Evolution of a Bluetooth Test Application Product Line: A Case Study

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Structure of Presentation

• Research problem overview
• Empirical Context
• Standardization-Customization (S-C) decision model
• Product Variability cost model
• Discussion / broader takeaways
Packaged software business

- Packaged software is big business
  - $10 billion (IDC 2009-10 forecast)
  - ERP, CRM, supply chain systems, office productivity

- a.k.a. “Off the shelf”, “COTS”
Lifecycle of Packaged Software

Vendor

Design
Develop
Test
Release

Features (Release plan)

Analyze fit with organizational context

Client

Use As-is or Customize?

Raise Requirements

Standardize

Customize
Vendor’s Dilemma / Decision

Customer request

- Standardize
- Customize

Which Release?

At what cost?

Should standardize later?
Research Questions

• What factors affect the standardization-customization decision?
  – An important step towards a generalizable theory of product line evolution

• How do you estimate customization costs (i.e., product variability costs)?
Empirical Context – the research site

• Measuretronics (not real name)
  – Wireless test and measurement product firm
  – Over $1.5 billion in product sales
  – Over 700 active technology patents
  – About 400 customers (firms) worldwide
Empirical Context – the product line

• Bluetooth Protocol Analyzer
  – test and measurement instrument used in the production of Bluetooth consumer products

• Hardware component

• Software component
  – Firmware (Operating system)
    • Capture test and measurement data
  – Client software
    • Analyze test and measurement data
Data Collection

• Participatory action research
  – Researchers co-investigate with or involve the communities whose practices they study
  – three-member core team
    • One of the authors
    • One program manager (who was a marketing specialist)
    • One engineering manager

• All product decisions between 1999-2003
Data Collection (Continued)

• Collected Data
  – In-depth records of product functional features and specification changes
  – In-depth process records detailing the product development processes and choices made
  – Structured interviews and group discussions
  – 154 customer requests. 2 to 1 S-C ratio
Standardization-Customization (S-C)?

• Major influential factors (from empirical data)

  – Evolving Standards
  – Competition
  – Compatibility
  – Nature of Change
  – Complexity
Evolving Standards

- Uncertainty over Bluetooth standards
  - Need to be one step ahead of consumer product firms (Microsoft, Sony, Nokia, Motorola, etc)
Competition

- > ½ of product features - no direct competition
- Sensitive to being “ahead of competitors”
Modeling S-C Decisions

- Collective influence of variables need to be examined
  - Interaction effects

- Generalizable software product line evolution theory
Empirical Model

- Installed-Base Impact
- Standards Constraint
- Compatibility Constraint

Control Variables:
- Nature of Change;
- Change Size;
- Customer Influence;
- Product Version

Standardized or Customized Solution?
Modeling S-C Results Summary

• Pro-customization factors
  – Increased Market Share
  – Standards Violation
  – Needed by customer
  – Incompatible with previous versions

• Pro-standardization factors
  – Incompatibility when you have market share
  – Impact on product obsolescence strategies
Customization Costs

– Estimating costs for product line variations

– An important variant of software cost estimation problem

– Needs to accommodate factors from the standardization-customization decision model
Empirical Model

- Functional Complexity
- Structural Complexity
- Compatibility Constraint
- Customer Knowledge
- Quality

Product variability Cost
(Customization cost)

Personnel Experience;
Size;
Product Version
S-C Costs Results Summary

• Increases Costs
  – Functional complexity
  – Structural complexity
  – Incompatible requests
  – Error-prone components

• Decreases Costs
  – Customer specific knowledge
  – Experienced personnel
Most Important Takeaways

1. Predictive model for S-C decisions
   – towards a generalizable product line evolution theory

2. A cost estimation model for S-C decisions
   – Models variability in product line evolution

3. Timing product feature obsolescence
   – Universal policies on compatibility not optimal

4. Economic incentives for reducing complexity
   – Reducing structural complexity of products has downstream benefits

5. Invest in organizational memory
   – Knowledge transfer between development, marketing, and implementation teams
Thank You

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6. Rejections are just another opportunity
   - This paper for example
   - Use the feedback to improve the paper
     - No such thing as a “perfect” paper!
   - Keep persevering and good things will happen!
Most Important Takeaways

1. Product line governance
   - Align the incentives for solving engineering problems and meeting market opportunities

2. Timing product feature obsolescence
   - Universal policies on compatibility not optimal

3. Economic incentives for reducing complexity
   - Reducing structural complexity of products has downstream benefits

4. Invest in Organizational memory
   - Knowledge transfer between development, marketing, and implementation teams
Major Contributions

1. Examined the S-C dilemma
   – constantly changing specifications originating from standards evolution and diverse customer requirements

2. Predictive model for S-C decisions
   – a step towards a generalizable theory of software product line evolution

3. A cost estimation model for S-C decisions
   – Models economic aspects of variability in product line evolution
Modeling S-C Empirical Model Specification

• Probability (Standardized or Customized Solution?) =

\[ \Phi [\alpha_0 + \alpha_1 \cdot \text{Installed-base impact} + \alpha_2 \cdot \text{Compatibility constraint} + \alpha_3 \cdot \text{Standards constraint} + \alpha_4 \cdot \text{Market share} + \alpha_5 \cdot \text{Customer influence} + \alpha_6 \cdot \text{Market share} \times \text{Compatibility constraint} + \alpha_7 \cdot \text{Market share} \times \text{Standards constraint} + \alpha_8 \cdot \text{Change size} + \alpha_9 \cdot \text{Version} + \alpha_{10} \cdot \text{Nature of change} + \delta] \]
## Modeling S-C Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Effect of one unit change on the probability to standardize a customer request</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed-Base Impact</td>
<td>$\alpha_1$ -0.007**</td>
</tr>
<tr>
<td>Compatibility Constraint</td>
<td>$\alpha_2$ -0.52**</td>
</tr>
<tr>
<td>Standards Constraint</td>
<td>$\alpha_3$ -0.61**</td>
</tr>
<tr>
<td>Market Share</td>
<td>$\alpha_4$ -0.02**</td>
</tr>
<tr>
<td>Customer Influence</td>
<td>$\alpha_5$ 0.27**</td>
</tr>
<tr>
<td><em>Interaction effect:</em></td>
<td></td>
</tr>
<tr>
<td>Market Share X Compatibility Constraint</td>
<td>$\alpha_6$ 0.25*</td>
</tr>
<tr>
<td><em>Interaction effect:</em></td>
<td></td>
</tr>
<tr>
<td>Market Share X Standards Constraint</td>
<td>$\alpha_7$ -0.02</td>
</tr>
<tr>
<td>Change Size</td>
<td>$\alpha_8$ -0.003**</td>
</tr>
<tr>
<td>Version</td>
<td>$\alpha_9$ 0.007</td>
</tr>
<tr>
<td>Nature of Change</td>
<td>$\alpha_{10}$ -0.3*</td>
</tr>
</tbody>
</table>
S-C Cost Empirical Specification

• Customization Cost =

$$\beta_0 + \beta_1 \times \text{Functional Complexity} + \beta_2 \times \text{Structural Complexity} + \beta_3 \times \text{Compatibility Constraint} + \beta_4 \times \text{Customer Knowledge} + \beta_5 \times \text{Quality} + \beta_6 \times \text{Personnel Experience} + \beta_7 \times \text{Size} + \beta_8 \times \text{Version} + \epsilon$$
### Customization Cost Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional Complexity</td>
<td>$\beta_1$</td>
<td>0.25**</td>
</tr>
<tr>
<td>Structural Complexity</td>
<td>$\beta_2$</td>
<td>3.57**</td>
</tr>
<tr>
<td>Compatibility Constraint</td>
<td>$\beta_3$</td>
<td>175.59***</td>
</tr>
<tr>
<td>Customer Knowledge</td>
<td>$\beta_4$</td>
<td>-0.53**</td>
</tr>
<tr>
<td>Quality</td>
<td>$\beta_5$</td>
<td>10.88**</td>
</tr>
<tr>
<td>Personnel Experience</td>
<td>$\beta_6$</td>
<td>-28.08*</td>
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<tr>
<td>Size</td>
<td>$\beta_7$</td>
<td>0.022</td>
</tr>
<tr>
<td>Version</td>
<td>$\beta_8$</td>
<td>-1.97</td>
</tr>
<tr>
<td>constant</td>
<td>$\beta_0$</td>
<td>247.95**</td>
</tr>
</tbody>
</table>

Number of Observations = 51  
Model Significance test F-stat (8, 42) = 9.28***, P-value = 0.000  
Adj.R-Squared = 56.99%; Mean MRE = 19%