A Parameter Driven World

In the future, parameters will drive everything

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June 9, 2015

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Agenda

What is a parameter ?

- A characteristic, feature, or measurable factor that defines a product or program
  - A quantitative measurement / characteristic, such as
    - Weight
    - Speed
    - Years to first flight
  - A qualitative or categorical characteristic, such as
    - Simple, Average, Complex
    - Navy, Air Force, Army
    - Unmanned, Manned
- The "Shall" statements on a systems requirements document often contain parameters
- Parametric analysis is used to develop mathematical relationships between parameters and program costs (for material and labor)

Some Aerospace Parameters

- Examples of parameters in aerospace (for a new development program)
  - Max speed
  - Weight / material breakdown
  - Range
  - Flight envelope / missions / stores
  - Manned vehicle / unmanned vehicle
  - Type of engine(s) / envelope for engine(s)
  - Interfaces / communication requirements
  - Envelopes for subsystems / black boxes
  - Observability
  - Special requirements
  - Security level
  - Quantity of aircraft
  - Number of drawings

Some IT Parameters

- Examples of parameters in information technology
  - Quantity of servers / hard drives
  - Quantity of desktop computers
  - Quantity of laptop computers
  - Specifications of hardware
    - Capacity
    - Speed
    - RAM
    - Range
    - Operating system
  - Level of security
  - Number of interfaces
  - Communication requirements
  - Lines of code
  - Programming language
  - Number of licenses
  - Number of users
  - Number of web pages
  - Number of records

In the Future, Parameters Will Drive Everything Related to Work

- Humans will choose the parameters, then computers will take over . . . to a greater and greater extent
- Parameters will drive estimates / cost proposals
  - Already happening
- Parameters will drive project management
  - 10 years from now
- Parameters will drive the design
  - 30 years from now
- Parameters will drive production
  - 50 years from now

Jobs will become scarce. Computers will do the bulk of the work.

Parametric Cost Estimating

What is Parametric Cost Estimating ?

- An estimating technique that uses a statistical relationship between historical cost data and "other variables"
(for example, square footage in construction, lines of code in software development) to calculate estimates for activities

  PMBOK

- A mathematical procedure where product or service descriptors (parameters or independent variables) and cost algorithms directly yield consistent cost information **NASA**

- Mathematical representation of Cost Estimating Relationships that provides a logical and predictable correlation between the physical or functional characteristics of a system, and the resultant cost of the system **NASA**

What is Parametric Cost Estimating ?

- Parametric estimating is a method by which aggregated costs are derived as a function of high-level product characteristics or parameters **DoD AMMTIAC**
- The resulting equations are known as Cost Estimating Relationships (CERs) **DoD AMMTIAC**
- Using parametric methodology can provide:
  - Accurate and supportable contractor estimates
  - Lower cost proposal processes
  - More cost-effective estimating systems
- Many companies need to improve the way cost information is collected with “other data”.   The “other data” is often lost or forgotten.

Parametric cost estimating should provide improved accuracy, depending on the data

Preferred Estimating Methodology

Analogous – compare to actual history for a similar task or factored with justification

Standard time or labor standards (backed up with time studies) with learning curve included

Parametric - historical relationships to non-cost parameters calibrated and adjusted for complexity

- Hours per drawing
- Hours per pound
- Hours per SLOC

Cost Estimating Relationships (CERs)

- Percent to factory touch labor

Level of Effort (LOE) compared to a previous project or phase

Judgment / expert opinion / grassroots

Most Preferred

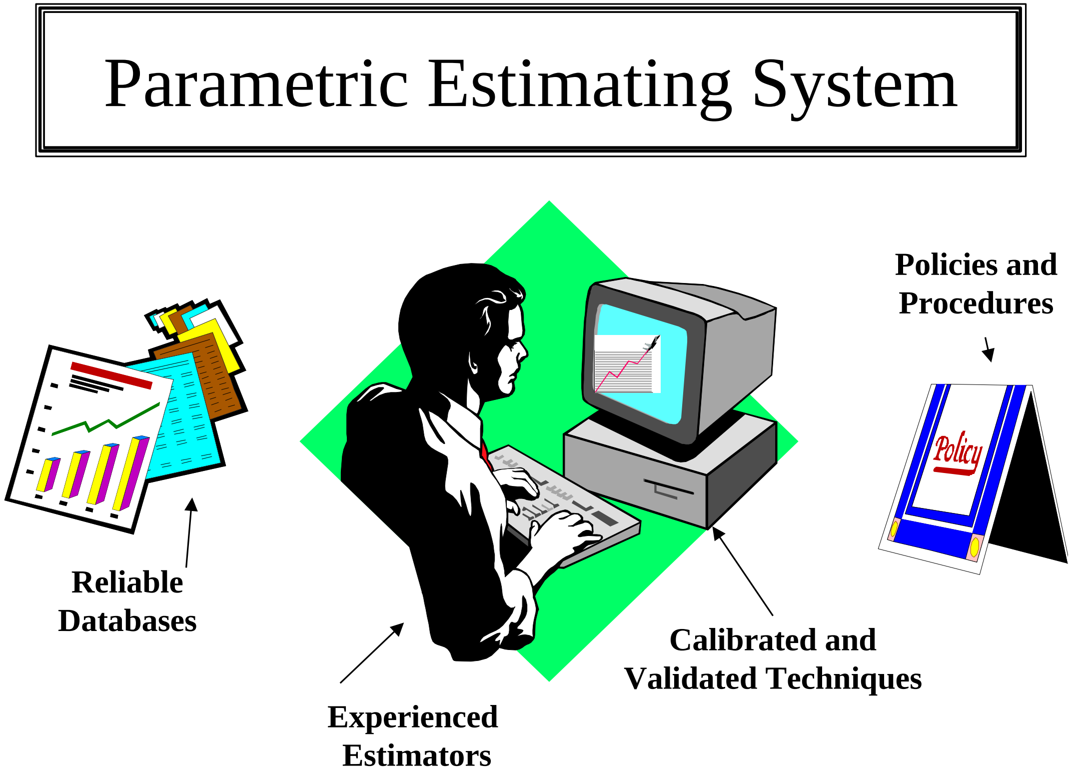
Parametric estimating has been viewed with some skepticism, but is gaining acceptance. It will eventually be at the top of the list.

CEBoK modules (formerly CostPROFS)

I. Cost Estimating
  1. Cost Estimating Basics
  2. Costing Techniques
  3. Parametric Estimating
II. Cost Analysis Techniques
  4. Data Collection and Normalization
  5. Index Numbers/Inflation
III. Analytical Methods
  6. Basic Data Analysis Principles
  7. Learning Curve
  8. Regression Analysis
  9. Cost Risk Analysis
  10. Probability and Statistics
IV. Specialized Costing
  11. Manufacturing Cost Estimating
  12. Software Cost Estimating
V. Management Applications
  13. Economic Analysis
  14. Contract Pricing
  15. Earned Value Management Systems (EVMS)
  16. Cost Management

Module 3 – Parametric Estimating

This module provides an overview of parametrics. It covers the process of building parametric models and describes how those models are used. The module discusses cost estimating relationships (CERs) and introduces the topics of data use, CER development, and development of complex models. The proper development and application of CERs depends on understanding the associated mathematical and statistical techniques. This module provides general guidance for use in developing and employing valid CERs, including differences between simple and complex CERs, techniques for developing and implementing CERs, including linear regression ordinary least squares (OLS) "best-fit" models. It also examines current "Off the Shelf" models and development tools such as PRICE, SEER, COCOMO II, and ACE-IT and their particular applications.



5.3.2 Data Collection and Analysis

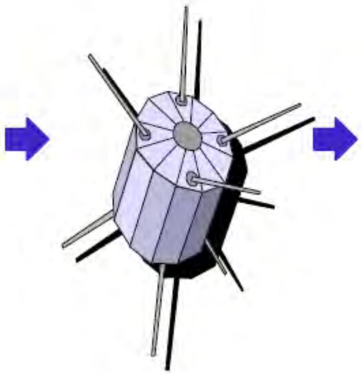
Parametric techniques require the collection of historical cost data (or labor hours) and the associated non-cost data which describes the physical, performance, and engineering characteristics that influenced those costs. Data should be collected and maintained with an audit trail. Historical cost data may need to be normalized or adjusted to account for differences related to scope of work, program anomalies, changes in technology, new business practices, inflation, learning curve and quantities, and production rate.

Non-recurring and recurring costs should be separately identified.

Hardware Modeling

A Hardware Model Uses Common Parameters
To Estimate and Evaluate New Requirements

- Input Parameters
  - Magnitude (quantity)
  - Operating environment
  - Amount of new design & design repeat
  - Engineering complexity
  - Manufacturing complexity
  - Schedule
  - H/W - S/W integration
  - Weight / volume



- Output Parameters
  - Cost
    - Development
    - Production
    - Engineering
    - Manufacturing
  - Schedule risks
  - Unit /system integration costs

Figure 5.1 Hardware Model Input and Output Parameters

Parameters will drive estimates / cost proposals

- Input the parameters
- Output will include the following :
  - Time-phased cost estimates
    - Direct labor
    - Support labor
    - Tooling
    - Parts
  - Supporting rationale (BOEs)
  - Cost Management Plan

- Estimates will be fast (almost instantaneous), accurate and time-phased
- Already happening at some companies
- Some companies do not have sufficient data - the transition to parametric estimating is difficult
- Off-the-shelf cost models can be used (PRICE, SEER, etc.)
- There are pros and cons of parametric cost estimating

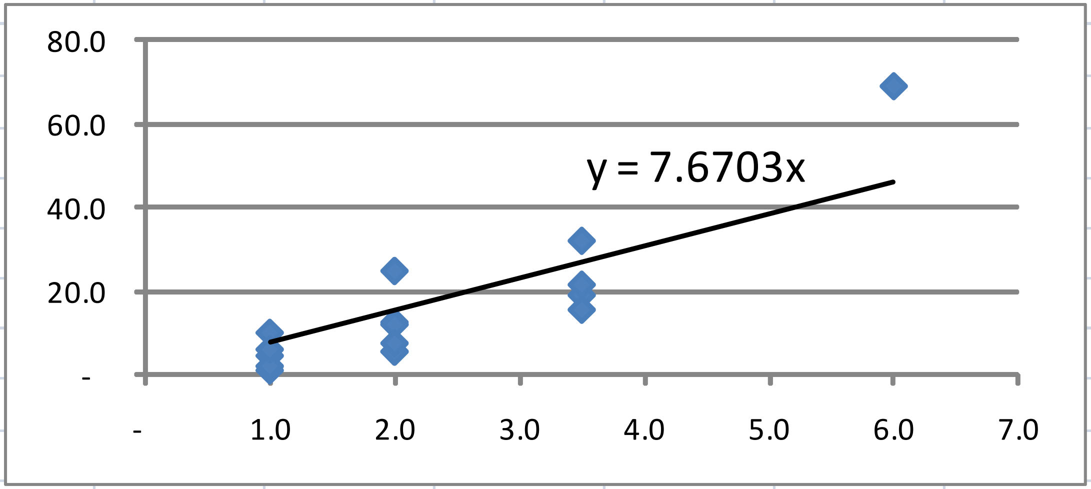
DFARS requirements for estimating systems

- DFARS 215.4 and 215.8 require
  - All DOD contractors to have acceptable estimating systems
  - Certain large businesses to disclose their estimating systems in writing, provide guidelines concerning the characteristics of an acceptable estimating system, and provide guidance for team estimating system reviews
  - If a contractor is required to disclose their system, all significant parametric cost estimating techniques need to be disclosed
  - Acceptable estimating system means
    1) Is maintained, reliable, and consistently applied
    2) Produces verifiable, supportable, documented, and timely cost estimates that are an acceptable basis for negotiation of fair and reasonable prices
    3) Is consistent with and integrated with the Contractor's related management systems
    4) Is subject to applicable financial control systems

A simple parametric estimating example

REGRESSION OUTPUT

Regression Statistics	
Multiple R	0.9209
R Square	0.8481
Adjusted R Square	0.7856
Standard Error	8.8153
Observations	17



ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6942.4	6942.4	89.3371	0.0000001
Residual	16	1243.4	77.7		
Total	17	8185.8			

	Coefficients	*Std Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0					
X Variable 1	7.6703	0.8115	9.4518	0.0000	5.9500	9.3907

Y = 7.67 X1

Example with one independent variable (complexity) in which values for the independent variable have been assigned as follows; simple=1, average=2, above average=3.5, complex=6

Pros and Cons of parametric cost estimating

- Pros
  - Faster estimating process
  - More accurate estimates
  - Better substantiation (less subjective)
  - Smaller negotiation decrements (if there is agreement on complexity)
  - Easily adjusted as parameters change
  - Faster negotiations
  - Faster budget release
- Cons
  - Less flexible estimates, less negotiating room
  - Estimates are at a higher level, less visibility at lower levels
  - Judgment on complexity will be the point of contention
    - Significant difference in estimate with a next up/down change in complexity
  - Customer reaction unknown
    - Giving the customer more data gives them more to pick at
    - Customer may not fully understand the methodology and be skeptical
  - Expectations may be raised (for other proposals) - It may be difficult to go back to the old way
  - Insufficient historical data on a key parameter (a new technology)

Aversion to any of the "Cons" causes many companies to be wary of parametrics

Building and maintaining an estimating database

Specific Steps for Starting a Database

- Locate Cost / Labor Data
- Copy Data to a Master Spreadsheet
- Verify Data (accuracy / completeness)
- Organize / Categorize / Sort Data
- Select / Exclude Data
- Locate Non-Cost Parameters
- Align Cost / Labor Data to Non-Cost Parameters
- Analyze / Develop Relationships
- Develop Model
    - Input Format / Parameters
    - Internal Equations
    - Output Format / BOE
- Test / Calibrate Model
- Document Procedures
- Use Model for Estimating

The key is to capture cost and parametric data upon closeout of each contract (each project / each phase / and each change that is separately tracked)

What makes a good parameter ?

Need these 3 things

1. Quantifiable
   - A quantitative parameter (such as weight)
   - A qualitative parameter which is converted to a quantitative value
     - Simple = 1, Average = 2, Complex = 4
2. Good correlation to the dependent variable, either positive or negative
   - Positive correlation
     - When the parameter increases, the dependent variable increases
     - When the parameter decreases, the dependent variable decreases
   - Negative correlation
     - When the parameter increases, the dependent variable decreases
     - When the parameter decreases, the dependent variable increases
3. The value is known or can be estimated accurately up front
   (At the time the estimate is made)
   - Do not use a parameter if its value is as uncertain as the dependent variable it is trying to estimate
     - For example, using SLOC (if you haven't a clue what the number is) to estimate software programming hours

How to convert a qualitative parameter to a quantitative value

- Many qualitative parameters can be converted to quantitative values
- Assign values which correlate with the dependent variable
- Example 1: If data suggests that an average item is twice as costly to produce as a simple item, and a complex item is twice as costly as an average item, then assign values as follows
  - Simple = 1, Average = 2, Complex = 4
- Example 2: If estimating machining time, assign values to the material type proportional to the achievable material removal rates, such as
  - Aluminum = 4, Brass = 3, Steel = 1, Titanium = 1
- If an important qualitative parameter cannot be converted to quantitative values, you must analyze the data for each category of that parameter separately

Parametric Project Management

Parameters will drive project / program management

- Input the parameters
- Output will include the following :
  (In addition to cost estimates, supporting rationale, and Cost Management Plan)
  - Integrated Statement of Work
  - Integrated Project Management Plan
  - Project Scope Statement / Plan
  - Work Breakdown Structure (WBS)
  - Task Schedules
  - Budget / Cost Management (EVMS) Plan
    - Accurate Tracking of Workload / Status for All Workers
  - Quality Management Plan
  - Human Resource Management Plan
  - Communications Management Plan
  - Risk Management Plan
  - Procurement Management Plan

This is starting to happen, and will be common practice within 10 years

Parametric Design and Production

Parameters will drive the design

- Input the parameters
- Output will include the following:
  (in addition to everything already discussed)
  - Basic initial design
  - Preliminary parts list

Parameters will drive the design

- Input the parameters
- Output will include the following :
  (in addition to everything already discussed)
  - N/C programming and fabrication of parts or ordering of parts
  - Tool design and fabrication
  - Sub-assembly
  - Final assembly

The long range future

- Computers and robots will do almost everything

Trivia Time:

Name these movies?

What year(s) were these set?

← How old was Michael York?

Name the actor below ↓?

One of the few remaining jobs will be end-of-life specialist

Parametric Affordability Improvement

Using parametric analysis to improve affordability

- The key to affordability is gaining parametric control over
  - Touch labor
  - Support labor
  - Material / supplier costs
- "Parametric control" is knowing what things should cost
- Use parametric analysis to right size / right cost all labor functions and supplier costs

Build cost models and databases to improve affordability

- Affordability starts by finding out what things and tasks should cost (with optimal processes)
  - To do this, you need to develop cost models / databases
- Compare "should cost" to what things / tasks are actually costing
- If actual costs are higher than what they should
  - Figure out what needs to be done to get to the "should cost"
  - Estimate nonrecurring costs to implement the change
  - Estimate the recurring savings (between "should cost" and current actuals)
  - Calculate ROI (= future savings / NR cost)
- Get program management approval to make the change
- Make the change

The more things you know what they should cost, the more opportunities you will find

How to gain parametric control over touch labor

- Measure / monitor work content on a regular basis
  - Use an industrial engineering technique such as
    - Time Study
    - Methods Time Measurement (MTM)
    - Random Time Observation Analysis (RTOA)
  - Develop accurate parametric standards for basic tasks: locating parts, drilling, fastener installation, etc.
- When employees know there is accurate measurement, they will not sandbag
- What gets measured, gets done
- What gets measured, gets improved
  - Increased motivation for process improvements

How to gain parametric control over support labor

- Use industrial engineering techniques
- Determine the parameters which drive the work
- Determine which tasks are necessary to get the job done
- Develop metrics for major tasks for all support functions
  - Interview workers
  - Collect parametric data (labor hours and parameters)
  - Develop parametric standards for tasks (the work content)
  - Develop improvement curves - support labor improvement curves are typically steeper than touch labor
- Staff to the right size
- Implement an earned value management system
- When employees know there is accurate measurement, they will not sandbag
- What gets measured, gets done
- What gets measured, gets improved
  - Increased motivation for process improvements

How to figure out what the parameters are for support labor

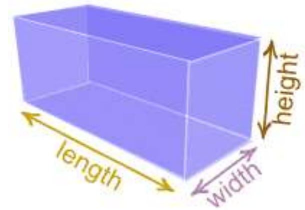
- Developing metrics for support functions is just a matter of:

  <u>asking the right questions</u>

  - What are the main categories of work in your function (the main tasks / things you do) ?
  - What are the outputs (drawings, reports, purchase orders) ?
  - What are the inputs (change requests, purchase orders) ?
  - What drives the amount of work for each of your tasks (what are the parameters) ?
    - Quantitative drivers (number of parts, number of drawings, number of interfaces, lines of code)
    - Categorical drivers (complexity, programming language)
  - How long does it take to do task A if the parameters are XYZ ?
  - How much more (less) if parameter X is changed ?
  - Here is some historical data for a completed task. Could you please describe the parameters that were associated with this task ?

How to gain parametric control over parts costs

- Figure out the parameters that drive costs
  - Material type (aluminum, titanium, composite)
  - Material form (plate, forging, sheet)
  - Weight
    - Raw material weight
    - Finished weight
  - Complexity (simple=1, average=2, above average=3.5, complex=6)
    Or perhaps surface area is a better parameter to use, to avoid subjectivity
  - Manufacturing process (high speed machining, sheet metal fab, handlay)
  - Additional finishing process (heat treat, anodize)
  - Lot quantity and cum unit number
  - Labor rates
  - Raw material cost per pound



- Put all the data on a spreadsheet

Part Number	Part Cost (Labor Portion)	Part Cost (Material Portion)	Material Type	Material Form	Raw Material Weight	Finished Weight	Complexity	Manufacturing Process	Additional Finishing Process	Lot Quantity	Labor Rate	Raw Material Cost Per Pound

How to gain parametric control over material costs

- Develop a parametric model for estimating “should cost” of parts based on the parameters
- Develop a parametric model for cost of changes to parts
  - Nonrecurring impact - the cost to make the change
  - Recurring impact - the delta cost per part for all future parts
- Data is available to develop these models
  – you just have to dig for it
- Major contractors need a parametric estimating model for parts costs for effective negotiations with suppliers, otherwise the suppliers have the advantage
- Keep up with state-of-the-art technologies
  (i.e. for optimal cutting speed)
- Select suppliers who are improving equipment / technology

Tips for developing a database for parts costs

Use analysis techniques to develop an estimating model for parts

- Calculate the raw material cost for a part
  - Raw material weight x cost per pound
- Calculate the processing costs (labor cost)
  - Note: only use data from the most efficient suppliers
  - Separate the labor into these categories
    - Basic processing:
      - Machining time (can be calculated using material removal rate)
      - Non-machining time (loading, unloading, cutter changes, etc.)
      - Setup (setup time / lot size = setup per part)
    - Additional finishing processes (if any)
    - Additional sub-assembly (if any)
    - If labor data not available, estimate (using ind eng techniques or reverse engineer)
  - Use analysis techniques to develop an estimating model for the labor cost
    - Use regression analysis: labor vs. Parametric factors (weight, complexity, etc.)
    - Labor cost per part = hours x labor rate
- Cost per part = raw material cost + processing costs

Run all your parts through the model and you will find the affordability opportunities

Questions ?

Thank you

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