

Capability-Based Software Cost Estimation:

Proposing a New Method to Estimate Software Costs

Carnegie
Mellon
University
Software
Engineering
Institute



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Anandi Hira is currently a Data Scientist/Researcher at the Carnegie Mellon University Software Engineering Institute (CMU SEI). Previously, Anandi performed several Agile and software cost estimation research projects as a Senior Cost Analyst at Tecolote Research Inc, leading to 3 publications. She received her PhD in software cost estimation under Dr. Barry Boehm at University of Southern California (USC), where she collected data and calibrated the COCOMO[®] II software cost estimation model to include functional size metrics. Her research interests include software metrics and its application to project management, software cost estimation, and software process improvement.



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Agenda

Capability-Based Planning Literature Review

- Motivation
- Definitions
- Implementation Guidance

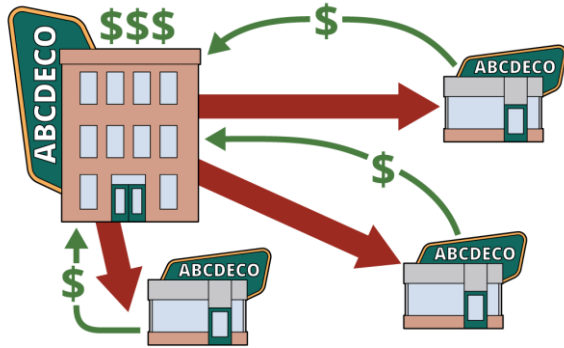
Capability-Based Software Cost Estimation

- Motivation
- Proposed Solution
- Proposed Approach

Capability-Based Software Cost Estimation

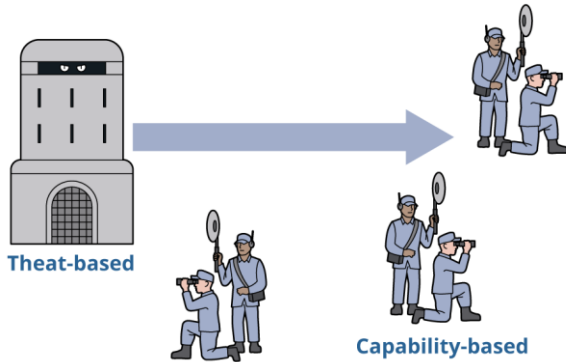
Capability-Based Planning Literature Review

Purpose of Capability-Based Planning (CBP)



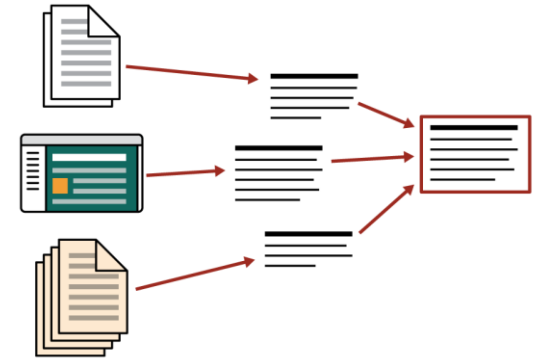
Business

- Identify success criteria and how to achieve them.



Government

- Identify required capability needs for a future, adaptive military force.
- Replace threat-based planning.



Purpose of a Literature Review

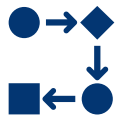
- Consolidate definitions across domains for a comprehensive view of CBP.
- Understand the potential of CBP and the practical implementation of its principles.

What Are Capabilities?



High-Level Objectives

- Capabilities are a “functional approach to the articulation of broad requirements without necessarily specifying the resources that may be involved.”¹
- “Capabilities are not the same as features and functions [...]”^{2, 3, 4}



Activities and Processes

- “Capabilities are formed through the coordination and integration of activities and processes and are the product of collective learning of individual assets.”⁷



Operational Outcomes

- Operational outcomes are “a description of the military operational output or outcome.”⁵
- They “define the future effects needed for agencies to meet their mission and transform into a more agile and adaptable force.”⁶



Ability to Achieve an Outcome

- It is the “ability to achieve a desired effect under specified standards and conditions through combinations of means and ways to perform a set of tasks.”⁸

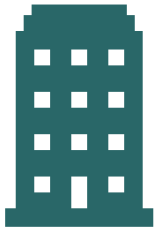
What Is Capability-Based Planning (CBP)?

Three Groups of Perspectives



Cross-Organizational

Evaluate “the development and evolution of capabilities, rather than specific programs or function[s]”⁹ to go “from programs to portfolios of capabilities”^{8,10} and “determine an efficient mix of military forces.”¹¹



Organizational

“An organization’s planning, investments and delivery are aligned to provide the business capabilities that will deliver strategic success.”^{12, 13, 14}



Scenarios

To support a high-level, generalizable framework, CBP “starts with a top-down definition through scenarios, case studies, or use cases” without eliciting detailed requirements.^{15, 13}

CBP Benefits and Challenges

Benefits

- CBP has the “power to create an agency that can better adjust to new threats, eliminate stovepipes, and increase both inter- and intra-agency information sharing,”⁶ maximizing the effectiveness of resources.¹⁶
- It “allows decision makers to consider both the likelihood of the scenario occurring and any consequences of failure.”¹⁷
- CBP “encourages innovation through moving away from determining equipment solutions prematurely”^{18, 19, 1} and “allows for competition among solutions.”²⁰

Challenges

- Accounting for uncertainty is the “most difficult part of” CBP.⁵ It “lacks the detailed analysis required to deal with the current realities of real future threats.”²¹
- There is a need to “incorporate fiscal constraints.”⁸
- There is a “need for estimates on a consistent basis, including costs for force elements that may not yet exist.”¹⁸
- A “common CBP language [is needed] to improve [the] community’s ability to collaborate.”^{8, 22, 23}

Requirements to Implement CBP



“Collaborative Strategies”²³

- “Stakeholder involvement must be achieved early in the lifecycle as [they] generally control information, resources, and [the] authority required to support CBP.”¹⁸
- Systems engineers need to be involved earlier in the “requirements and concept refinement process” of the CBP process.⁸
- “Commitment to a strategy [is] more important than the agreement on every detail.”²³



Capability Levels

- Identify a “desired level of capability needed to achieve [the] stated objectives.”¹⁸
- It must account for “options at different levels of details.”¹⁶



Broad & Specific Scenarios

- These scenarios require stakeholders to “think broadly about entire scenario space of possibilities.”^{25, 10, 16}
- Specific scenarios help with providing context for capability assessment²² and identifying gaps.²⁰



Estimation

- Seek the “most effective and efficient options to satisfy requirements.”²⁴
- Conduct an analysis of alternatives and determine the best solutions.



Common Framework

- “Evaluate multiple performance indicators for capabilities and capability groups.”⁸
- Use “tools that enable visual understanding and dependencies across broad areas of interest.”⁸
- Support collaborations and a portfolio level of planning.⁸

Measures for CBP

Measures of Effectiveness (MOEs)

- Operational measures of success closely related to the achievement of the mission or objectives^{2, 17, 26, 41}
- Tradeoffs: “accuracy vs. collateral damage vs. probability of kill with one weapon”¹⁷

Measures of Performance (MOPs)

- Characterize physical or functional attributes related to system operation^{2, 26, 27}

Measure of Suitability (MOS)

- Degree to which the system can be placed satisfactorily in the field^{27, 28}

Technical Performance Measures (TPMs)

- Attributes that determine how well a system is satisfying a technical requirement or goal²

Key System Attributes (KSAs)

- A system capability considered crucial in support of achieving a balanced solution approach^{2, 27}

Key Performance Parameters (KPPs)

- System capabilities that must be met for a system to deliver its operational goals^{2, 27}

Capability-Based Software Cost Estimation

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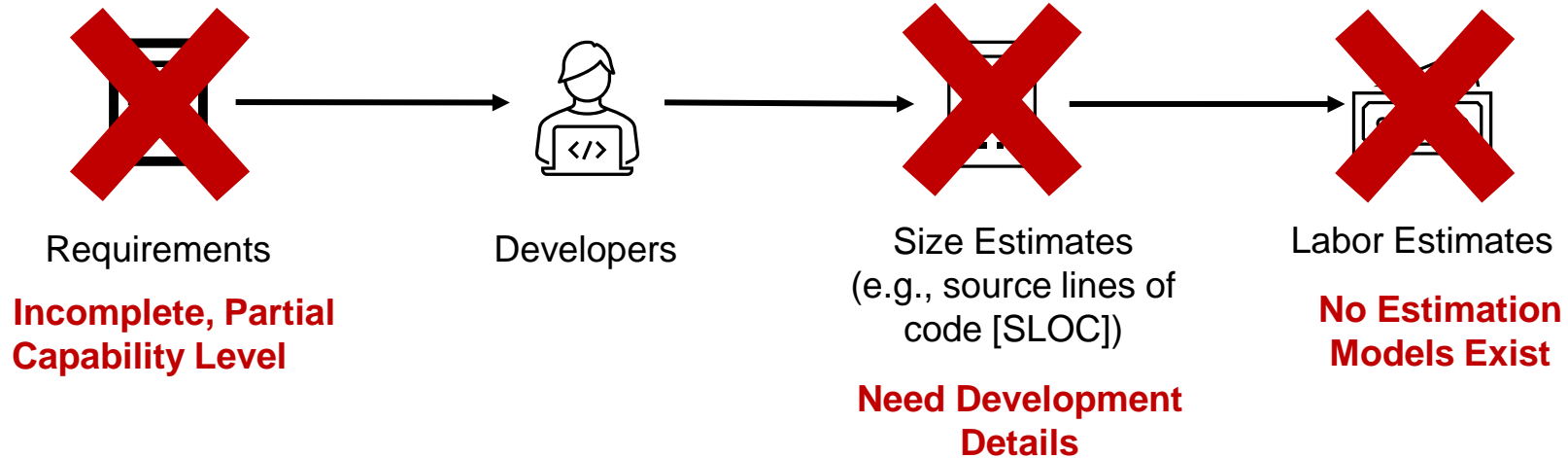
Why are Cost Estimates Important?

- Give Government Acquisition, DoD, Service Cost Agencies, and Congress basis of budget and estimated budget of program
- Answer questions such as: will capabilities be completed by deadline, when will capabilities be completed, what are effects of budget cut?
- Inform margins necessary to mitigate cost and schedule risks.

Unsound estimates have consequences

- Program portfolio cannot balance costs with benefits
- Underfunded programs in the POM (Program Objective Memo) will be perceived as failing by stakeholders, possibly triggering Nunn-McCurdy breaches
- Delayed capabilities increases risk to warfighters and mission accomplishment

Software Estimation Challenge



Need Size and Estimation Model Based on Capabilities

Examples of Problems with Existing Methods

The following are examples of struggles to build reliable, evidence-based cost estimates:

- A software-intensive program does not have faith in estimates based on a SLOC-based parametric model due to significant changes in SLOC estimates over time and a lack of a credible estimate of effort needed to deliver critical capabilities or assess current progress.
- A DevSecOps program budget was developed with level of effort (LOE). It was cut because it failed to justify the budget request by demonstrating capability completion dates.

The literature review suggests the potential for research to address and overcome these challenges.

Potential Research Areas

New software sizing method: capability clusters/groups based on similar software functions

- Based on information known at program initiation (capabilities)
- Accounts for uncertainties (e.g., implementation variations)

Note: The size is not a number, it's a capability type.

Cost model based on capability clusters and group sizing

- Effort ranges of similar capabilities
- Evidence based but also flexible

What Are Clusters of Capabilities with Similar Functions?

GPS/Navigation



vs.

Compilers/Parsers

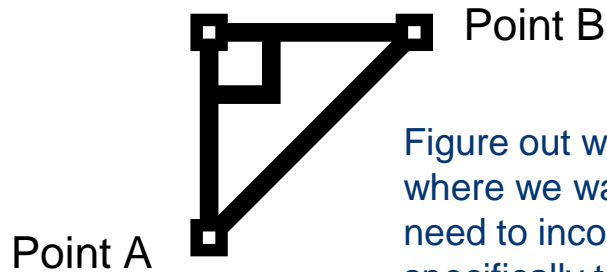
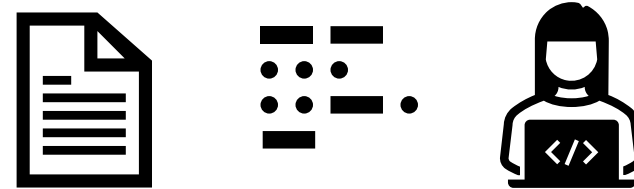


Figure out where we are and where we want to go. We will need to incorporate some math, specifically trigonometry, to determine how to get there.

Parse text and code for prespecified patterns.

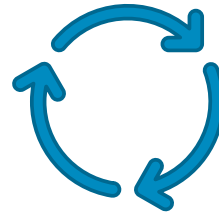
Redefining software size means demystifying the software sizing process while providing an objective, flexible, and defensible estimation method.

Identify Capability Clusters

ISBSG Development & Enhancement (D&E) Data

ID	Descriptive Variables	Effort Hours
1234	ABC 123	#
2234	XYZ acd	#
1345	mn ABC	#
2346	ABC yyy	#
3456	dco XYZ	#
4456	XYZ qrs	#

Study Descriptions to Identify Clusters



Iterate for Improvements

Capability Clusters

ID	Name/Description	Effort
1234	ABC 123	#
2234	XYZ acd	#
1345	mn ABC	#
2346	ABC yyy	#
3456	dco XYZ	#
4456	XYZ qrs	#

Orange and purple represent two capability clusters .

Developing Corresponding Cost Model

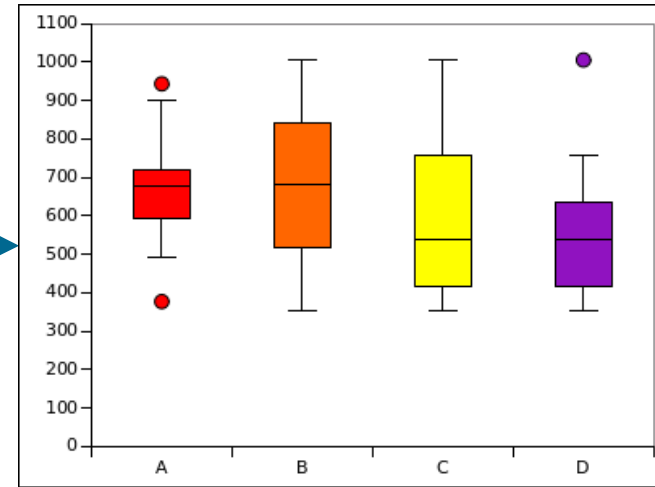
Capability Clusters

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1234	ABC 123	#
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Get Effort Ranges per Capability Cluster

Min, Max, Mean, Median, Variance, Standard Deviation

Cost Model



Orange = Cluster B
Purple = Cluster D

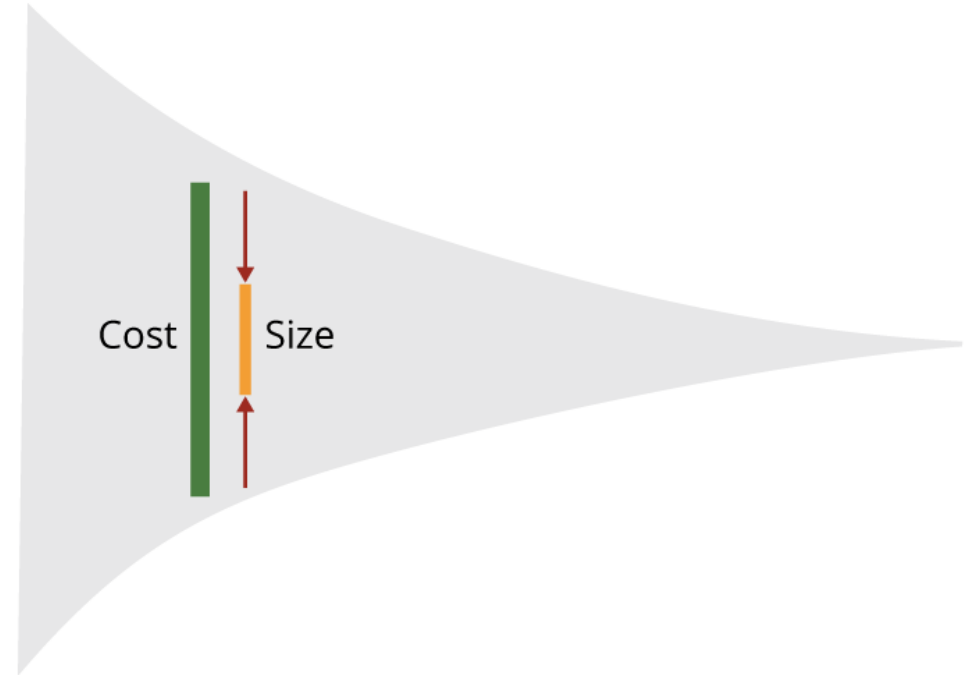
Relevance and Impact of Potential Research

Overcomes Weaknesses of Other Size Metrics

- Use early in the lifecycle.
- Use for evidence-based estimates.
- Reduce sizing error.

Uncertainty Clarity

- Current reports on scope/cost growth also include sizing errors.
- With size constant, now changes can be tracked due to
 - Implementation uncertainty
 - Scope growth



Cone of Uncertainty^{28, 29}

Contact Us!



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Capability-Based Software Cost Estimation

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