... [You name it]
- Scenario has a probability of occurrence – can occur but does not have to
- Estimated probability: **45 %**
- Additional time is needed (= impact if risk does occur)

**Impact/Consequences**

- Best case: 0.5 h
- Most likely: 1 h
- Worst case: 2.5 h
Act As Your Own Risk Manager – Plan For Controls

Plan for Controls:

→ How important is your attending the ITA/WTC in Dubrovnik on time?
→ Can you afford being (too) late?
→ Cover the risk of coming in late → Plan for Controls - Start earlier or not ...

Distribution Function (Impact in [h])

- Cover 100% plan 7.5 h
- Cover 80% plan 5.5 h
- Cover 10% plan 3.8 h
Aggregating All Your Cost Components → Determine Your Budget

Create a budget for each cost component or for the total costs. How much of the cost potential do you want to cover? → Say 70% → Budget: 37.2 Mio
Section 6
How do you do this?
How Do You Do This?

You will need Software.

While there are some commercially available packages, we recommend to use RIAAT Risk Administration & Analysis Tool

⇒ http://riaat.riskcon.at/
⇒ English Version

Top Advantages:
• Project Structure
• Full excel Import & Export
• Strong Visualizations
• ...
Visualize Your Results – Top Down by Tornado Diagrams
Section 7

Your Lessons Learned – Here & Today
1. Avoid single figure, deterministic estimates
2. Identify & include your Base Cost & your Risks
3. Use Three-Point-Estimates for quantities & price
4. Aggregate all cost items probabilistically
5. Choose a Value @ Risk (VaR) on the safe side
6. Just start with it ... now!
7. Control your risks (uncertainties) before they control you!
8. You are not alone – we are ready to help
Where is Your Project on This Curve? How Do You Know ...?

Value at Risk (VaR) = a certain amount, within a distribution, that will not be exceeded according to the corresponding probability.

... By Your Next Estimate on a Risk-Based Approach
Risk-Based, Probabilistic Cost Estimating Methods
Section 8 - Your Questions ... Our Answers - Thank you!

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