CEBoK Overview

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INAC’s Costing Centre of Expertise

ICEAA Canada Workshop, 2018
Outline

• What is the CEBoK?

• Overview of the various modules (16 of them!)

• Level of effort

• Study tips

• Costing in your environment

• Conclusion
What is the **CEBoK**?

- **Cost Estimating Body of Knowledge**

- Summarizes all notions needed to become certified as a full CCE/A

  “The official International Cost Estimating and Analysis Association (ICEAA) cost estimating and analysis body of knowledge and training course materials.”

- *A self study tool, not a course you take…*
What is the **CEBoK?** (Cont’d.)

- More than just the process and methods for developing an estimate, but also a “culture”.

  - “Estimating that future cost involves employing inter-disciplinary quantitative analysis techniques. It is partly science, art and judgment.” (1)
CEBoK – Not the only tool

• Multiple information sources:

  • Costing books: To see concepts from another angle
  • Math: May require a good review of key concepts
  • Stats: Those who have done lots will enjoy the ride!
OVERVIEW
of the 16 Modules
Module 1
Introduction to Cost Estimating

• Definition of Cost Estimating
• Purpose of Cost Estimating
• Reasons for Cost Estimating
  • Budgeting
  • Planning
  • Trade-Offs
Module 1
Applications of Cost Estimating

• Program Affordability
• Acquisition Milestone Decisions
• Budgets
• Technology Changes
• Analysis of Alternatives (AoA)
• New Business Proposals
• Source Selection
• In-Process Reviews (IPRs)
• Contracting and Project Management
• Design Trade-Offs
• Program Oversight

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Module 1
Overview of Cost Estimating

• Context for Cost Estimating
• Benefits of Cost Estimating
• Cost Estimate Qualities
• Limitations of Cost Estimating
• Cost Estimating Challenges
• Cost Products
• Cost Estimating Process
• Cost Estimating Certification
• Cost Estimating Policy and Regulations
Module 1
Professional Certifications

• Professional Cost Estimator/Analyst (PCEA)
• Certified Cost Estimator/Analyst (CCEA)

• Combination of educational and job experience requirements
  • Minimum 2 years for PCEA, 5 years for CCEA
  • Equivalencies for related work, in proportion to relevancy
Module 1
Cost Estimating Disciplines

- Mathematics
  - Arithmetic
  - Algebra and Functional Forms
  - Probability and Statistics
  - Numerical Methods

- Operations Research
  - Management Science
  - Modeling and Simulation
  - Optimization

- Industrial Engineering

- Economics
  - Econometrics
  - Business
  - Finance

- Accounting
  - Financial Systems
  - Enterprise Resource Planning (ERP)
  - Management Accounting

- Computer Science
  - Software Development

- Engineering
  - Mechanical Engineering
  - Electrical Engineering
  - Aerospace Engineering
  - Naval Architecture
  - Systems Engineering
  - Physics
  - Production Engineering/Manufacturing
  - Logistics

- Budgeting
  - Programming, Planning, Budgeting, and Execution System (PPBES)

- Marketing
  - Sales
  - Business Development
  - Voice of the Customer
  - Written Communication

- Contracting
  - Contract Pricing
Overview – Module 2
Cost Estimating Techniques

• Cost Estimating Techniques:
  • Method
  • Application
  • Strengths
  • Weaknesses
  • Challenges
  • Example
  • Quantification of Uncertainty and Risk
## Overview – Module 2
### Main Cost Estimating Techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Approach</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analogy</td>
<td>Comparative analysis of similar systems</td>
<td>Can be used early in programs before detailed requirements are known, but there is no objective test of validity</td>
</tr>
<tr>
<td>Parametric Estimating</td>
<td>A mathematical relationship between parameter(s) and a cost</td>
<td>Historical data is difficult to obtain, but CERs can be easily adjusted for requirements changes and provide statistical results</td>
</tr>
<tr>
<td>Engineering Build-Up</td>
<td>Estimating is done at lower levels and results rolled up to produce higher-level estimates</td>
<td>It is easy to see exactly what the estimate includes, but it is expensive and requires detailed data to be collected, maintained and analyzed</td>
</tr>
<tr>
<td>Extrapolation from Actuals</td>
<td>The trend from current program cost is used to estimate final cost</td>
<td>Typically used later in a program when much of the actual cost is known</td>
</tr>
</tbody>
</table>

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Different techniques are used for the different stages in the acquisition/product development cycle.

<table>
<thead>
<tr>
<th>Program Life Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase A Technology Development</td>
</tr>
<tr>
<td>Analogy</td>
</tr>
</tbody>
</table>

- **Gross Estimates**
- **Detailed Estimates**
Module 3
Parametric Estimating

• The process of using cost estimating relationships (CERs) based on historical data to estimate a project’s cost

• Parametric Estimating Process:
  • Collecting data
  • Identifying cost drivers
  • Developing CERs
    • Cost Estimating Relationships
  • Building a parametric model
Module 3
Parametric Estimating - CERs

The preferred method for deriving CERs is via regression analysis:
1. Select Variables
2. Test Relationships
3. Perform Regression

• Analytical Constructs
  - Linear equations
  - Other functional forms
    • Power, exponential, log, polynomial
  - Curve fitting

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Module 3
Parametric Estimating - Regression

Perform Regression

Examples of equations:
• Linear: $y=a+bx$
• Power: $y=ax^b$
• Logarithmic: $y=a+b \ln x$
• Exponential: $y=ae^{bx}$
• Polynomial: $y=a+b_1x+b_2x^2+b_3x^3+\ldots+b_nx^n$
Module 3
Parametric Estimating – CERs Types

• A **rate**: uses a parameter to predict cost via a simple multiplicative relationship.

• A **factor** uses the cost of another element to predict cost

• The **ratio**: Parameter on parameter, primarily used to estimate effort
Module 4
Data Collection and Normalization

• Importance of Data
• Types of Data
• Considerations
• Data Collection Process
• Sources of Data
• Data Normalization
  • To make the data consistent and comparable to other data being used in the estimate.
Module 4
Data… Why so important

• Data are the lifeblood of cost estimating

• Different types of data for different purposes

• Data Collection follows a process

• Consistency, Comparability, Usability

• Where do you go for data?
Module 5
Inflation and Index Numbers

• Inflation Concepts
• Inflation and Cost Estimating
• Index Numbers
  • Raw Indices
  • Composite Indices
  • Weighted Indices
• Inflation Tables and Escalation Procedures
Module 5
Inflation and Cost Estimating

• When using historical costs to estimate current or future purchases, costs must be escalated to adjust for change in purchasing power (inflation)

• When developing CERs, historical costs should be represented in one **Constant Year** in order to normalize for inflation
Module 5
Escalation Procedure

How to adjust for inflation correctly, using inflation index tables

- CY $ From Year
- TY $ From Year
- CY $ To Year
- TY $ To Year

**Step 3:** Divide

**Step 4:** Multiply
Module 6
Basic Data Analysis Principles

• Types of Data
• Univariate Data Analysis
• **Scatter Plots**: visual depiction of the relationships in the data
  • Variables
  • Axes and Function Types
• **Data Validation**
  • Descriptive Statistics
  • Outliers (data quality check)
  • Rules of Thumbs
## Module 6
Data Analysis Formulas

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variance</strong></td>
<td>$S^2 = \frac{\sum(Y_i - \bar{Y})^2}{n-1}$</td>
</tr>
<tr>
<td><strong>Coefficient of Variation</strong></td>
<td>$CV = S/\text{Mean} = %$</td>
</tr>
<tr>
<td><strong>Sample Sizes</strong></td>
<td>$(1\text{-CI}) = CV / \sqrt{n}$</td>
</tr>
<tr>
<td></td>
<td>$\sqrt{n} = CV / (1\text{-CI})$</td>
</tr>
<tr>
<td><strong>Linear Function</strong></td>
<td>$y = a + bx$</td>
</tr>
<tr>
<td><strong>Power Functions</strong></td>
<td>$y = ax^b$</td>
</tr>
<tr>
<td><strong>Exponential Function</strong></td>
<td>$y = ae^{bx}$</td>
</tr>
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</table>
Module 7
Learning Curve Analysis

• The phenomenon of cost improvement with increasing production quantities and how to account for it analytically.

• Learning Curve: Constant rate of reduction in touch labor costs for each doubling in quantity
  • Assumes no major change in product design, production processes, workforce composition, and interval between units
  • Extrapolation from Actuals for ongoing production run
Module 7
Learning Curve - Graphically

- Learning Curve theory can be shown graphically as follows:

Each time quantity doubles, cost decreases by a constant percentage. “Learning Curve Slope” or “LCS” (e.g., 90%) is defined to be “100% - Percent of Cost Reduction.”
# Module 7

## Learning Curve - Formulas

<table>
<thead>
<tr>
<th>Learning curve equation:</th>
<th>$y = ax^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Log Space equation</strong></td>
<td>$\ln(y) = \ln(a) + b \ln(x)$</td>
</tr>
<tr>
<td><strong>LCS</strong></td>
<td>$\text{LCS} = 2^b$</td>
</tr>
<tr>
<td><strong>Learning Curve Slope</strong></td>
<td>$b = \frac{\ln(\text{LCS})}{\ln(2)} = \log_2\text{LCS}$</td>
</tr>
<tr>
<td>$a$</td>
<td>$= \frac{y}{xb}$</td>
</tr>
<tr>
<td>$a$</td>
<td>$= e^{\ln(a)} = \ln(e^a)$</td>
</tr>
<tr>
<td>$a$</td>
<td>$= \frac{y}{x^b}$</td>
</tr>
</tbody>
</table>
Module 8
Regression Analysis

• How to develop and assess a CER

• Key Ideas
  • Correlation
  • Best fit / minimum error
  • Homoscedasticity!
  • Statistical significance
  • Quantification of uncertainty

• Practical Applications
  • CER Development
  • Learning Curves
Module 8
Regression Analysis – WHY?

• One of the **Key Ideas** of all cost estimating is that of correlation, observing patterns that show that certain cost driver variables are consistently related to cost.

• Regression analysis exploits these patterns by allowing us to develop the “best” possible cost estimating relationships (CERs) in the sense that they best fit the data.
Module 8
Regression Analysis – What

• A mathematical function must be specified before regression analysis is performed
  • The specified function is called a regression model
  • Many types of models may be considered

\[
\begin{align*}
\text{linear: } & \quad y = a + b x \\
\text{quadratic: } & \quad y = a + b x + c x^2 \\
\text{power: } & \quad y = a x^b \\
\text{exponential: } & \quad y = a e^{b x} \\
\text{logarithmic: } & \quad y = a + b \ln x
\end{align*}
\]
Module 8
Regression Analysis – Choices

• This module covers:
  • The basic math behind the analysis
  • How to interpret the results from a regression tool such as Excel
  • How to apply the results and choose among models
Module 9
Cost and Schedule Risk Analysis

• Covers appropriate analytical steps to account for uncertainty and to capture various kinds of risk in your cost estimate

• Key Ideas
  • Risk / bias (accuracy)
  • Uncertainty (precision)
  • Cost realism
  • Risk vs. Sensitivity
  • Inputs vs. Outputs Risk
Module 9
Risk Analysis

- Risk analysis is a significant part of cost and schedule estimation
  - Captures *uncertainty* about the point estimate, expressed as Confidence and Prediction Intervals
  - Captures anticipated *growth* used to adjust estimates, budgets, and schedules
Module 9
Risk Sources

• Sources of cost understatement

• Independence and Risk

• Types of Risk
  • **Cost Growth** = Cost Estimating Growth + Sked/Tech Growth + Requirements Growth + Threat Growth
  • **Cost Risk** = Cost Estimating Risk + Sked/Tech Risk + Requirements Risk + Threat Risk
Module 10
Probability and Statistics

• Mathematical underpinnings of cost estimating

• To lay the mathematical groundwork for many areas of cost analysis
  • Measures of Central Tendency
  • Measures of Dispersion
  • Types of Distributions
  • Introduction to Hypothesis Testing
  • Statistical Tests
Module 10
Probability and Statistics: Usage

- Practical Applications
  - Descriptive Statistics
    - Mean, Median, Mode, CV
  - CER Development
    - t, F, R², CI, PI
  - Modeling Uncertainty and Risk
    - Normal, Triangular, Lognormal
Module 11
Manufacturing Cost Estimating

• Techniques for estimating in a manufacturing environment:
  • Standard Time
  • Direct Labor
  • Realization Factor
  • Time series analysis
    • Moving average
Module 11

Manufacturing Cost Estimating

• Development vs. Production
• Production Set-up Activities
• Production Run Characteristics
  • Labor Estimating
  • Rates Estimating
  • Materials Estimating
Module 12
Software Cost Estimating

• Techniques for estimating in a software development environment

• Key Ideas:
  • Cost Drivers
    • Size
    • Complexity
    • Capability
  • SLOC vs. ESLOC vs. Function Points
  • Development Methodologies
Module 12
Software Cost Estimating

• Source Lines of Code (SLOC)
  • Prior to development, must be estimated using standard estimating techniques

• Equivalent Source Lines of Code (ESLOC)
  • The effective size of reused and adapted code adjusted to its equivalent in new code + The size of the new code
The COCOMO II CER is commonly used since it is publicly available:

\[ PM = A \cdot \text{Size}^E \cdot \prod_{i=1}^{n} EM_i \]

Where:
- \( PM \) = Person Months
- \( A \) = Constant = 2.94
- \( \text{Size} \) = SLOC in thousands (KSLOC)
- \( E \) = Sum of Scale Factors (Economies or Diseconomies of Scale)
- \( EM \) = Effort Multipliers

*Software Cost Estimation with COCOMO II*,
Boehm et al., Prentice Hall PTR, 2000
Module 13
Economic Analysis

• Key Ideas
  • Competing investment alternatives
  • Time value of money
  • Commensurability of costs and benefits

• Analytical Constructs
  - Discount rates
    • Real and nominal
  - Net present value (NPV)

\[ PV = FV \cdot \left( \frac{1}{(1+i)^{(n-0.5)}} \right) \]
Module 13

EA = Iterative Process

- Considerable dependencies between EA Process steps

- Should continually revisit earlier steps and always “recalibrate” to the objective
Module 13
Economic Analysis

• EA provides objectivity and completeness to decision making process
  • Includes discussion and/or analysis of all possible alternatives/solutions to a predefined objective/problem
  • Economically adjusts time-phased costs and benefits
Module 14
Contract Pricing

• One of the key ideas of contracting is that of commensurate risk and reward.

• Practical Applications
  • Cost Proposal Development
  • Cost Proposal Evaluation
    • Including suppliers
  • Negotiations
  • Risk-based ROS (Return On Sales)
Module 14
Contract Types

**Objective:** Reasonable contractor risk and provide the contractor with the greatest incentive for efficient and economical performance

1. Firm Fixed Price (FFP)
2. Cost Plus Fixed Fee (CPFF)
3. Fixed-Price Incentive (FPI)
4. Cost Plus Incentive Fee (CPIF)
5. Cost Plus Award Fee (CPAF)
Module 15
Earned Value Management (EVM)

• Tracking cost and schedule performance on projects
  • Integrated baseline
    • Resource-loaded schedule
  • Earned value
    • Objective progressing
  • Extrapolation from Actuals
  • Cost and schedule performance
Module 15
EVM - Performance Measurement

Contract Budget Base
- Price $110M
- Cost (CBB) $100M
- Fee $10M

Management Reserve $10M
- MR covers unanticipated, in scope changes

Performance Measurement Baseline (PMB) $90M
- Earned Value is measured against the PMB

Control Accounts are the management control point for the integration of scope, schedule & cost

Distributed Budget (Control Accounts) $85M
- Work Packages $40M
- Planning Packages $45M

Undistributed Budget $5M
- Work is tied to an activity, but is not detail-planned
Module 16
Cost Management

• Cost management generally takes a holistic approach, incorporating cost considerations into the overall management approach.

• Help lead to decisions that providing optimal value to the organization:
  • Proactively managing costs
  • Cost estimating involved “early and often”
  • Improvements and trade-offs
  • Do Less, Do It Better, or Do It Differently

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Module 16
Cost Management Concepts

- Total Ownership Cost (TOC)
- Cost As an Independent Variable (CAIV)
- Target Costing
  - Design to cost (DTC)
  - Design for manufacturability and assembly (DFMA)
  - Value engineering (VE)
  - Decision Analysis with Risk Assessment
  - Quality function deployment (QFD)
  - Total quality management (TQM)
- Activity-Based Costing (ABC)
All modules
CEBoK Structure

• **Links** to other modules, will help fill in missing information for a module studied in isolation

• A **Related and Advanced Topics** section at the very end of each module will treat interesting subjects above and beyond the core material of each module

• CEBoK also has many other helpful features, such as **student exercises** to test your knowledge, a glossary of terms, and a bibliography of resources for further study.
Level of effort

• 16 Chapters + Exercises
  • About **150 hours** of study time
  • At DND, that time used to be allocated to employees over several months to prepare…

• Varies with your ability to:
  • Do Math and Stats
  • Understand and memorize concepts
  • Integrate and **link** multiple new notions
Study Tips

• 70% passing mark
  • On each exam
  • Can’t skip subjects
  • Can’t guess!
  • Do all possible exercises!

• Calculator:
  • Your new best friend
  • Use it for your exercises (not Excel!)
  • Develop tricks for speed (ex: Mem.)
Study Tips (2)

• Summarize your knowledge

• Try BOTH exams at the same time
  • Same material
  • Part II is only a bit more in depth, requires better integration, judgement, speed!

• Speed, speed, speed!!
  • Not much time for second thoughts during exams
Costing in your environment

• The CEBoK is oriented mainly towards Defence procurement and development processes, with a US colour to examples and notions…

• However, these notions will help you structure your approach, and gain the confidence necessary to overcome the challenges inherent to Costing…
Costing in your environment

Challenges

• Data:
  • Will always be key, and hard to obtain/validate

• Time:
  • Never sufficient

• Politics:
  • Trumps costing

• Culture:
  • Will need to evolve in order to include costing throughout the business process
Conclusion

• If you’re:
  • Curious
  • Open
  • Patient
  • A critical thinker
  • Logically inclined / fact oriented

You can become a great Certified Cost Estimator/Analyst (CCEA)!!
Questions?
Comments?