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Cost Engineering

Is Your Organization Ready for Model-Based Cost Engineering (MBCE)?

ICEAA, Pittsburgh PA, 2022 Mike Ahearn & John Swaren

Bottom Line Up Front

- Model-based design continues to yield unprecedented speeds in technology solution development.
- Integrated and data-driven Model-Based Cost Engineering ("MBCE") promises to estimate concurrently at the speed of design.
- Taking advantage of MBCE requires vision and a level of organizational maturity.
- This presentation discusses discuss critical attributes regarding people, processes, data and technology that impact the success of model-based costing.

What is Model-Based Cost Engineering

- Model-Based Cost Engineering (MBCE) is a cost engineering approach that applies scientific principles and techniques to cost, schedule, uncertainty estimation, cost control, business planning, management science, profitability analysis, project management, and planning and scheduling.

MBCE and Organizational Readiness

- Model-based design should derive optimal technology solutions with achievable implementations supported by affordable cost estimates.
- Simply put, the best solution must also be executable with acceptable costs.
- Organizational readiness to adopt MBCE, informed by model-based design, reflects commitment to streamlined, credible, repeatable, integrated business processes.
- The latter is well served by design-specific, data-driven estimation via predictive cost modeling that is accurate, timely and defensible.

Attributes for Success

- An organization must evaluate its maturity by surmising attributes critical to MBCE success:
  - **DATA** in two forms: (i.) Information, cost and technical, concerning historical projects, and (ii) future project descriptors from design tools that directly inform predictive cost model input drivers as well as attributes to best find the latter;
  - **PEOPLE** identified and available who are either (i.) required to interpret historical data, (ii.) SMEs/influencers for future project descriptors above, or (iii.) stakeholders affected by cost engineering;
  - **PROCESS**, including culture, necessary so that estimation is conducted in a rational, repeatable, timely manner, ensuring that the outputs are traceable to source data and assumptions;
  - **TECHNOLOGY** both supporting interpretation of historical data, as well as facilitating direct transfer of design-model artifacts and project descriptors to MBCE tools.

Traditional Challenges of Engineering Build-up Estimating

Time Consuming & Expensive

Ties up valuable engineers for weeks at a time, is frequently not repeatable and generally leads to rework

SME Dependency

Heavy dependence on SME's nearing retirement as well as an engineering shortage

Failure to harness data

Failure to systematically harness past performance data to inform estimates

Knowledge Capture

SME knowledge is not a corporate asset

Spreadsheet Dependence

High Excel dependence – much time wasted and little governance

Lifecycle Turbulence

Disconnect between estimates across the lifecycle

No Food Label

No consistent "food label" leading to delayed decisions and waning confidence

Low Morale

Engineers don't consider cost estimating a core competency

Goal: Improve cost estimation speed, accuracy and defensibility through data-driven, model-based cost engineering

Integrated Suite of Capabilities

Integration streamlines the process from data exploration to BOE

System-of-Systems

Rapidly model technology solutions regardless of size or complexity

Total Lifecycle Estimating

Estimate development, production and O&S dynamically tied to the technical solution

Unparalleled Speed

Complex estimates in weeks, not months. Requirement changes accommodated in minutes, not weeks

Cost, Schedule & Uncertainty

Predictive analytics generate credible cost estimates over predicted or prescribed schedules including uncertainty analysis

Total Lifecycle Metrics

Automatically generate critical decision support metrics such as T1 cost, unit production cost and cost/flight hour

Custom Models

Proprietary or custom predictive models can be built and published into your estimate to ensure comprehensive estimates

Basis-of-Estimate Capability

Data-driven, BOE documentation generated in minutes including an operational Excel model

Onboarding: A comprehensive approach to implementing data-driven, model-based cost engineering

People

People are required to interpret historical data and predict the cost for the new projects and services that will satisfy the perceived capability or requirements.

Process

Process is necessary to conduct an estimate rationally and repeatably so that the outputs are traceable to source data and assumptions.

Data

Data is any information, cost and technical, concerning historical projects and services, which are the foundation of future cost engineering estimates

Technology

Technology is the software system that enables cost engineers to interpret historical data, including tools used to create cost estimating relationships, historical trend analysis, or other technology that allow the application of such relationships to generate estimates.

Stakeholder

Stakeholders are anyone that has interest in or is affected by cost engineering. There are four categories of stakeholders: users, providers, influencers and governance.

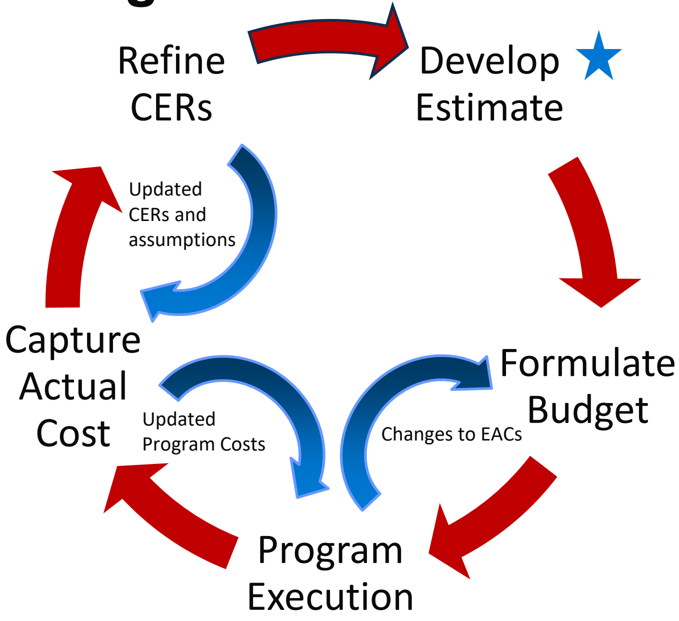
Culture

Culture in a corporation guides how employees of the company act, feel and think. It symbolizes the unique personality of a company and expresses the core values, ethics, behaviors, and beliefs of an organization

MBCE Discovery Process

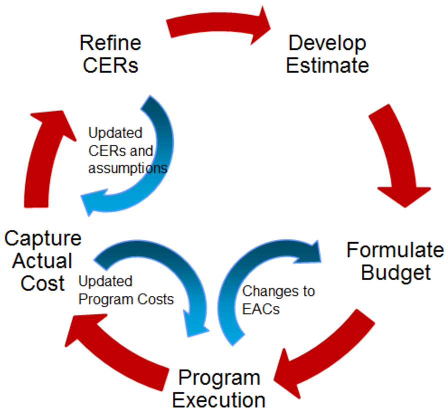
- **Process** – Describe the estimating process for your functional area
- **Data** – Describe the source/destination of the data used to inform your estimates
- **Data** – Describe how the data supports estimation
- **Tools** – What tools are currently used in your functional area for estimation; indirectly; directly; homegrown, commercial
- **Approvals** – What approval processes are required relating to your cost engineering efforts
- **Challenges** – What challenges related to your cost engineering efforts exist that prevent you from doing the best job possible? Classify them as Major or Minor Challenges.
- **Successes** – What successes can you identify concerning your cost engineering efforts in your functional area?
- **Recommended Process Changes** – What cost engineering process changes, if any, would you recommend in your functional area?

Cost Estimating is a Cyclical Process with past programs informing future estimates…



Typical Tasks: Data Mining

- Decide on parameters for study
- Develop an initial methodology
- Outline study ground rules
- Identify stakeholders
- Schedule interviews of stakeholders
- Characterize past project parameters
- Normalize past project actuals
- Identify subsystems with suitable data
- Calibrate suitable subsystems parameters
- Decide on next-steps for further study



Creating Data Collection Plan

- Document the plan…write it down!
- Data collection is lengthy process; continues throughout estimate
- Four main types of data:
  - Cost
  - Schedule
  - Program
  - Technical
- What types of data do you need?
- What types of data are available?
- Develop plan to bridge the gap between these two questions

Data Collection Sources

- Some sources require advance notice for access / clearance
- Sources include:
  - Program Management Plan
  - Cost Analysis Requirements Document (CARD)
  - Integrated Master Schedule
  - Specifications
  - Drawings
  - Size, Weight & Power (SWAP)
  - Labor Rates and Inflation Tables
  - Earned Value data
  - Publicly available sources
  - Paid access sources (i.e. ISBGS®, Haystack)

Interviewing Sources

- Ensure both the interviewer and interviewee are prepared!
- Interviewing is part of the "art" of cost estimating
- Avoid "yes or no" questions or seeking point estimate values
- Bad example:
  - Question: Are we buying 100 widgets this year?
  - Answer: Yes!
- Better example:
  - Question: How many widgets are we buying this year?
  - Answer: We want to buy 100, but we may buy between 80 and 120, based on price.
- Second example provides idea of uncertainty around quantity
- As always, documentation is critical

Collecting and Normalizing Data

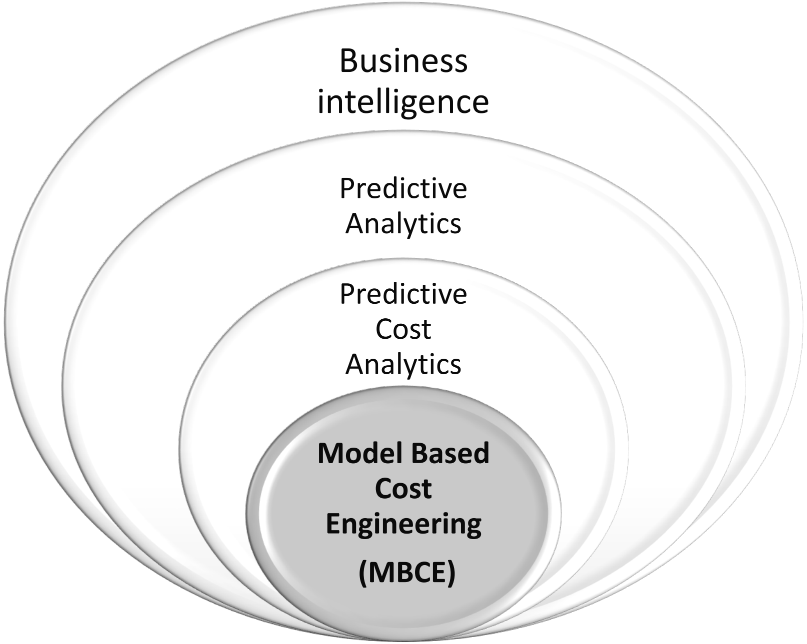
- Collection is just one step in a series to develop a historical data set
- Data points are often (usually) not in the format we need
  - Level of detail may be incorrect
  - May require escalation or de-escalation
  - Cost or price
- Normalization aligns data points in same format for comparison
  - Cost units: may require inflation or currency adjustments
  - Size units: metric units or imperial units?
  - Groupings: mission types, commodities, recurring vs. nonrecurring costs
  - Technology maturity: solid state electronics or vacuum tubes?
- Other Issues: EV, WBS-mapping, completeness, reassignment
- Document any ground rules or assumptions used for normalization
  - Exchange rates
  - Inflation indices
  - Technology or grouping definitions

Biggest Lessons-Learned

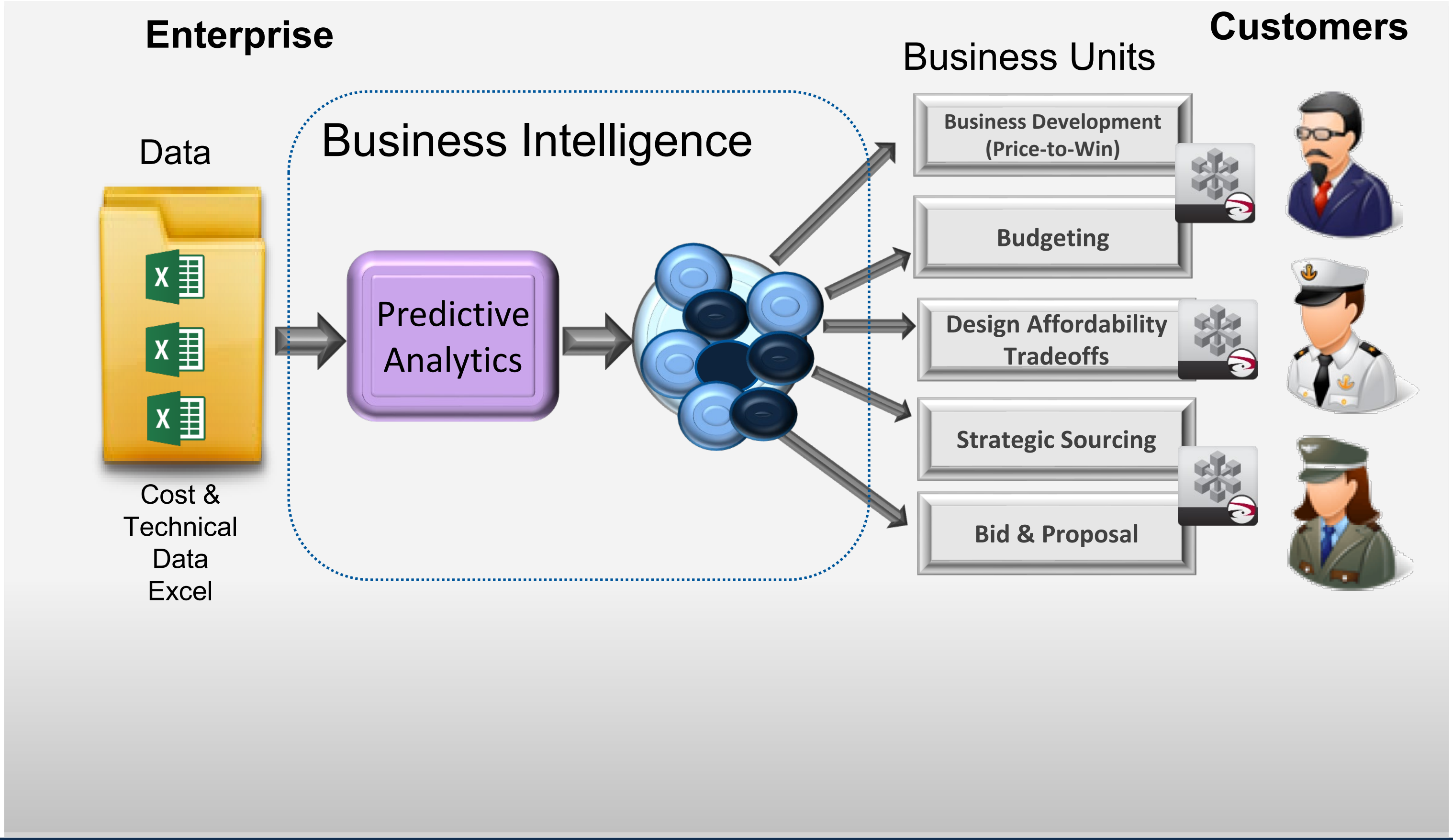
- **Obtain management support** prior to data collection effort with a clear plan and expected results
- **Schedule SMEs** (PMs/Engineers & CAMs) with flexible timing and patience
- **Prepare** “Parametric” and other cost, technical and programmatic data templates to provide consistent method for interviews and to limit rework and re-requests
- **Appreciate** that time with SMEs **is limited, send templates** to SMEs for review **ahead of time**, and **know** that they also want the best outcomes
- **Accept** that memory, fidelity and availability may vary by SME and subsystem
- **Provide SMEs with feedback** once initial results are ready – they will appreciate that their knowledge and work helped the process
- **Document, Document, Document** – be sure to have complete history of the data collection and normalization
- **Expect** that process will take time and that it’s not free for either the data collector or provider!
- **Update or validate** data set periodically to maintain credibility
- **Expect management** (and customers) to appreciate the results of a well documented and efficient data collection process and event

Cost Analytics Overview

- **Business intelligence (BI)** is the set of techniques and tools for the transformation of raw data into meaningful and useful information for business analysis purposes (Wikipedia 2015)
- **Predictive Analytics** encompasses a variety of statistical techniques from modeling, machine learning, and data mining that analyze current and historical facts to make predictions about future, or otherwise unknown, events (Wikipedia 2015)
- **Predictive Cost Analytics** is a library of predictive analytics specifically targeting cost and schedule estimating for products, projects, on-going operations, other cost-incurring activities
- **Model-based cost engineering** encompasses a prescriptive, targeted implementation of predictive cost analytics encompassing a suite of proven processes, automation software, and predictive models



Model Based Cost Engineering



SOFTWARE CASE STUDY

- Sensor-Software Development data in Excel

Calibrated Complexity and Productivity Drivers

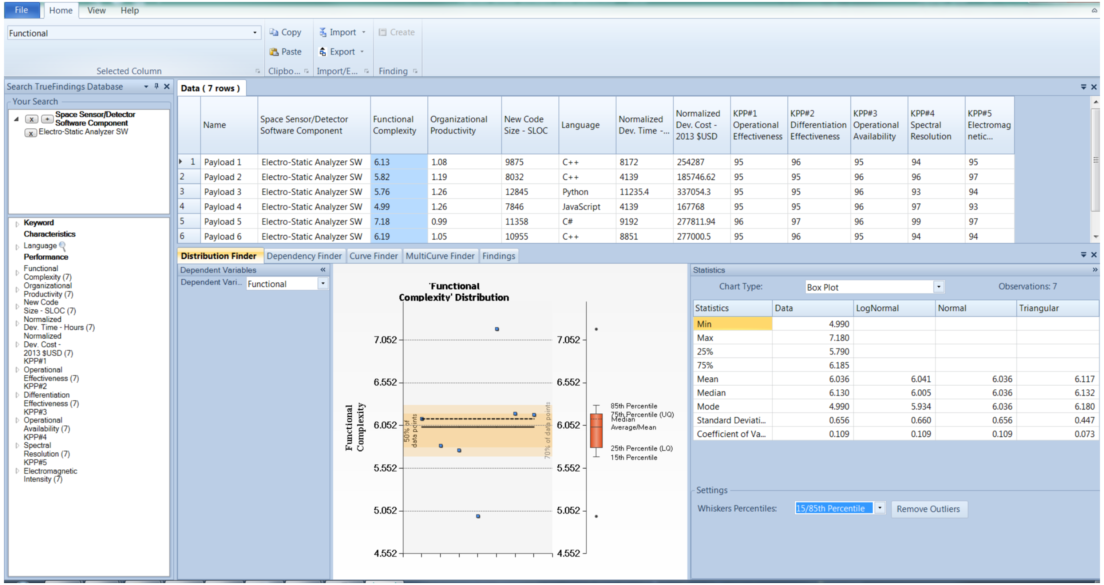
SW Code Descriptors and Hours/Costs

Key Performance Parameters

	A	B	E	F	G	H	I	J	K	L	M
1	Name	Space Sensor/Detector Software Component (Text)	New Code Size - SLOC (Number)	Language (Text)	Normalized Dev. Time - Hours (Number)	Normalized Dev. Cost - 2013 $USD (Number)	KPP#1 Operational Effectiveness (Number)	KPP#2 Differentiation Effectiveness (Number)	KPP#3 Operational Availability (Number)	KPP#4 Spectral Resolution (Number)	KPP#5 Electromagnetic Intensity (Number)
2	Payload 1	Spectrometer SW	4,459	JavaScript	1,681	$ 77,871	95	96	97	95	94
3	Payload 1	Electro-Static Analyzer SW	9,875	C++	8,172	$ 254,287	95	96	95	94	95
4	Payload 1	Gamma Sensor SW	14,129	Java	12,048	$ 357,427	96	97	96	95	96
5	Payload 1	Neutron Sensor SW	14,750	Java	12,257	$ 367,696	97	97	98	98	99
6	Payload 1	Radiometer SW	153,824	Ada95	22,642	$ 746,347	98	98	99	99	99
7	Payload 2	Spectrometer SW	6,237	JavaScript	3,252	$ 133,449	95	96	95	94	95
8	Payload 2	Electro-Static Analyzer SW	8,032	C++	4,139	$ 185,747	95	95	96	96	97
9	Payload 2	Gamma Sensor SW	12,056	Java	10,214	$ 320,078	96	96	95	94	95
29	Payload 7	Gamma Sensor SW	7,495	JavaScript	3,967	$ 145,581	95	96	97	97	96
30	Payload 7	Neutron Sensor SW	12,050	C++	9,413	$ 306,413	95	96	97	95	94
31	Payload 8	Radiometer SW	6,132	Python	3,071	$ 121,318	95	95	94	93	94
32	Payload 8	Spectrometer SW	9,860	C#	7,679	$ 254,287	95	96	95	98	93
33	Payload 9	Electro-Static Analyzer SW	8,176	JavaScript	4,327	$ 185,747	95	96	97	97	97
34	Payload 9	Gamma Sensor SW	13,146	C++	11,943	$ 353,178	95	96	95	98	96
35	Payload 10	Neutron Sensor SW	5,451	Python	2,437	$ 104,469	95	95	94	97	93
36	Payload 10	Radiometer SW	8,764	C#	4,668	$ 189,816	95	96	97	95	95

Perform Predictive Analytics to determine method for fine-tuning software cost drivers as a function of KPPs

TrueFindings® Visualization

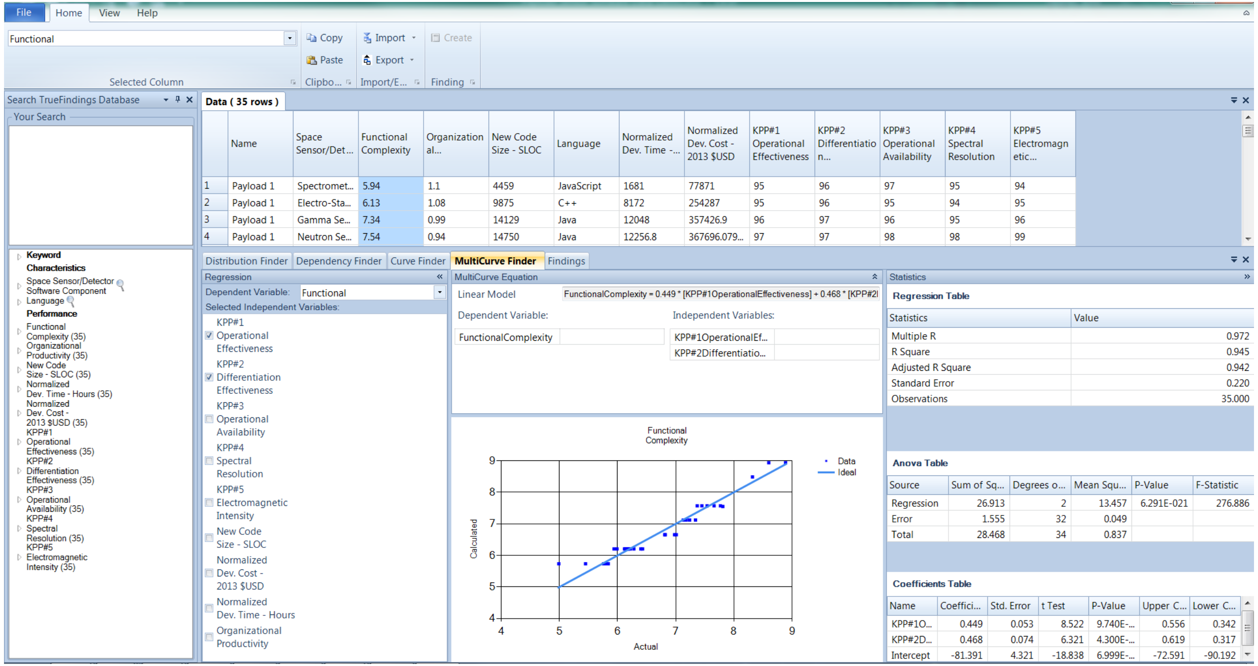


- Example Software Development data: Distribution Finder

  Spreadsheet rows become knowledgebase fields for search/filtering

  1st tab-function shows descriptive statistics for all or (above) selected data

TrueFindings® Visualization



- Example Software Development data: Multicurve Finder

4th tab-function shows multiple (two or more predictors) regression and tables

Q&A

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