Standardizing Product Development Processes

Sid Rupani, Presenter

LAI Web Knowledge Exchange Event

December 1, 2010
Agenda

- Motivation and Overarching Question
- Map of Research Project
- Phase 1 – Immersion in Phenomenon - Case Studies
- Phase 2 – Detailed Project-Level Analysis
- Conclusions and Future Work
Product Development Process

- “A product development process is the sequence of steps or activities which an enterprise employs to conceive, design, and commercialize a product”
  
  *Ulrich and Eppinger 2000*

- “Processes can be regarded and treated as systems that should be engineered purposefully and intelligently, facilitated by useful models.”
  
  *Browning, Fricke, and Negele 2006*
The issue

“Companies made up of many different business units will face an important question as they make the shift to a process enterprise:

Should all units do things the same way, or should they be allowed to tailor the process to their own needs?

In a process enterprise the key structural issue is... process standardization versus process diversity.

There’s no one right answer.”

Hammer and Stanton
Harvard Business Review, 1999
Overarching Question: What is the influence of process standardization on performance?
What is the influence of process standardization on performance?

Process Standardization

+ Effort
  - Efficiency
  - Knowledge Transfer
  - Decision making / Resource Allocation

- Effort
  - Project performance
  - Innovation
  - Creativity
  - Adaptation/ Learning over time
  - Employee Satisfaction

Adler et. al 1999; Morgan, Liker 2006
Argote 1999; Adler and Cole 1993
Krubasik 1988; Shenhar 2001
Benner & Tushman 2002
Tilcsik 2008; March 2007
March 1991; Levinthal and March 1993
Adler et al. 1999
“On both sides of the question, complex causal mechanisms play out in diverse ways in diverse situations. This might imply that we should not be aspiring to general conclusions with respect to the overall question, but rather seeking to sort out the mechanisms and the contingencies.”

Sid Winter

in Adler et al. (2008)
Map of Research Project

**Research Activity Undertaken**

**Phase I**
- Immersion in Phenomenon
  - 3-month internship, Company Contacts, Secondary Sources
  - 5 Company Case Studies
    - Interviews
    - Documents

**Phase II**
- In-depth study at one company
  - Collection and Analysis of detailed project, process, and project performance data

**Lessons Learned**

**Phase I**
- Occurrence of process variation at different times, levels, sources
- Importance of Individual Process Dimensions

**Phase II**
- Integrated framework and summary of current state of knowledge
- Established, Contested, and Unexplored Links

**Research Activity Undertaken**

**Detailed Literature Study**
- Systematic study of 350+ papers from relevant areas
Phase 1 – Immersion in Phenomenon: Case Studies

- **Selected Cases (Theoretical Sample):**
  - 5 large companies ($5B+ annual sales)
  - Develop electromechanical assembled products
  - Different industries (Computer Hardware, Aviation Electronics and Communication Equipment, Automobiles, Electronic Equipment)
  - Different approaches to process standardization

- **Data Collection**
  - Interviews (48 total) with various roles
  - Process documentation
Lessons from Case Studies: Individual Process Dimensions

“The biggest benefit is that because of the standard deliverables at the reviews, we all talk the same language and expect to see the same things in the same format. It’s easy for the Senior Management Team to know when a red flag comes up or when a project is moving into exception.”

Process Manager at Company E

“One good thing was that since we started using the same tools, it allows us to easily move between projects. We didn’t have to retrain every time we switched.”

Engineer at Company E

“Because of the tools, we can get engineers from other projects in crunch time and they don’t spend too much time ramping up. They can be integrated relatively seamlessly.”

Project Manager at Company E
Lessons from Case Studies: Individual Process Dimensions

Process Standardization

+ Efficiency
+ Knowledge Transfer
+ Decision making / Resource Allocation

- Project performance
- Innovation
- Creativity
- Adaptation/ Learning over time
- Employee Satisfaction
### Process Design
- Activities/Tasks
- Order, Flow, and Dependencies
- Timing
- Roles/Agents
- Tools/Methods
- Deliverables/Outputs

### Project Performance
- Product Cost
- Product Quality
- Development Time
- Development Cost

### Process Standardization
- Activities/Tasks
- Order, Flow, and Dependencies
- Timing
- Roles/Agents
- Tools/Methods
- Deliverables/Outputs

### Organizational Performance
- Efficiency
- Knowledge Transfer
- Creativity/Innovation
- Decision making / Resource Allocation
- Adaptation/ Learning over time
- Employee Satisfaction
Lessons from Case Studies: Variation in Standardization Approach

- All companies
  - Acknowledged and controlled some amount of process variation, left some free to the discretion of project team

- Companies differed on:
  - What project characteristics they took into consideration to customize their process
  - Which process dimensions were centrally specified and which were left to project team’s discretion
## Company A

### Computer Hardware

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Algorithm</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Hardware/Software balance</td>
<td>Table - each product archetype column, activities as rows. yes/no indicated.</td>
<td>• Activities</td>
</tr>
<tr>
<td>• Extent of In-House Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Product ‘Archetypes’</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Company A - Project Archetypes

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Hardware (not MNL, not ABC)</th>
<th>Software &amp; Hardware</th>
<th>Software OEM-in</th>
<th>Hardware OEM-in</th>
<th>Hardware Reseller</th>
<th>ABC Software</th>
<th>ABC XYZ Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples:</td>
<td>AB4000, AB5000, some Tape</td>
<td>none, except RST going to PQR</td>
<td>SVC</td>
<td>AB3000, Brokeman 20</td>
<td>Sysco PQR</td>
<td>Note: These are special in that are closely tied to system software of which ABC is a part</td>
<td></td>
</tr>
</tbody>
</table>

### Development

<table>
<thead>
<tr>
<th>Accessibility Checklist(s)</th>
<th>Hardware</th>
<th>Software</th>
<th>Software OEM-in</th>
<th>Hardware OEM-in</th>
<th>Hardware Reseller</th>
<th>ABC Software</th>
<th>ABC XYZ Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-Smoke - HW only</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td>NA - handled by pDA</td>
<td>NA - done at major release. Not required for SPE maint</td>
<td></td>
</tr>
<tr>
<td>Cost of Originality (COO &amp; VOO)</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td></td>
</tr>
<tr>
<td>Chemical Emissions Data</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
<td>NA - not HW</td>
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</tr>
</tbody>
</table>

### Finance
### Company B
#### Avionics and Communication Equipment

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Algorithm</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Complexity</td>
<td>Logic Table – each activity decision made by referring to answers for pertinent questions</td>
<td>• Activities (required and suggested)</td>
</tr>
<tr>
<td>• Newness</td>
<td></td>
<td>• Deliverables</td>
</tr>
<tr>
<td>• Cost</td>
<td></td>
<td>• Templates</td>
</tr>
<tr>
<td>• Certifications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Technology Readiness</td>
<td></td>
<td>~80 technical activities</td>
</tr>
<tr>
<td>• Business Unit</td>
<td></td>
<td>~50 management activities</td>
</tr>
<tr>
<td>• Testing Requirements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Support Requirements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Hardware/Software</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Extent of Outsourcing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Supplier Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Production Needs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32 questions</td>
<td></td>
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~80 technical activities
~50 management activities
## Company B

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td></td>
<td>What is the projected cost of this project?</td>
<td></td>
<td>Select one.</td>
</tr>
<tr>
<td></td>
<td>a</td>
<td>At or Above $ABC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Below $ABC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q2</td>
<td></td>
<td>Please indicate maturity of technology on the project</td>
<td></td>
<td>Select one.</td>
</tr>
<tr>
<td></td>
<td>a</td>
<td>Risky technology - unproven or limited application; emerging within market</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Mature technology - proven and applied in similar applications; established within market</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
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<tr>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>'x' = YES</td>
<td>Req/Audit</td>
<td>Cust Req</td>
<td>ACTIVITIES AND TASKS</td>
<td>DELIVERABLE</td>
</tr>
<tr>
<td>☒</td>
<td></td>
<td></td>
<td>Capture Originating Requirements</td>
<td></td>
</tr>
<tr>
<td>☒</td>
<td></td>
<td></td>
<td>1. Capture stakeholders needs</td>
<td>stakeholder needs</td>
</tr>
<tr>
<td>☒</td>
<td></td>
<td></td>
<td>2. Capture source requirements</td>
<td>source requirements</td>
</tr>
<tr>
<td>☒</td>
<td></td>
<td></td>
<td>3. Capture architectural context</td>
<td>architectural context(s)</td>
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<td>☒</td>
<td></td>
<td></td>
<td>4. Define most important</td>
<td>most important requirements</td>
</tr>
<tr>
<td>☒</td>
<td></td>
<td></td>
<td>5. Define technical performance</td>
<td>technical performance measures (TPMs)</td>
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<tr>
<td>☐</td>
<td></td>
<td></td>
<td>Define Concepts</td>
<td></td>
</tr>
<tr>
<td>☐</td>
<td></td>
<td></td>
<td>1. Define concept</td>
<td>concept</td>
</tr>
<tr>
<td>☐</td>
<td></td>
<td></td>
<td>2. Perform conceptual analysis</td>
<td>conceptual analysis document</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td></td>
<td>Define Requirements</td>
<td></td>
</tr>
<tr>
<td>☒</td>
<td></td>
<td></td>
<td>1. Perform requirements trade</td>
<td>trade studies</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td></td>
<td>2. Define product requirements</td>
<td>product requirements</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td></td>
<td>3. Conduct traceability analysis from-</td>
<td>requirements trace/analysis</td>
</tr>
<tr>
<td>☒</td>
<td></td>
<td></td>
<td>4. Perform functional hazard</td>
<td>functional hazard assessment</td>
</tr>
<tr>
<td>Inputs</td>
<td>Algorithm</td>
<td>Outputs</td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
</tbody>
</table>
| “Degree of Product Change” in three key subsystems | Three digit code maps to a “timing template” | • Activities  
• Sequence  
• Timing  
• (Reviews)  
• Deliverables  
• Templates  
• Roles |
| Rated from 1-6 |
Why do companies differ in process standardization approach?

- Because they differ on:
  - Variation in project characteristics across portfolio
  - Strategic priorities across performance outcomes
Portfolio Characteristics

Process Dimensions to Standardize and Centrally Control

Strategic Priorities in Performance Outcomes
Map of Research Project

**Phase I – Immersion in Phenomenon**
- 3-month internship, Company Contacts, Secondary Sources
- 5 Company Case Studies
  - Interviews
  - Documents

**Phase I**
- Occurrence of process variation at different times, levels, sources
- Importance of Individual Process Dimensions

**Detailed Literature Study**
- Systematic study of 350+ papers from relevant areas

**Phase II – In-depth study at one company**
- Collection and Analysis of detailed project, process, and project performance data

**Phase II**
- Links between project performance and variation from standard process at the studied company

**Research Activity Undertaken**

**Lessons Learned**
Why Project Performance?

- *Salient*: Project performance outcomes are directly relevant and very familiar to managers.
- *Important*: Other outcomes translate into improvement on project performance and organizations actively manage project performance.
- *Data Available*: Data on organizational performance outcomes unavailable or subjective. Objective data on project performance available.
Phase 2 Electronic Equipment Co.
Detailed examination of project level process data within one company

- Detailed data on 15 projects (18 products)

Variables

- Project Characteristics
  - Complexity
  - Newness
  - Extent supplier development
  - Resources
  - Agents (PM)

- Process Design
  - Reviews/Gates
  - Deliverables
  - Activities
  - Time spent

- Project Performance
  - Quality (Reliability)
  - Development Cost
  - Schedule
  - Unit Product Cost

Primary Data Sources

- Product Data Sheet
- Product Requirements Document
- Review Presentations
- Meeting Minutes
- Customer Satisfaction and Reliability Reviews (12 out of 15)
- Project Schedules
Analysis Strategy

**Control Variables**

- Complexity
- Newness
- Extent of supplier development
- Resources
- Project Manager

**Independent Variables of interest**

**Process Design**

- Reviews/Gates
- Deliverable Waivers
- Activities (Testing)
- Time spent in Phases

**Dependent Variables**

**Project Performance**

- Quality (Service Cost Overrun)
- Development Cost (and overrun)
- Schedule (and overrun)
- Unit Manufacturing Cost Overrun
## Explaining Development Time

### Results of Regression Analysis for Development Time in Weeks

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newness Low Dummy</td>
<td>-20.72***</td>
<td>-17.48**</td>
<td>-20.18***</td>
<td>-13.51</td>
<td>-16.30*</td>
</tr>
<tr>
<td>Newness High Dummy</td>
<td>-7.08</td>
<td>-7.91</td>
<td>-6.49</td>
<td>-5.67</td>
<td>-5.72</td>
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<tr>
<td>Complexity Low Dummy</td>
<td>-2.75</td>
<td>-2.01</td>
<td>-3.93</td>
<td>-4.60</td>
<td>-0.75</td>
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<tr>
<td>Complexity High Dummy</td>
<td>8.88</td>
<td>15.07*</td>
<td>16.71**</td>
<td>17.65*</td>
<td>16.47*</td>
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<tr>
<td>Ext. of dev. done by supplier Low Dummy</td>
<td></td>
<td>-6.43</td>
<td></td>
<td></td>
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<tr>
<td>Ext. of dev. done by supplier High Dummy</td>
<td></td>
<td>3.48</td>
<td></td>
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<tr>
<td>Resources (FTEs)</td>
<td></td>
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<td>-0.15</td>
<td>-0.20</td>
<td>-0.15</td>
</tr>
<tr>
<td>Project Manager 1 Dummy</td>
<td></td>
<td></td>
<td>-9.29</td>
<td>-4.65</td>
<td></td>
</tr>
<tr>
<td>Project Manager 2 Dummy</td>
<td></td>
<td></td>
<td>-9.82</td>
<td>-3.41</td>
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<tr>
<td>Project Manager 3 Dummy</td>
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<td></td>
<td>-8.25</td>
<td>-4.23</td>
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<tr>
<td>Combined Gates Dummy</td>
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<td></td>
<td></td>
<td>-7.32</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>51.91***</td>
<td>49.36***</td>
<td>57.77***</td>
<td>62.69***</td>
<td>62.58***</td>
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<tr>
<td>Adjusted R²</td>
<td>0.723</td>
<td>0.712</td>
<td>0.749</td>
<td>0.763</td>
<td>0.778</td>
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</table>

* * p < .10 ; ** p < .05; *** p < .01
# Explaining Development Cost

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
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<tbody>
<tr>
<td>Newness Low Dummy</td>
<td>-1.59</td>
<td>1.38</td>
<td>0.86</td>
<td>2.52</td>
<td>0.84</td>
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<tr>
<td>Newness High Dummy</td>
<td>-0.64</td>
<td>-1.66</td>
<td>-1.61</td>
<td>-1.34</td>
<td>-1.18</td>
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<tr>
<td>Complexity Low Dummy</td>
<td>-1.10</td>
<td>-1.19</td>
<td>-0.96</td>
<td>-1.54</td>
<td>-0.29</td>
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<tr>
<td>Complexity High Dummy</td>
<td><strong>8.89</strong>*</td>
<td><strong>11.22</strong>*</td>
<td><strong>9.55</strong>*</td>
<td><strong>10.22</strong>*</td>
<td><strong>9.46</strong>*</td>
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<tr>
<td>Ext. of dev. done by supplier Low Dummy</td>
<td></td>
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<tr>
<td>Ext. of dev. done by supplier High Dummy</td>
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<tr>
<td>Resources (FTEs)</td>
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<td></td>
</tr>
<tr>
<td>Project Manager 1 Dummy</td>
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<tr>
<td>Project Manager 2 Dummy</td>
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<tr>
<td>Project Manager 3 Dummy</td>
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<tr>
<td>Combined Gates Dummy</td>
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</tr>
<tr>
<td>Intercept</td>
<td><strong>5.97</strong>*</td>
<td><strong>2.35</strong></td>
<td><strong>1.85</strong></td>
<td><strong>3.60</strong></td>
<td><strong>4.50</strong>*</td>
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<td>Adjusted R²</td>
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<td>0.940</td>
<td>0.937</td>
<td>0.930</td>
<td>0.967</td>
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</table>

* p < .10; ** p < .05; *** p < .01
## Explaining Service Cost Overrun - $

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<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
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<td>-139.1</td>
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<td>39.1</td>
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<td>172.8</td>
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<td>Ext. of dev. done by supplier Low Dummy</td>
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<td>Ext. of dev. done by supplier High Dummy</td>
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<tr>
<td>Resources (FTEs)</td>
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<td>1.44</td>
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<td></td>
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<td>9.84</td>
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<td>Project Manager 2 Dummy</td>
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<td>77.9</td>
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<td>-12.2</td>
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<td>Combined Gates Dummy</td>
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<td></td>
<td></td>
<td></td>
<td>201.7**</td>
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<tr>
<td>Testing (Prototypes and Software Builds)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>2.97</td>
<td>127.0</td>
<td>-70.8</td>
<td>-7.98</td>
<td>-37.4</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.076</td>
<td>0.065</td>
<td>-0.007</td>
<td>-0.516</td>
<td>0.601</td>
</tr>
</tbody>
</table>

* p < .10; ** p < .05; *** p < .01

For service cost overrun, n= 12
Consequences of Process Customization: Gate Combination

- Gate combination associated with:
  - reduced development time by 10.5 weeks
  - reduced development cost by $2.6m

- Gate combination associated with reduced testing
  - When gates are combined projects do 3.66 less tests

- Testing is strongly negatively related to service cost overrun
  - Each unit of testing associated with reduction in service cost overrun of $33.91 (no other significant predictors of service cost overrun)
  - Each unit of testing reduces total service cost overrun/year (each product overrun multiplied by 80% of intended sales for that product) by $0.77m
  - Gate combination is associated with an increased service cost overrun of $2.81m/year (0.77m x 3.66). This is a conservative estimate. Direct regression shows increase of $4.34m/year.

- Products are serviced for at least two, often three, years.
- The negative spillover effects of gate combination in terms of increased service cost easily outweigh the benefits.
Conclusions from Phase 2

- Variation on different process dimensions associated with different performance effects
- Results indicate that variations from the process standard (specific variations, not all) are associated with net negative project performance outcomes.
- Results support that process standardization can be beneficial for project performance even across varied projects.
Contributions and Future Work

- Importance of individual process dimensions
- Framework to aid organizations in decision making about process standardization
- Evidence from one company that standard process can be associated with better performance across varied projects

Need to extend work to other companies
- Seeking generalizability
- Seeking understanding of company contingencies
Thank You!

Questions? Comments?