CEBoK Overview

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INAC's Costing Centre of Expertise

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****?*

- ***C****ost* ***E****stimating* ***B****ody* ***o****f* ***K****nowledge*
- 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
  - The U.S. Government Accountability Office (**GAO**) "Cost Estimating and Assessment Guide"
  - 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

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*
  - *Public Speaking / Presentation Skills*
- *Contracting*
  - *Contract Pricing*

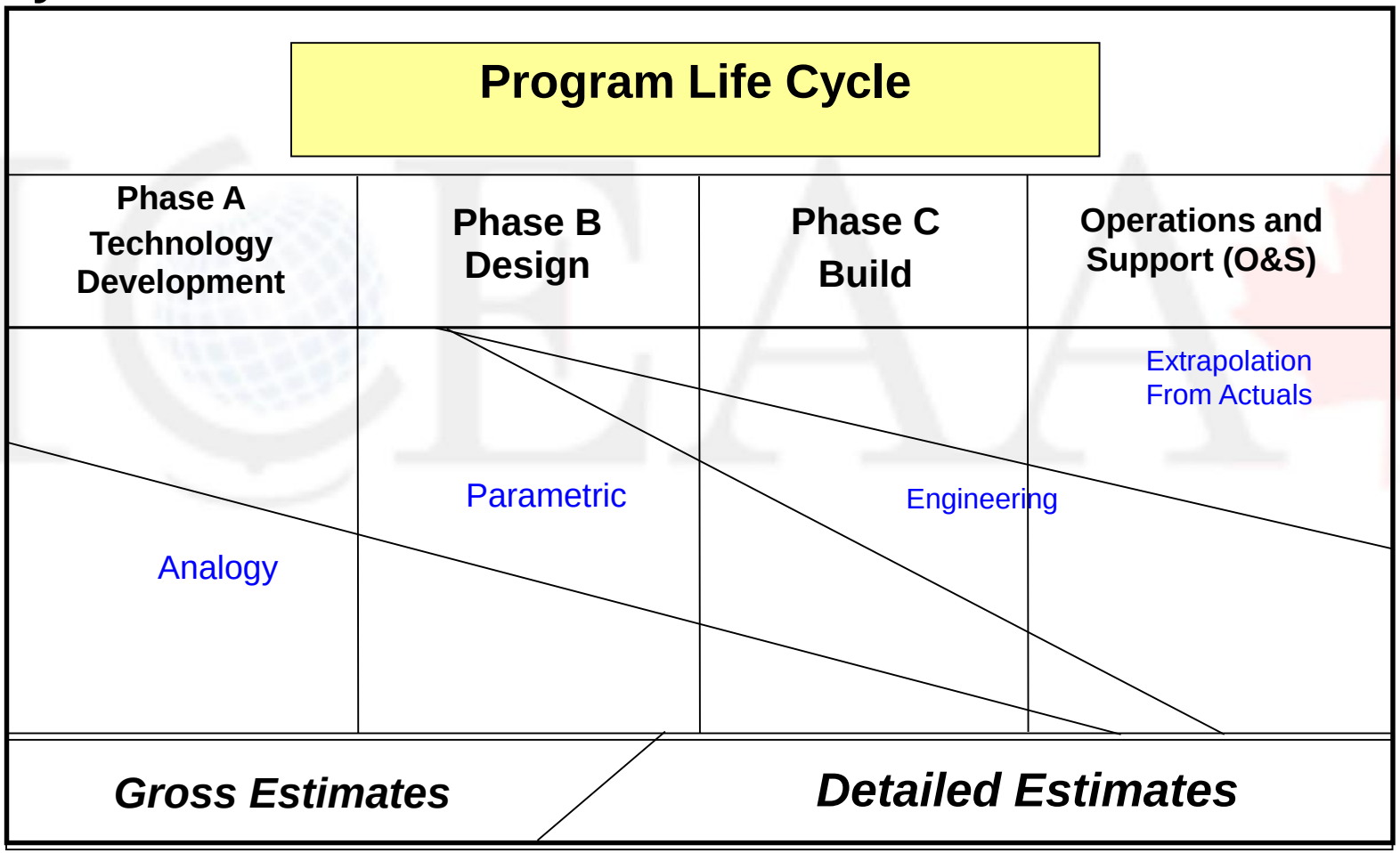
Overview – Module 2
Cost Estimating Techniques

- Cost Estimating Techniques:
  - *Method*
  - *Application*
  - *Strengths*
  - *Weaknesses*
  - *Challenges*
  - *Example*
  - *Quantification of Uncertainty and Risk*

Overview – Module 2
Main Cost **Estimating Techniques**

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

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



Module 3
Parametric Estimating

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

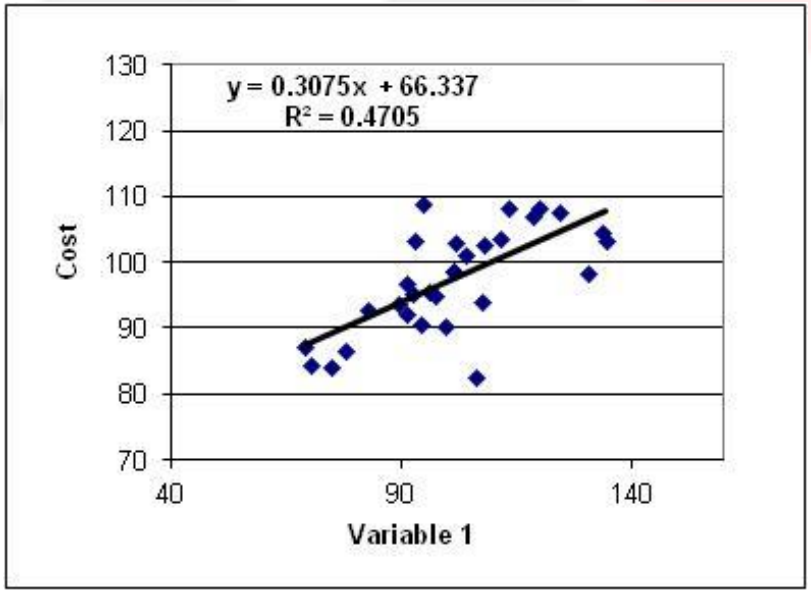
- Parametric Estimating Process:
  - Collecting data
  - Identifying cost drivers
  - Developing CERs
    - Cost Estimating Relationships
  - Building a parametric model

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



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: P**arameter 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

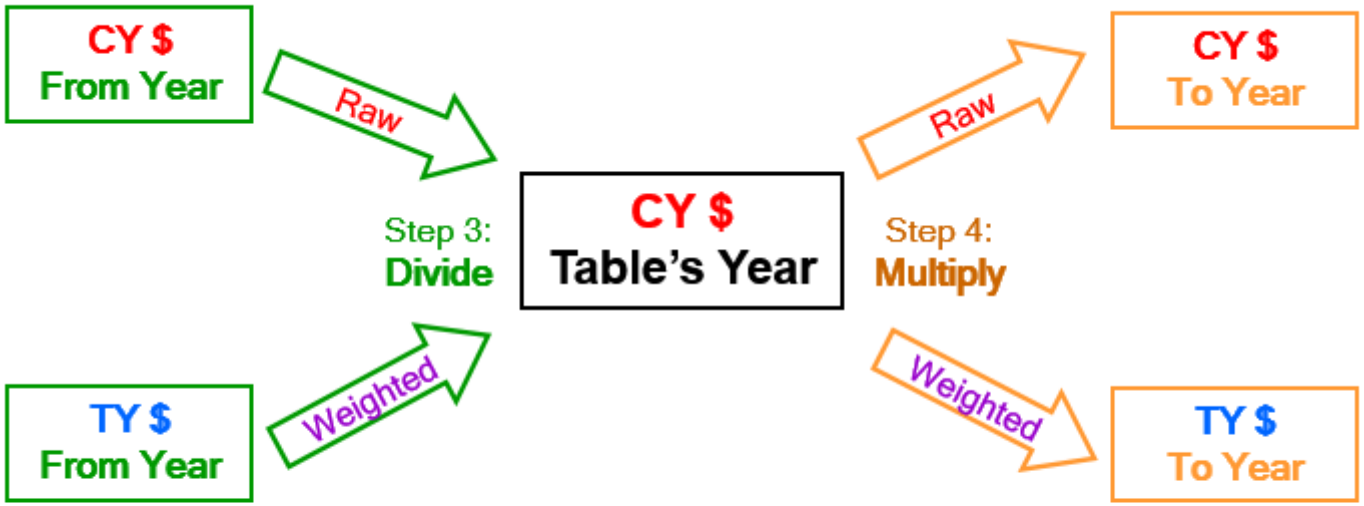
Module 5
Inflation and Cost Estimating

- 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



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

Variance	$S^2 = \sum(Y_i - \bar{Y})^2/(n-1)$
Coefficient of Variation **CV**	**CV = S/Mean = %**
Sample Sizes	**(1-CI) = CV / √n** **√n = CV / (1-CI)**
Linear Function	**y = a + bx**
Power Functions	$y = ax^b$
Exponential Function	$y = ae^{bx}$

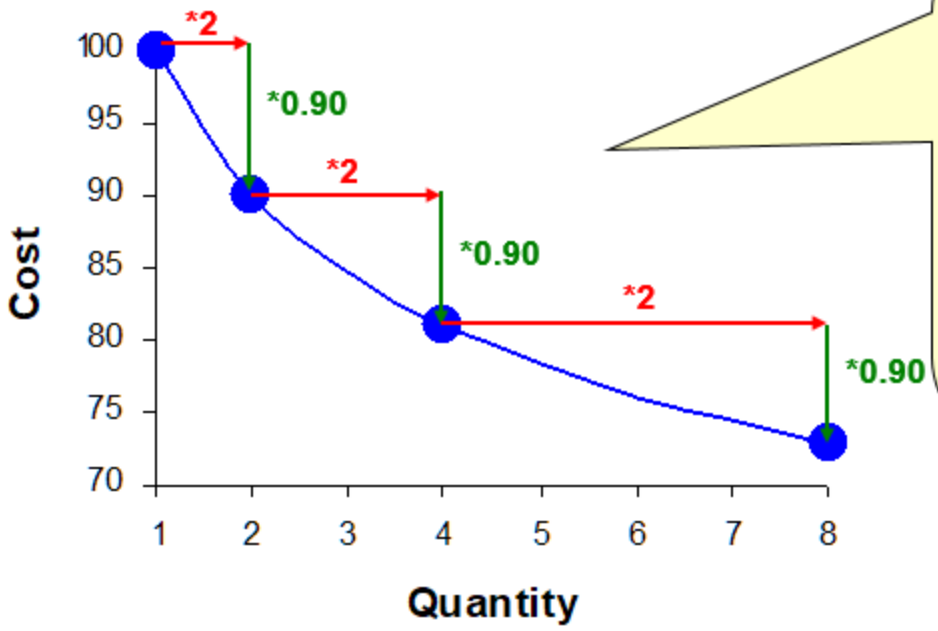
Module 7
Learning Curve Analysis

- 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

Learning curve equation:	$y = ax^b$
Log Space equation	$\ln(y) = \ln(a) + b \ln(x)$
LCS Learning Curve Slope	$LCS = 2^b$
b	$= \ln(LCS) / \ln(2)$ $= \log_2 LCS$
a	$= y / xb$ $= e^{\ln(a)} = \ln(e^a)$
a	$= y / x^b$

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

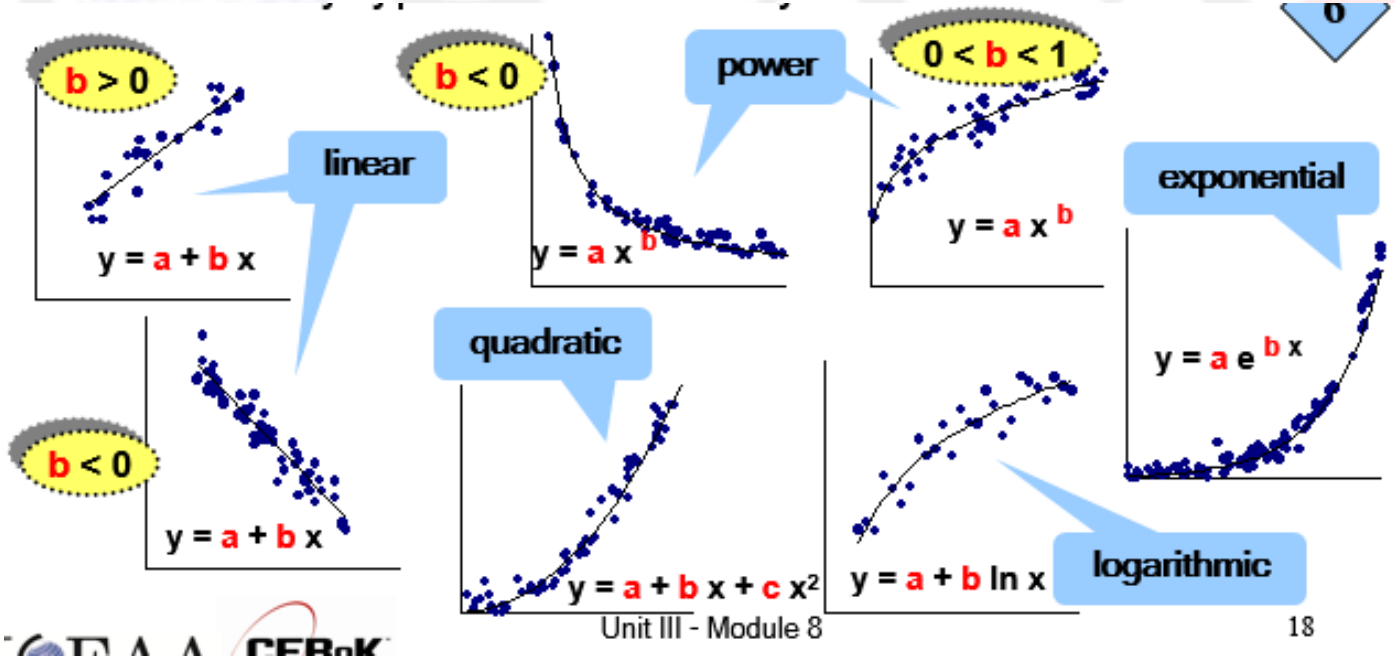
Module 8
Regression Analysis – WHY?

- 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



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

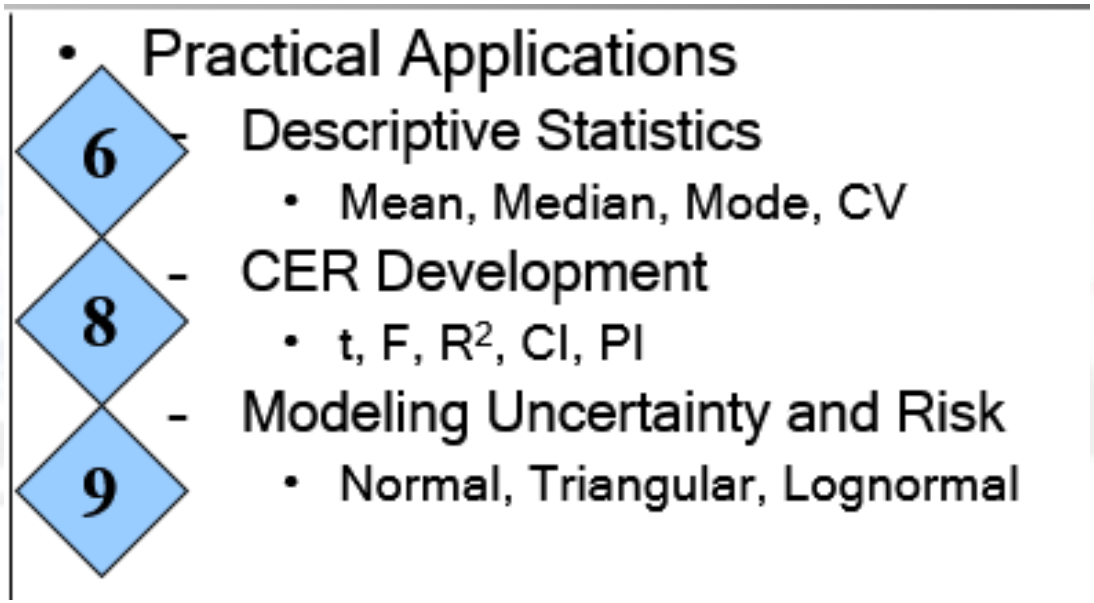
Module 9
Risk Sources

- 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



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

Module 12
Software Cost Estimating

The COCOMO II CER is commonly used since it is publicly available:

- COCOMO II CER equation

$$PM = A \left(Size^{E} \cdot \prod_{i=1}^{n} EM_i \right)$$

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

Size

Complexity and Capability

Software Cost Estimation with COCOMO II, Boehm et al., Prentice Hall PTR, 2000

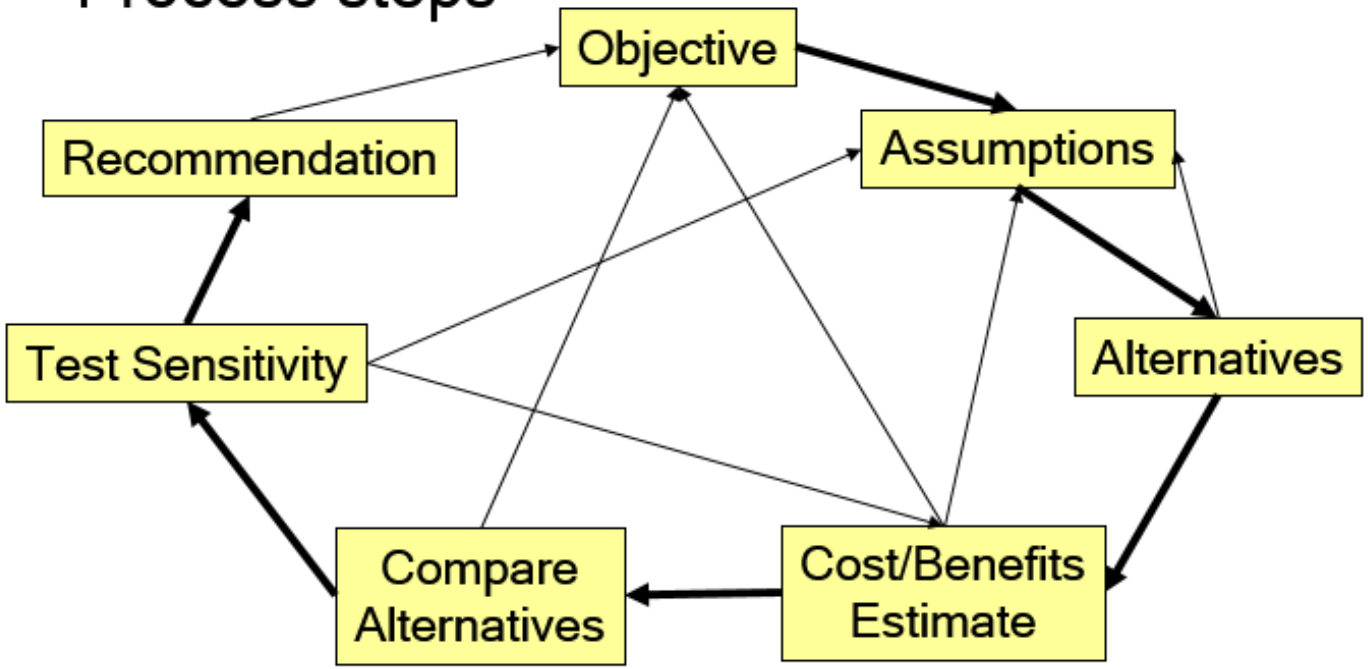
Module 13
Economic Analysis

- 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.

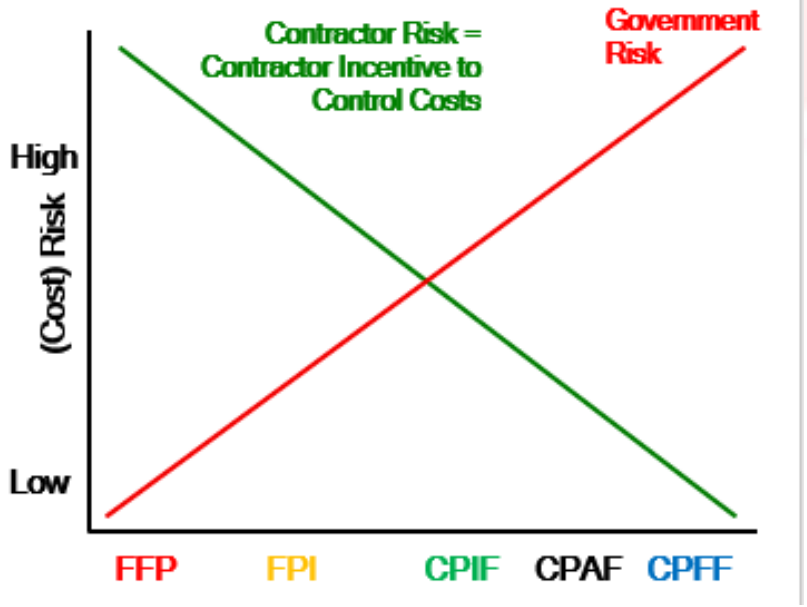
- Practical Applications
  - Cost Proposal Development
  - Cost Proposal Evaluation
    - Including suppliers
  - Negotiations
  - Risk-based ROS (Return On Sales)

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)

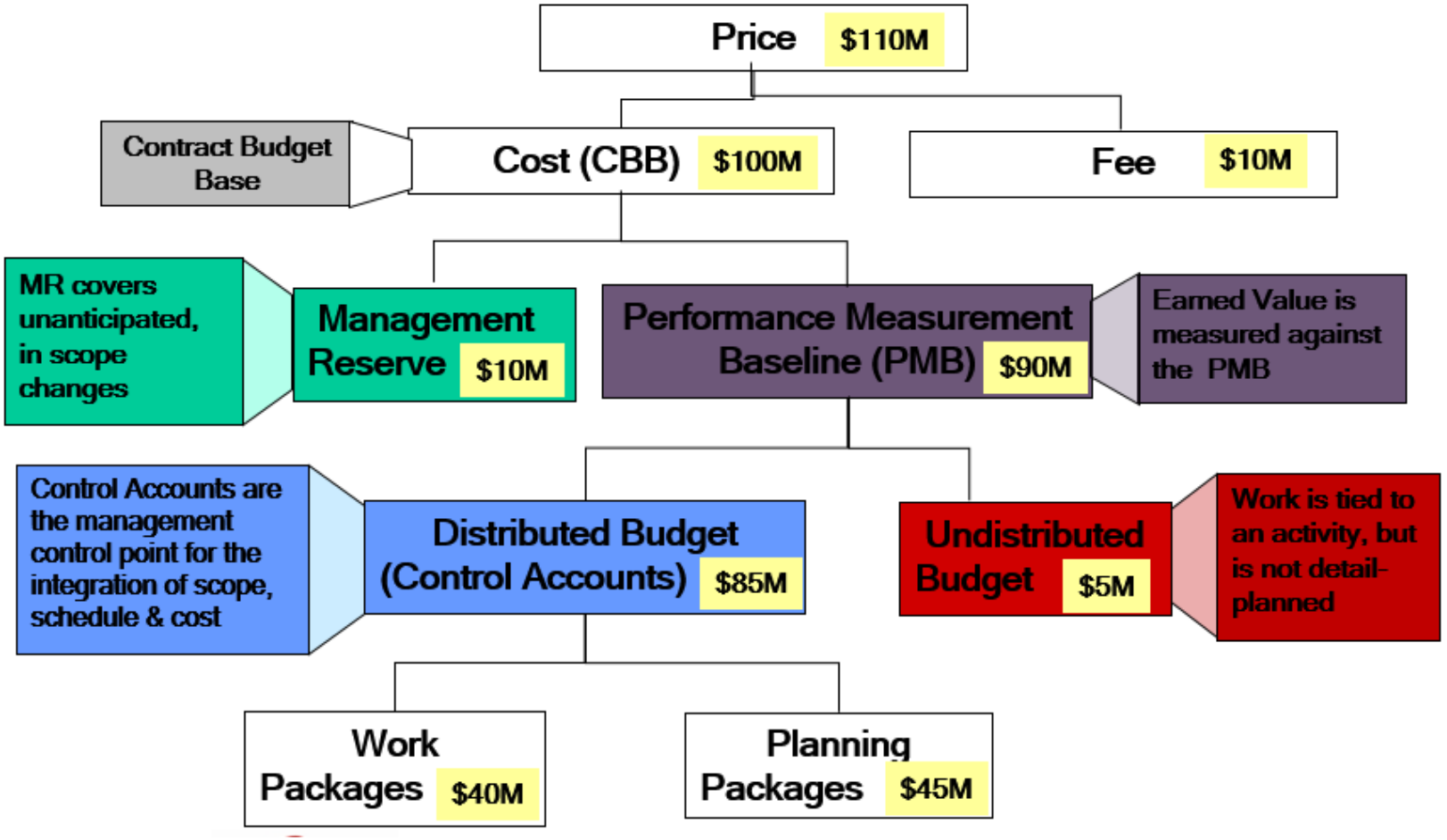
Risk graph



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**



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

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

- 10 **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.

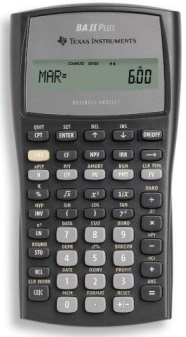
Level of effort

- 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?