CHARACTERIZING THE IMPACT OF REQUIREMENTS VOLATILITY ON SYSTEMS ENGINEERING EFFORT

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Agenda

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Motivation

“Requirements are the foundation of the project. They form the basis for design, manufacture, test and operations….changes in requirements later in the development cycle can have a significant cost impact, possibly resulting in cancellation”

Overview of Research Findings

• Field research validated findings from prior studies:
  – Requirements volatility is linked to an increase in rework and project size
  – The impact of changing a requirement increases the later the change occurs in the system lifecycle

• The research provided additional insights:
  1. Causal model linking volatility to a number of technical, organizational and contextual factors
  2. The level of volatility is a function of lifecycle phase
  3. Respondents from S/W intensive projects tend to expect more volatility than those who work on H/W intensive systems
  4. There are spikes in volatility after the transitions between lifecycle phases
  5. Requirements changes early in the lifecycle may not be considered “volatility”
Requirements Volatility Definitions

Requirements volatility is the % change in requirements (added, deleted, and modified) over a given time interval.

Also known as:

Requirements creep: An increase in scope and/or number of system requirements.

Requirements churn: Instability in the requirements set – requirements are frequently modified or reworked without necessarily resulting in an increase in the total number of requirements.


Leading Indicators are defined as “measures for evaluating the effectiveness of the systems engineering activities on a program in a manner that provides information about impacts that are likely to affect the system or program performance objectives.”

Requirements Trends as a Systems Engineering Leading Indicator

- Evaluates trends in the growth and change of the system requirements
- It helps to determine the stability and completeness of the system requirements which could potentially impact project performance

Implications to COSYSMO

• During the development of COSYSMO, volatility was identified as a relevant adjustment factor to the model’s size drivers

• However, there was insufficient data to incorporate volatility effects into the initial version of the model

• The primary objective of the research is to complete the requirements volatility extension to COSYSMO within the existing structure and scope of the model

COSYSMO Volatility Factor

- Reuse Categories
  - # Requirements
  - # Interfaces
  - # Scenarios
  - # Algorithms

- Volatility Factor

- Size Drivers
- Effort Multipliers
  - Application factors
    - 8 factors
  - Team factors
    - 6 factors

- COSYSMO
- Calibration
- Effort

Method

First Phase of the Study:
- Review of relevant literature
- Data collected through field research: surveys and discussions conducted at industry/academic conferences and workshops

Literature Background

- Most of the requirements volatility research to date has been focused on software systems.
- Various research methods have been utilized to investigate the causes and effects of requirement volatility, including:

There is still a lack of empirical data on the quantitative impact of requirements volatility on for a broader base of engineering projects.
Cost Commitment on Projects

Changes to the System are more difficult to implement the later they occur in the lifecycle

Causal Model (normative)

Based on the review of the literature, a causal model was developed that relates technical, organizational and contextual project factors to requirements volatility.

Survey results were used to rank the level of subject-matter expert agreement with each of the postulated causes of requirements volatility.
Exploratory Survey

• Developed to gather the perspectives of subject-matter experts on the causes, impacts, and expected level of requirements volatility for a given system of interest
• Piloted at the 2010 USC-CSSE Annual Research Review
• Incorporated feedback and administered the survey at the 2010 Lean Advancement Initiative (LAI) knowledge exchange event in Dana Point, CA
• Organizations represented:
  – The Aerospace Corporation, Northrop Grumman Corporation
  – The Boeing Company, Softstar Systems, Raytheon
  – United Launch Alliance, Massachusetts Institute of Technology, University of Southern California, and
  – United States Army
  – United States Navy
**Expected Level of Volatility**

Most respondents expect >20% volatility during the conceptualize phase of the project, decreasing to <5% in the transition to operation phase.
Impact of Hardware/Software Project Breakdown on Expected Volatility

Operational Test & Evaluation Lifecycle Phase

Transition to Operation Lifecycle Phase

Respondents from S/W intensive projects tend to expect more volatility later in the lifecycle.
Impacts of Volatility

- In general, results of the survey support observations from the literature and causal model.
- Most respondents stated that requirements volatility will cause a moderate to large increase in the number of system requirements and rework.
Survey Exercise

- Survey Exercise administered during the 2010 Practical Software and Systems Measurement Conference
- Participants were asked to:
  1. Draw a requirements volatility profile across the lifecycle phases covered by COSYSMO
  2. Draw an “ease of change” profile across the same lifecycle phases to determine the volatility weighting factor
  3. Discuss variation in 1 and 2 above for:
     1. Large and Small Projects
     2. Hardware and Software Projects
     3. Development and Recurring Projects
Expected Requirements Volatility Profile

4 out of 9 participants indicated that requirements changes should not be considered volatility during the conceptualize phase.

Localized peaks in volatility due to the transitions between lifecycle phases.

Profile Representative of Participant Feedback
No significant differences between type of projects.
Ease of Change Profile

Cost Penalty defined as $1 / \text{ease of change}$

Representative of Participant Feedback

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<thead>
<tr>
<th></th>
<th>Conceptualize</th>
<th>Development</th>
<th>Operational Test &amp; Evaluation</th>
<th>Transition to Operation</th>
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<tbody>
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<td>Average Ease of Change Factor (Estimated)</td>
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<td>Average Cost Penalty (Estimated)</td>
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Conclusions

• Field research validated the literature findings that:
  – Link volatility to an increase in rework and project size
  – Predict a cost penalty due to late requirements changes

• Additional insights developed through the research:
  1. Causal model linking volatility to a number of technical, organizational and contextual factors
  2. The level of volatility is a function of lifecycle phase
  3. The presence of localized peaks in requirements volatility after the transitions between lifecycle phases
  4. Feedback that suggests requirements changes during the conceptualize phase should not be labeled as volatility
  5. Respondents from S/W intensive projects tend to expect more volatility later in the lifecycle than those who work on H/W oriented systems
Next Steps

• The findings from the field research will be used to further define the volatility extension to COSYSMO
  – Additional work is required to understand the cost penalty of late requirements as it relates to systems engineering effort
  – The point in the lifecycle during which volatility starts to be measured and accounted for also needs to be further defined
  – Interviews with industry experts and mini-case studies will be conducted to validate the usefulness of the causal model

• Industry data will be collected to quantify the impact of requirements changes on systems engineering effort
References

Call for Participation

• In order to complete the requirements volatility extension of COSYSMO, we are seeking industry data for engineering projects in terms of:
  – Systems engineering effort actuals (labor hours)
  – Requirements volatility: the number of requirements, added, deleted, and modified added after the requirements baseline

• By providing these data your organization will benefit by:
  – Improving its ability to estimate the impact of requirements changes on project cost
  – Calibrating and tailoring the updated Model for your application domain

• USC-CSSE and LAI at MIT have proven processes in place to ensure the confidentiality and protection of the data with its Corporate Affiliates and Consortium Members

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