CHARACTERIZING THE IMPACT OF REQUIREMENTS VOLATILITY ON SYSTEMS ENGINEERING EFFORT

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Agenda

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- Introduction and Background
- Implications to COSYSMO
- Method
- Causal Model
- Survey Results
- Conclusions
- Next Steps

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"

INCOSE Systems Engineering Handbook (2006)

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"**

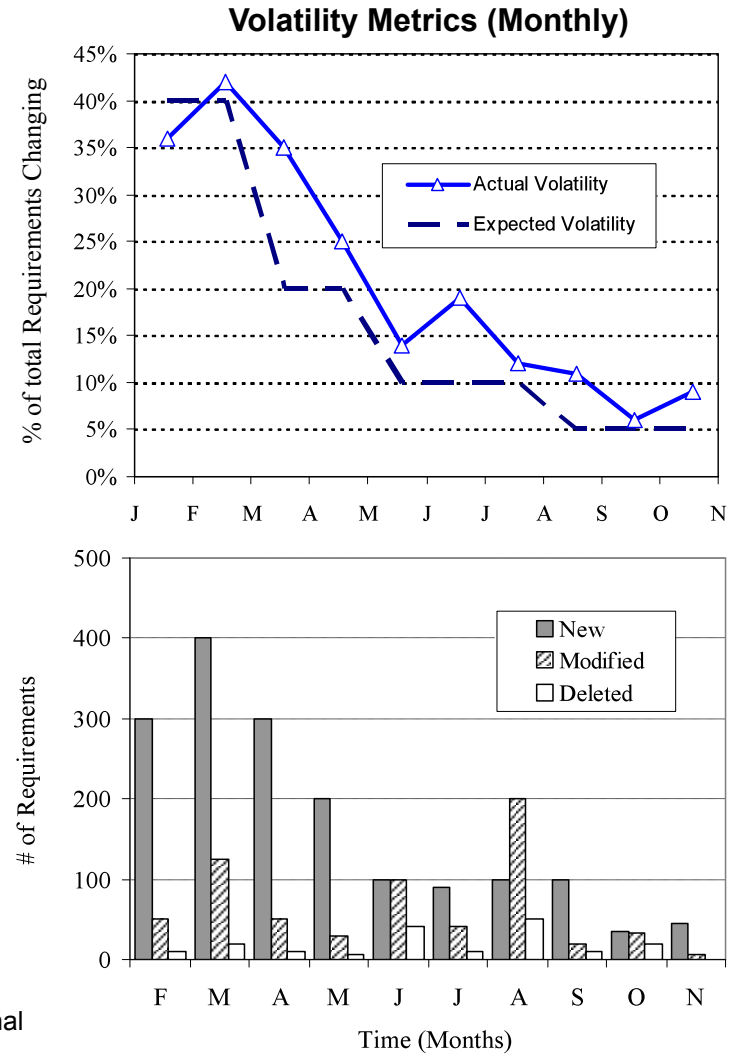
Requirements Volatility Definitions

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



Costello, R. and Liu, D. (1995). "Metrics for Requirements Engineering," Journal of Systems and Software. Vol 29 (No. 1), pp. 39-63
MIL-STD-498. 1994. Software Development and Documentation. U.S. DoD

SE Leading Indicators Guide

Developed and Published by Members of

LAI MIT LEAN ADVANCEMENT INITIATIVE

SEA RI Systems Engineering Advancement Research Initiative

INCOSE International Council on Systems Engineering

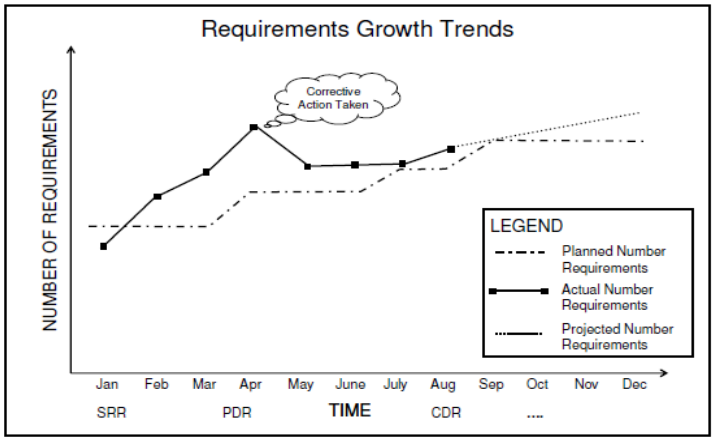
PSM

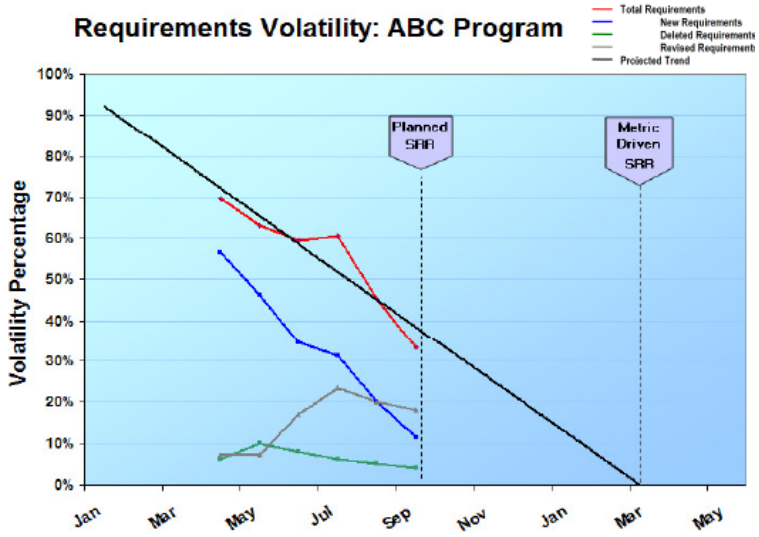
Leading Indicators are defined as "measures for evaluating the effectiveness of the systems engineering activities on a program in a manner that provides information about impacts that are likely to affect the system or program performance objectives."

Rhodes, D., Valerdi, R., and Roedler, G. (2009). "Systems engineering leading indicators for assessing program and technical effectiveness." *Systems Engineering* Vol. 12 (No. 1), pp 21-35.

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**



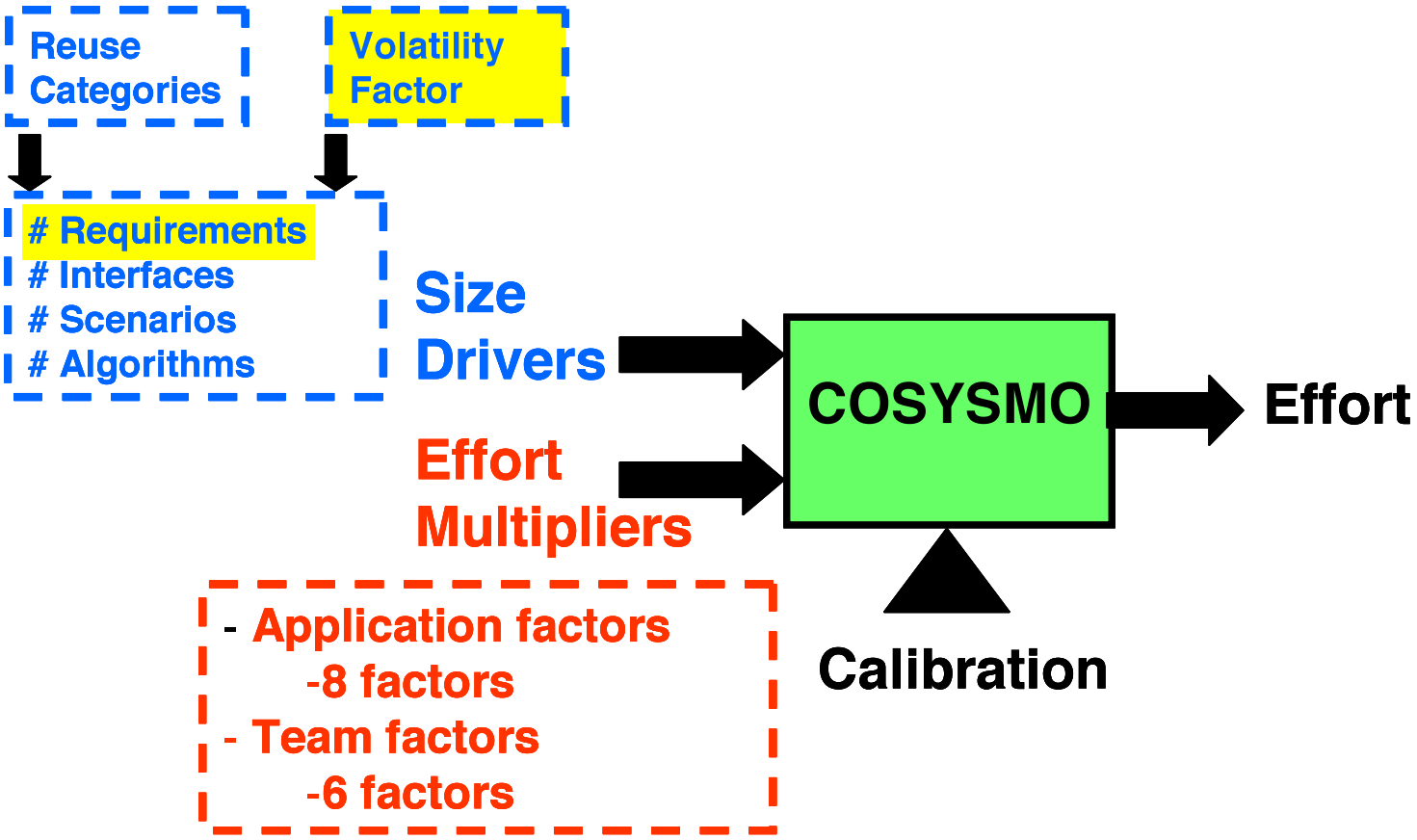


Implications to COSYSMO

- 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

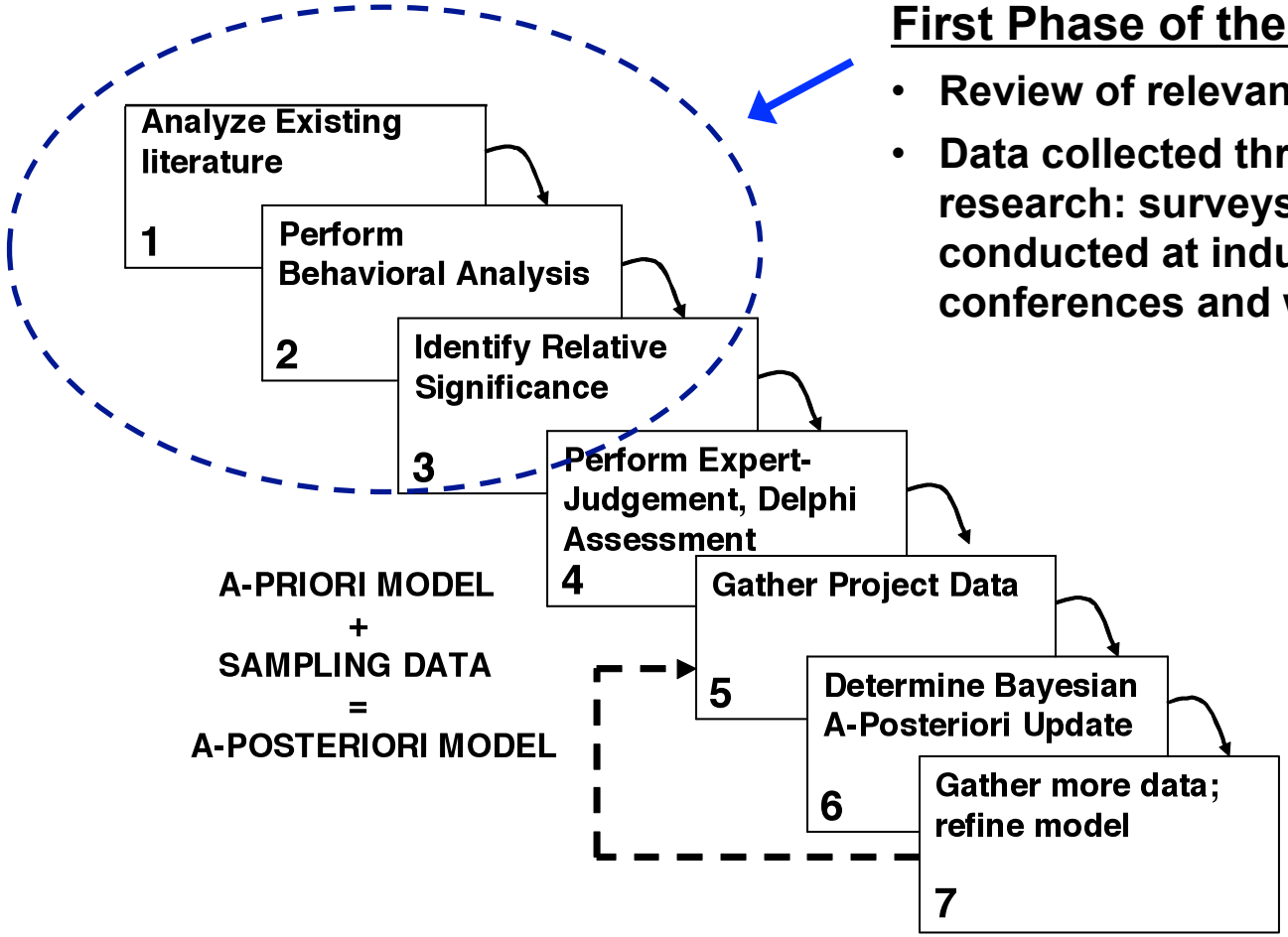
Valerdi, R. (2005). The constructive systems engineering cost model (COSYSMO). Doctoral Dissertation. University of Southern California, Industrial and Systems Engineering Department.

COSYSMO Volatility Factor



Fortune, J. (2009). Estimating systems engineering reuse with the constructive systems engineering cost model (COSYSMO 2.0). Doctoral Dissertation. University of Southern California, Industrial and Systems Engineering Department.

Method



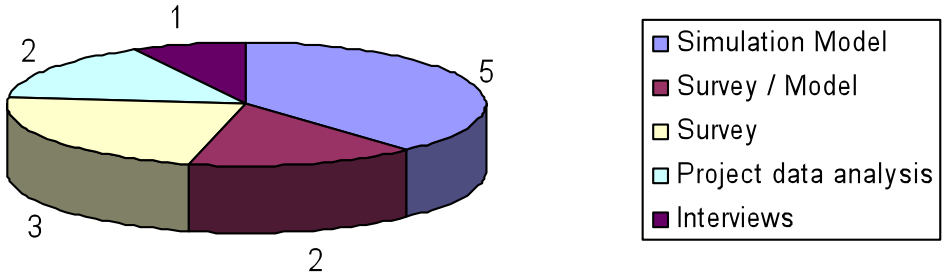
First Phase of the Study:

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

Boehm, B. (1981). Software Engineering Economics. Prentice Hall.

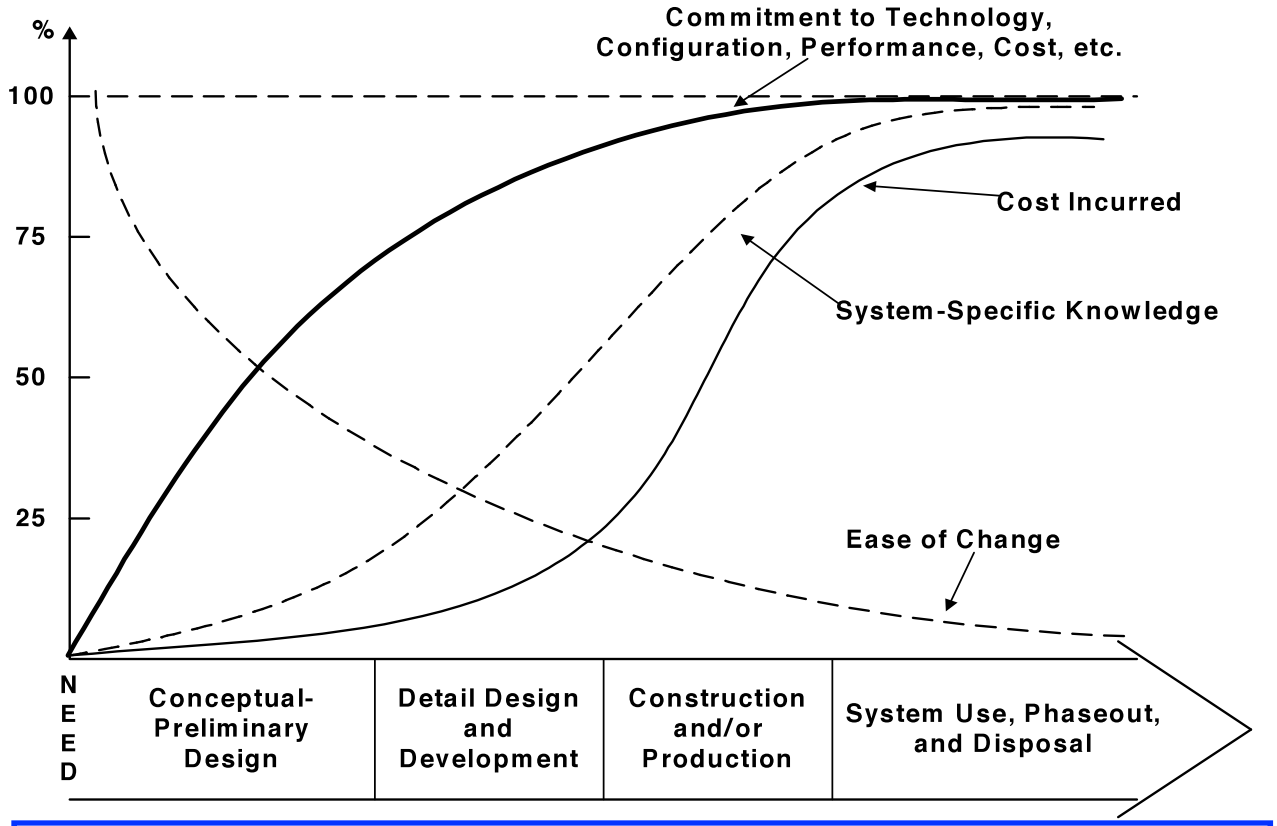
Literature Background

- **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

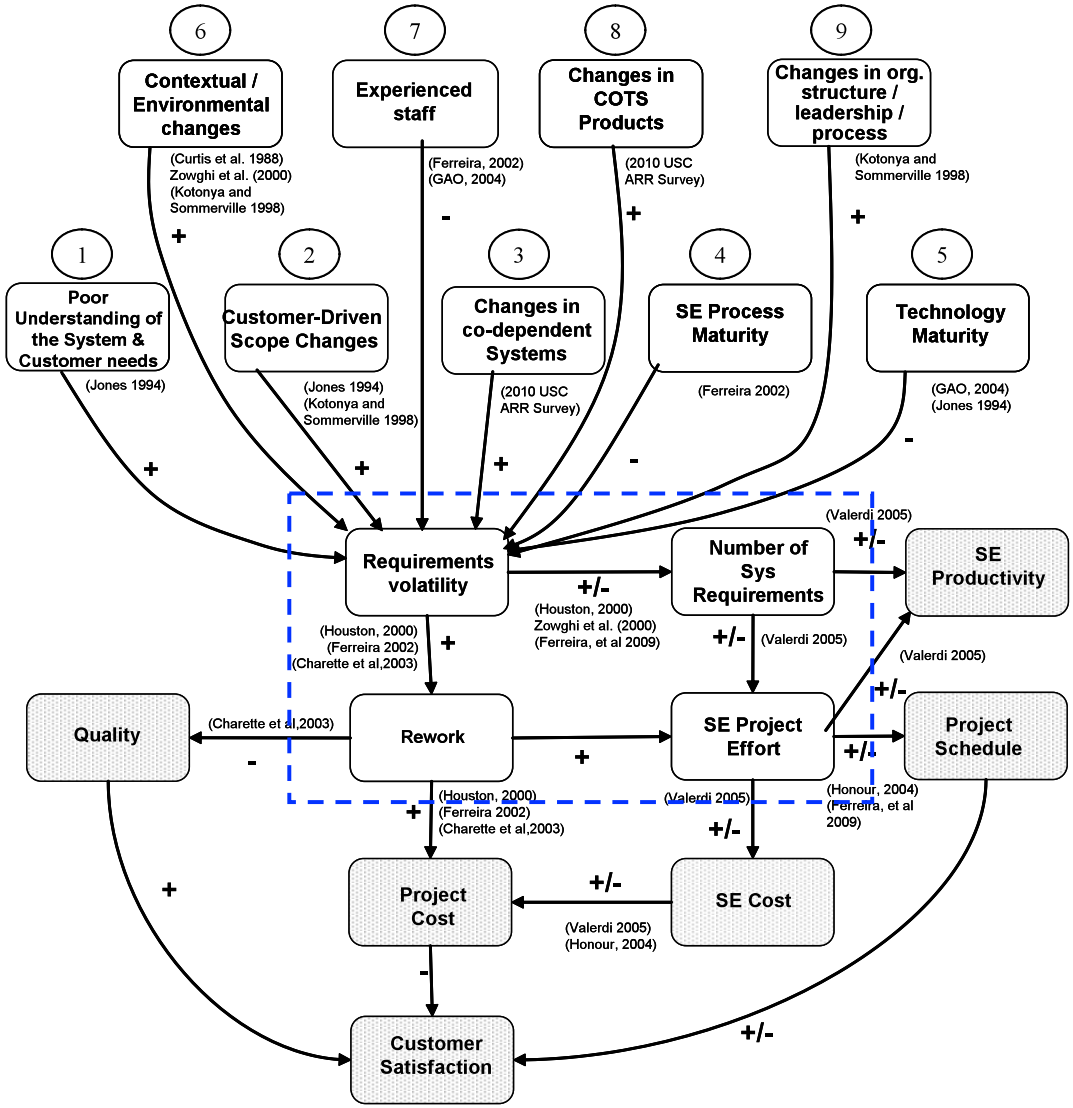
Cost Commitment on Projects



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

Blanchard and Fabrycky (1998), Systems Engineering & Analysis, Prentice Hall, 1998

Causal Model (normative)



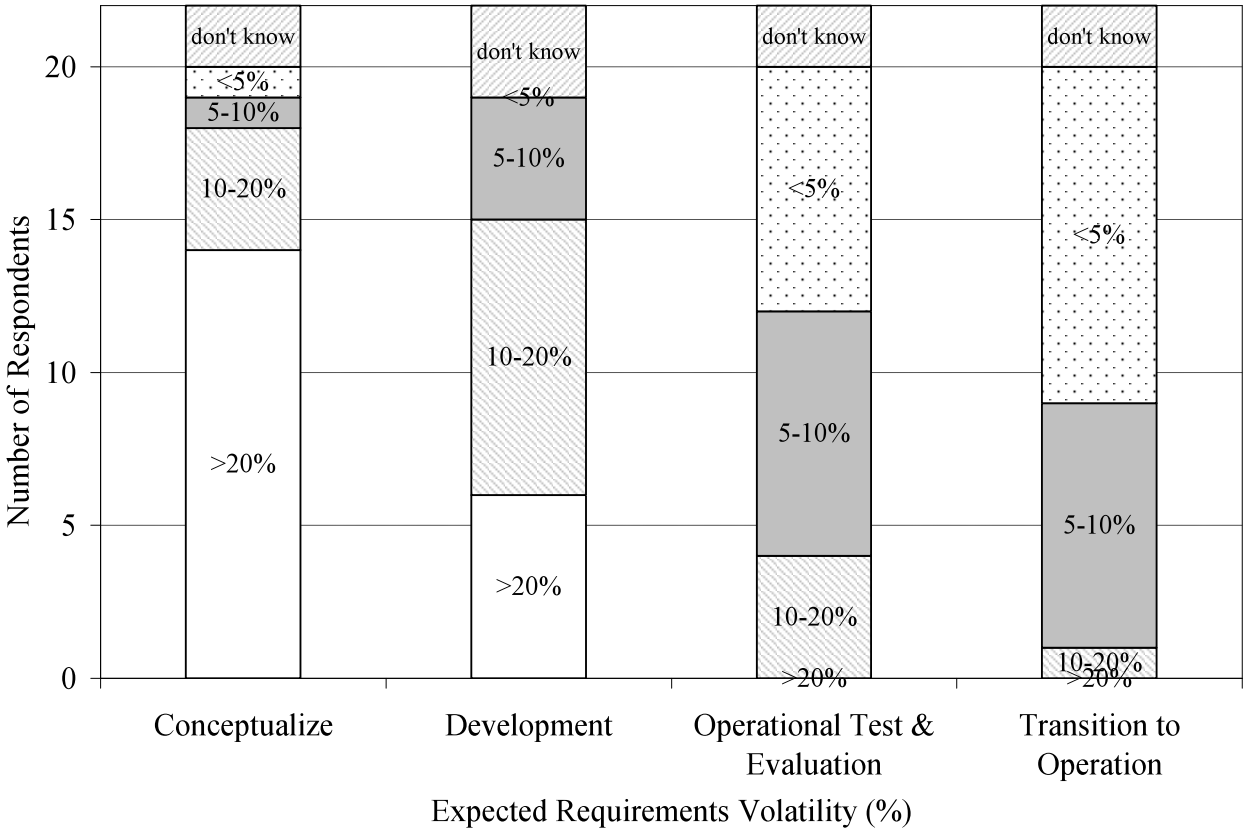
Based on the review of the literature, a causal model was developed that relates technical, organizational and contextual project factors to requirements volatility

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

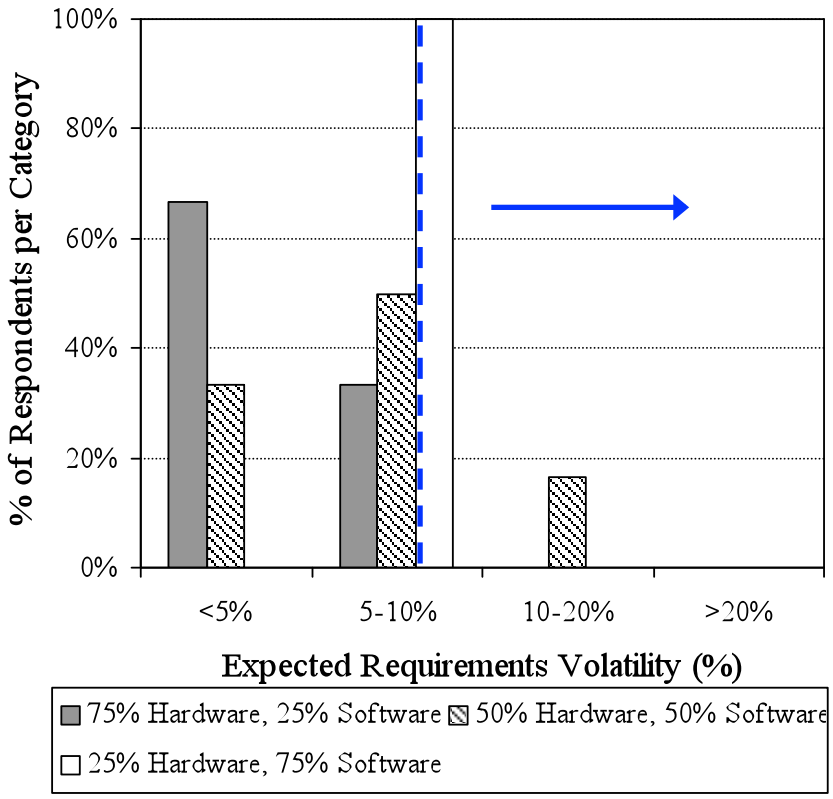
Expected Level of Volatility



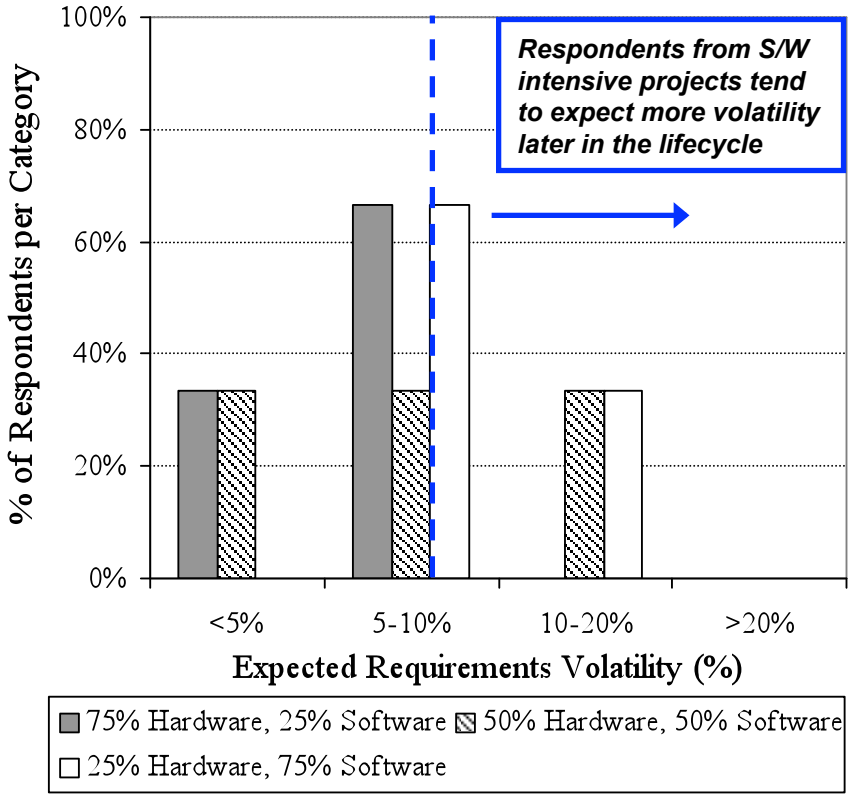
Most respondents expect >20% volatility during the conceptualize phase of the project, decreasing to <5% in the transition to operation phase

Impact of Hardware/Software Project Breakdown on Expected Volatility

Operational Test & Evaluation Lifecycle Phase

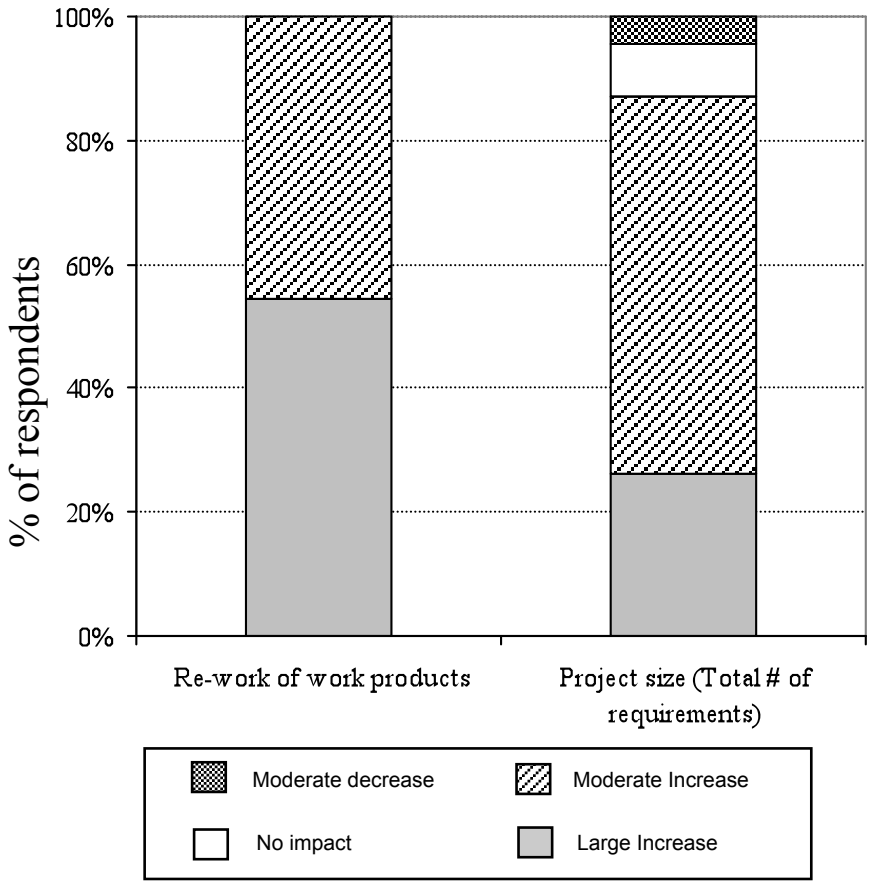


Transition to Operation Lifecycle Phase



Impacts of Volatility

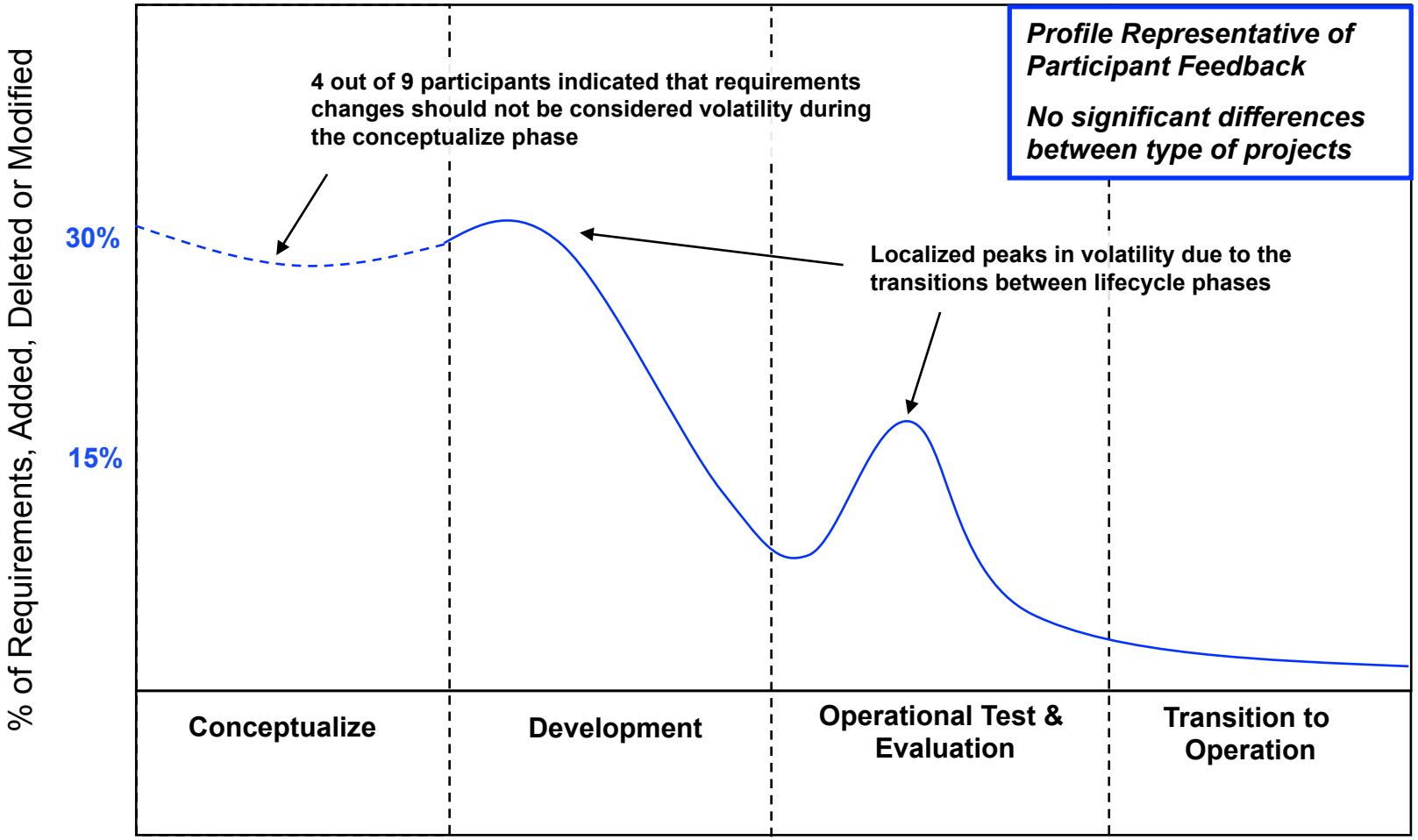
- In general, results of the survey support observations from the literature and causal model
- Most respondents stated that requirements volatility will cause a moderate to large increase in the number of system requirements and rework



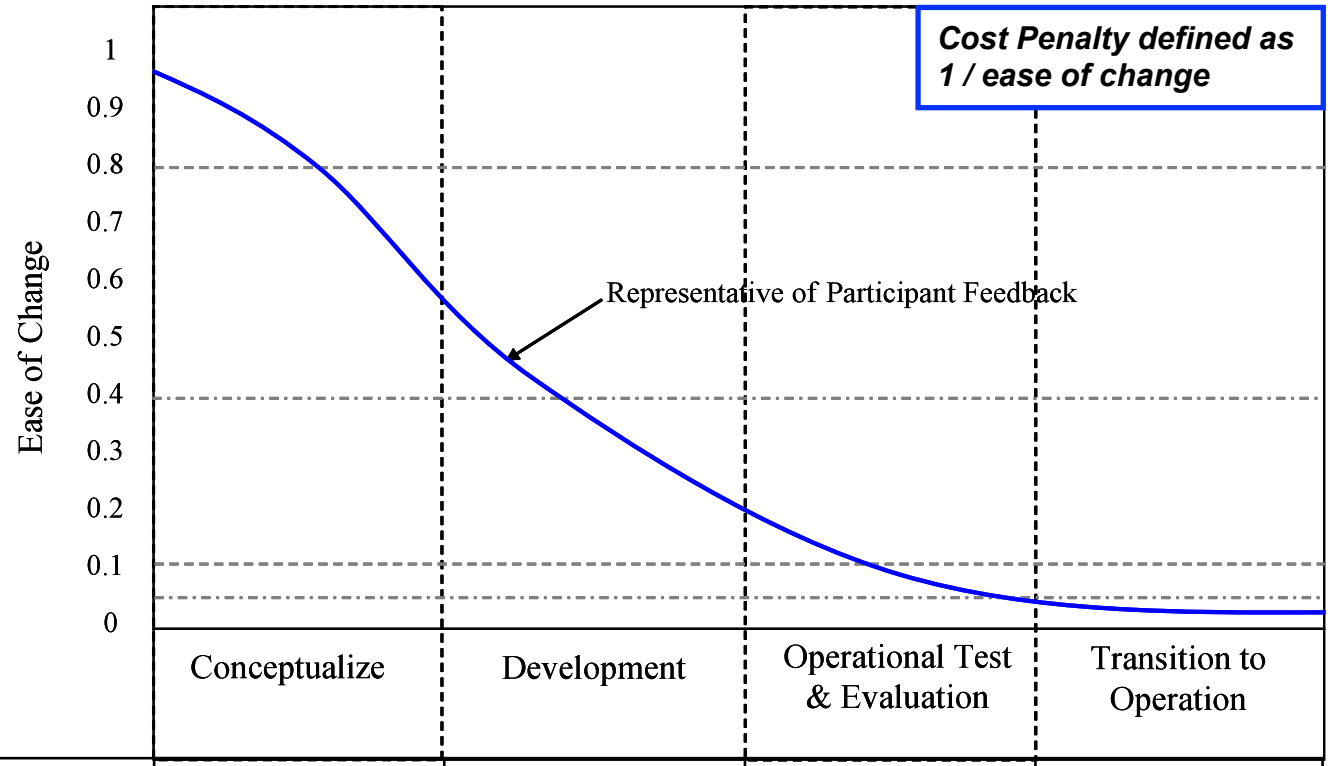
Survey Exercise

- **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 life cycle 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



Ease of Change Profile



Average Ease of Change Factor (Estimated)	**0.8**	**0.4**	**0.1**	**0.05**
Average Cost Penalty (Estimated)	**1.25**	**2.5**	**10**	**20**

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

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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**
- **Contact:**

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