Early Phase Software Cost and Schedule Estimation Models

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Outline

- Introduction
- Experimental Design
- Data Analysis
- Descriptive Statistics
- Effort Models
- Schedule Models
- Conclusion

Introduction

Problem Statement

- Software cost estimates are more useful at early elaboration phase, when source lines of code (SLOC) and Function Points Analysis (FPA) are not yet available.
- Mainstream software cost models do not provide alternate functional size measurements for early phase estimation

Significance of Proposed Study

- This study will remedy these limitations in 3 ways:
  1. Introduce effort and schedule estimating models for software development projects at early elaboration phase
  2. Perform statistical analysis on parameters that are made available to analysts at early elaboration phase such as
     - Estimated functional requirements
     - Estimated peak staff
     - Estimated Effort
  3. Measure the direct effect of functional requirements on software development effort

5

Research Questions

Question 1:

Does estimated requirement relate to actual effort?

Question 2:

Do estimated requirements along with estimated peak staff relate to actual effort?

Question 3:

Does estimated effort relate to actual development duration?

Question 4:

Are estimating models based on Estimated Size more accurate than those based on Final Size?

6

Experimental Design

Quantitative Method

- A non-random sample was used since NCCA had access to names in the population and the selection process for participants was based on their convenience and availability (see next slide)
- This study focused on programs reported at the total level rather than by CSCIs, as requirements count at elaboration phase are provided at the aggregate level
- To minimize threats to validity the analysis framework focused on estimated inputs rather than final inputs

8

Instrumentation

- Questionnaire:
  - Software Resource Data Report" (SRDR) (DD Form 2630)
- Source:
  - Cost Assessment Data Enterprise (CADE) website:
    http://cade.osd.mil/Files/Policy/Initial_Developer_Report.xlsx

    http://cade.osd.mil/Files/Policy/Final_Developer_Report.xlsx
- Content:
  - Allows for the collection of project context, company information, requirements, product size, effort, schedule, and quality

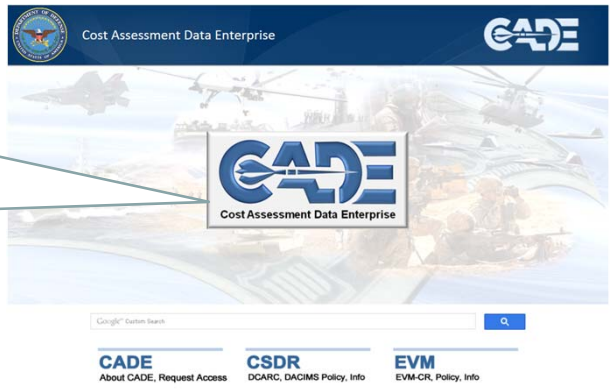
9

Sample and Population

- Empirical data from 40 very recent US DoD programs extracted from the Cost Assessment Data Enterprise:
  http://dcarc.cape.osd.mil/Default.aspx

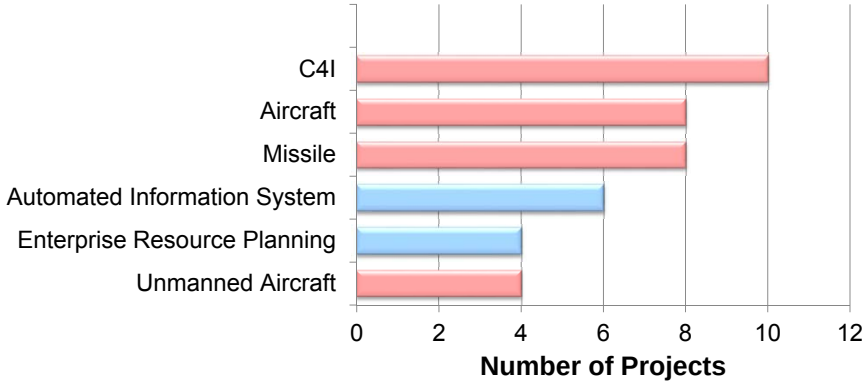
Each program submitted:

SRDR Initial Developer Report (Estimates)
&
SRDR Final Developer Report (Actuals)



10

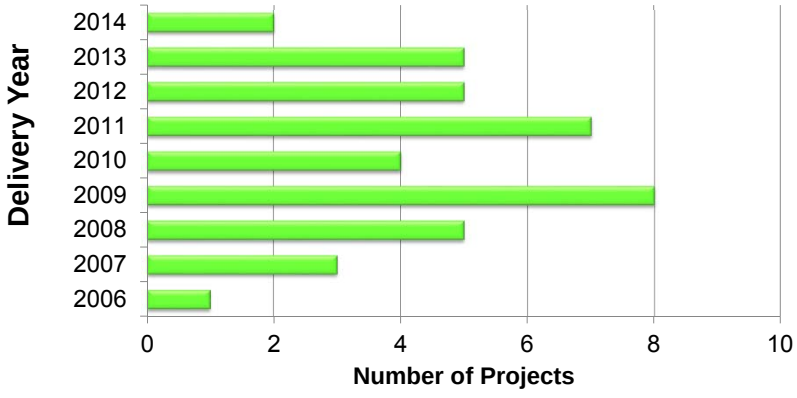
Operating Environments



Major Automated Information Systems (AIS)
Major Defense Systems

11

Project Delivery Year



Projects were completed during the time period from 2006 to 2014

12

Model Reliability and Validity

- Accuracy of the Models verified using five different measures:

Measure	Symbol	Description
Coefficient of Variation	CV	Percentage expression of the standard error compared to the mean of dependent variable. A relative measure allowing direct comparison among models.
P-value	α	Level of statistical significance established through the coefficient alpha ($p \leq \alpha$).
Variance Inflation Factor	VIF	Indicates whether multicollinearity (correlation among predictors) is present in a multi-regression analysis.
Coefficient of Determination	R^2	The Coefficient of Determination shows how much variation in dependent variable is explained by the regression equation.
F-test	F-test	The value of the F test is the square of the equivalent t test; the bigger it is, the smaller the probability that the difference could occur by chance.

13

Data Analysis

Pairwise Correlation Analysis

- Variable selection based on Pairwise Correlation
  - Pairwise Correlation chosen over structural equation modeling as the number of observations (40) was far below the minimum observations (200) needed
  - Variables examined:

Actual Effort
Actual Duration

Estimated Total Requirements
Actual Total Requirements
Estimated New Requirements
Actual New Requirements
Estimated Peak Staff
Actual Peak Staff
Scope
Volatility
Estimated Effort

15

Pairwise Correlation Analysis

	Actual Effort	Actual Duration	Estimated Total REQ	Actual Total REQ	Estimated New REQ	Actual New REQ	Estimated Effort	Actual Peak Staff	Estimated Peak Staff
Actual Effort	1.0	0.6	0.7	0.7	0.7	0.5	0.6	0.4	0.4
Actual Duration	0.6	1.0	0.4	0.4	0.5	0.3	0.2	-0.2	-0.2
Estimated Total Requirement	0.7	0.4	1.0	0.9	0.9	0.7	0.6	0.2	0.2
Actual Total Requirement	**0.7**	0.4	**0.9**	1.0	0.8	0.8	0.6	0.3	0.3
Estimated New Requirement	**0.7**	0.5	**0.9**	**0.8**	1.0	0.9	0.7	0.2	0.2
Actual New Requirement	0.5	0.3	0.7	**0.8**	**0.9**	1.0	0.5	0.5	0.4
Estimated Effort	0.6	0.2	0.6	0.6	0.7	0.5	1.0	0.6	0.6
Actual Peak Staff	0.4	-0.2	0.2	0.3	0.2	0.5	0.6	1.0	1.0
Estimated Peak Staff	0.4	-0.2	0.2	0.3	0.2	0.4	0.6	**1.0**	1.0
RVOL	0.1	0.1	0.0	0.0	0.5	0.2	0.1	0.1	0.1
Scope	0.2	-0.1	0.1	0.1	0.4	0.3	0.1	0.4	0.4

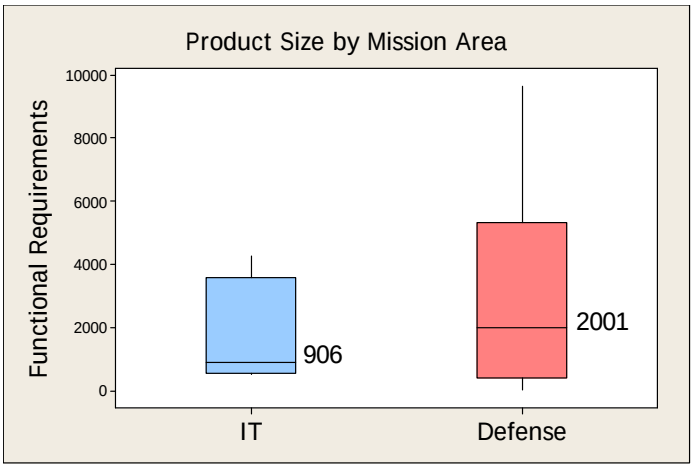
Strong Correlation Moderate Correlation Weak Correlation

- *Estimated Requirements* should be considered in the effort model, as it is strongly correlated to Actual Effort
- *Estimated Peak Staff* should also be considered in the effort model, as it is correlated to Actual Effort
- Although estimated effort is weakly correlated to actual duration, it was still chosen based past literature

16

Descriptive Statistics

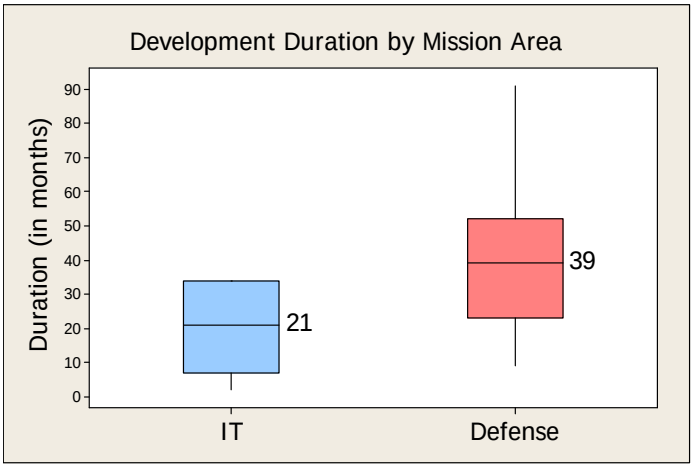
Project Size Boxplot



Observation: higher requirements count for defense projects

18

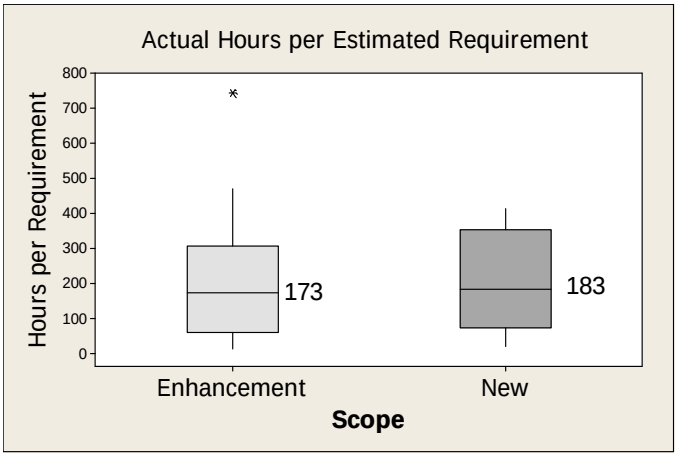
Project Duration Boxplot



Observation: longer duration for defense systems due to interdependencies with hardware design and platform integration schedules.

19

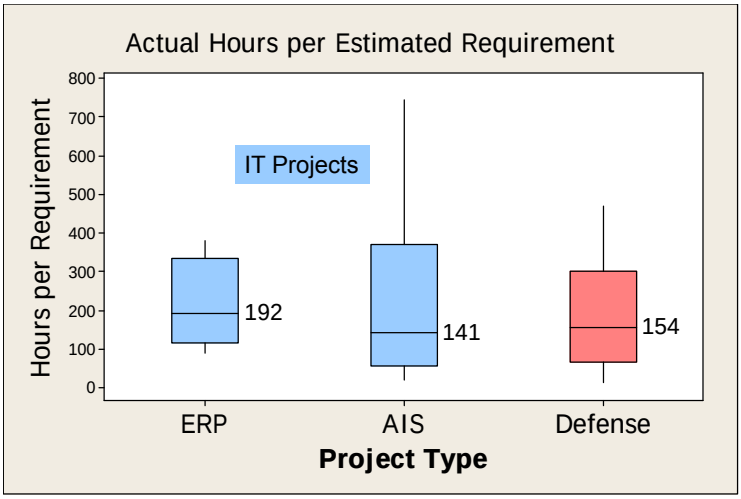
Productivity Boxplot
New vs Enhancement



Observation: No significant difference between new and enhancement projects

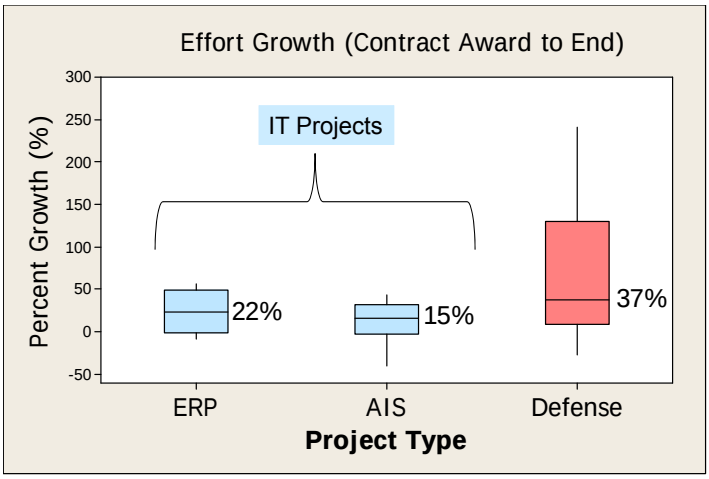
20

Productivity Boxplot
IT vs Defense Projects



Observation:
- ERP shows higher "hours per requirement" due to challenges with customizing SAP/Oracle

Effort Growth Boxplot
Contract Award to End



Observation: No significant difference between Defense and IT projects

22

Effort Models

Effort Model Variables

Variable	Type	Definition
Actual Effort	Dependent	Actual software engineering effort (in Person-Months)
Actual Total Requirements	Independent	Total Requirements captured in the Software Requirements Specification (SRS). These are the final total requirements at end of contract.
Estimated Total Requirements	Independent	Total Requirements captured in the Software Requirements Specification (SRS). These are the estimated total requirements at contract award.
Actual Peak Staff	Independent	Actual peak team size, measured in full-time equivalent staff. Only include direct labor.
Estimated Peak Staff	Independent	Estimated peak team size at contract award, measured in full-time equivalent staff. Only include direct labor.

24

Effort Model 1: using Estimated REQ

Equation:

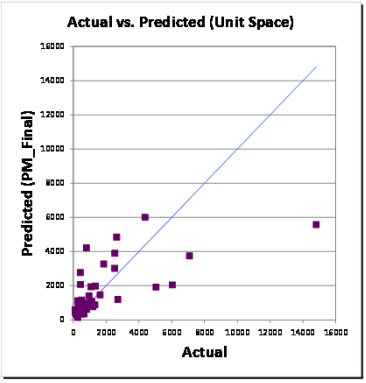
Model Form	N	R^2	CV	Mean	MAD	REQ Min	REQ Max
PM = 22.37 x eREQ$^{0.5862}$	40	76	64	1739	58	25	13900

Where:

PM = Actual effort (in Person Months)

eREQ = Estimated total requirements

Variable	Coeff	T stat
Intercept	22.37	1.8262
eREQ	0.5862	7.3870



25

Effort Model 2: using Actual REQ

Equation:

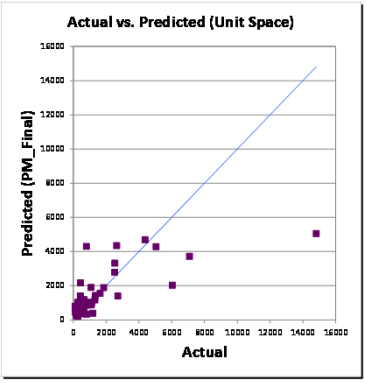
Model Form	N	R^2	CV	Mean	MAD	REQ Min	REQ Max
PM = 29.08 x aREQ$^{0.5456}$	40	74	54	1739	55	35	12716

Where:

PM = Actual effort (in Person Months)

aREQ = Actual total requirements

Variable	Coeff	T stat
Intercept	29.08	1.7464
aREQ	0.5456	6.600



26

Effort Model 3: using Estimated REQ and Staff

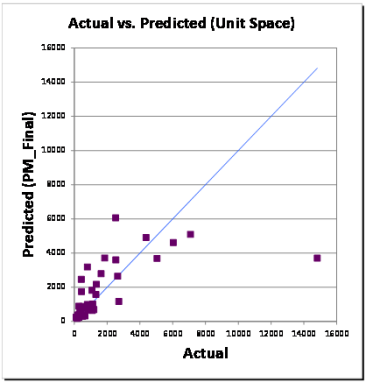
Equation:

Model Form	N	R^2	CV	Mean	MAD	REQ Min	REQ Max
PM = 11.82 x **eREQ**$^{0.4347}$ x **eStaff**$^{0.4269}$	40	78	54	1739	47	25	13900

Where:

PM = Actual effort (in Person Months)
eREQ = Estimated total requirements
eStaff = Estimated Peak Staff

Variable	Coeff	T stat
Intercept	11.82	1.8790
eREQ	0,4347	4.7140
eStaff	0.4269	3.5372



27

Effort Model 4: using Actual REQ and Staff

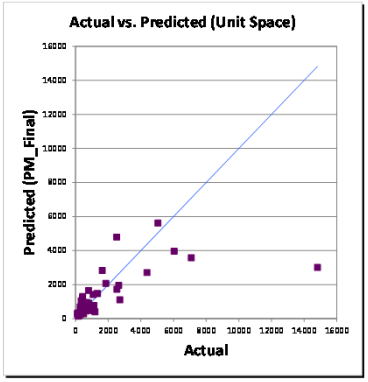
Equation:

Model Form	N	R^2	CV	Mean	MAD	REQ Min	REQ Max
PM = 17.01 x **aREQ**$^{0.3006}$ x **aStaff**$^{0.5124}$	40	66	50	1739	57	35	12716

Where:

PM = Actual effort (in Person Months)
aREQ = Actual total requirements
aStaff = Actual Peak Staff

Variable	Coeff	T stat
Intercept	17.01	5.8891
aREQ	0.3006	3.3815
aStaff	0.5124	4.2866



28

Schedule Models

Schedule Model Variables

Variable	Type	Definition
Actual Duration	Dependent	Actual software engineering duration (in Months) from software requirements analysis through final qualification test
Actual Effort	Independent	Actual software engineering effort at the end of the contract
Estimated Effort	Independent	Estimated software engineering effort at contract award.

Schedule Model 1: using Estimated Effort

Equation:

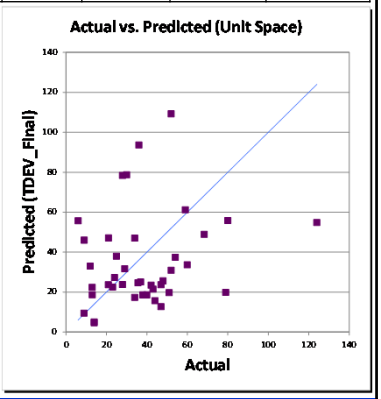
Model Form	N	R^2	CV	Mean	F-stat	PM Min	PM Max
TDEV = $ePM^{0.5290}$	40	94	60	38	683	17	7132

Where:

TDEV = Actual Duration in Months

ePM = Estimated Effort (in Person Months)

Variable	Coeff	T stat	P value
ePM	0.529	26.14	0.0000



31

Schedule Model 2: using Actual Effort

Equation:

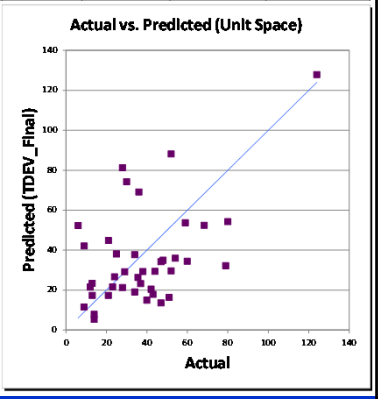
Model Form	N	R^2	CV	Mean	F-stat	PM Min	PM Max
TDEV = $aPM^{0.5051}$	40	95	48	38	887	27	14819

Where:

TDEV = Actual Duration in Months

aPM = Actual Effort (in Person Months)

Variable	Coeff	T stat	P value
aPM	0.529	26.14	0.0000



32

Conclusion

Primary Findings

- Estimated functional requirements is a significant contributor to software development effort.
- Variation in effort becomes more significant when estimated peak staff is added to the effort model.
  - Thus, the effect of estimated functional requirements on effort shall be interpreted along with estimated peak staff.
- Estimated effort is a significant contributor to development duration.

Model Usefulness

- ❑ Effort models based on estimated requirements and estimated peak more appropriate at early elaboration phase.
- ❑ Effort Models based on final requirements and final peak staff more appropriate after Critical Design Review, once requirements have been stabilized
- ❑ Productivity Boxplots (effort per requirement) are useful for crosschecking estimates at Preliminary Design Review
- ❑ Appropriate for both, Defense and IT projects

35

Study Limitations

- Since data was collected at the aggregate level, the estimation models are not appropriate for projects reported at the CSCI level.
- Do not use *Effort Models 1 through 4* if your input parameter is outside of the effort model range.
- Do not use *Schedule Models 5 & 6* if your input parameter is outside of the schedule model range.

36

Future Work

- Develop similar effort and schedule estimation models using data reported at the CSCI level.
- Build effort models using functional requirements along with other cost drivers such as
  - Complexity/Application Domain
  - Percent reuse
  - Requirements Volatility
  - Process Maturity

37

Acknowledgement

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38