

Standardization of Product Development Processes in Multi-Project Organizations

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Abstract

An important question for a large company with multiple product development projects is how standard or varied the sets of activities it uses to conceive, design, and commercialize products should be across the organization. To help address this question, this project is comprised of three research activities to improve understanding of the influence of standardization of product development processes on performance. Previous research indicates that process standardization has many positive (improved efficiency, knowledge transfer, decision making and resource allocation) and negative (reduced creativity, innovation, adaptation and learning, employee satisfaction) performance effects. Even focusing on specific performance outcomes, the influence of process standardization is contested.

The first phase was a set of theory-building case studies at five large companies that develop electromechanical assembled products. One important lesson from the case studies was that to appropriately evaluate the impact of standardization on performance it is essential to disaggregate the process into its individual 'dimensions' (activities, deliverables, tools, etc.) because standardization on different dimensions of the process impacts performance outcomes quite differently. Another lesson was that companies differ in their process standardization approach because of differences in their portfolio characteristics and in their strategic priorities across performance outcomes.

Based on the importance of focusing on individual process dimensions, a broad and systematic literature study was conducted with the aim of better capturing the current state of knowledge. This literature study resulted in a framework to characterize the problem space, a comprehensive set of relevant project characteristics, process dimensions, and performance outcomes and a summary of the established links, contested links, and unexplored links between these elements.

Focusing on one set of contested links from the literature, the final research activity was a detailed empirical study at one company. The goal was to study the effect of variation in project-level product development processes, operating under the guidance of an established process standard, on project performance. The purpose-assembled data set includes measures of project characteristics, process dimensions, and project performance outcomes for 15 projects. Statistical analyses were performed to examine the relationships between process variation and project performance outcomes. Where possible, the statistical analyses were supported and enriched with available qualitative data. The results indicated that, at this company, process variation in the form of both customization and deviation was associated with negative net outcomes. Customization (in the form of combining project reviews) was associated with reduced development time and development cost, but also with lower quality, likely because of reduced testing. On net, in dollar terms, combining reviews was associated with negative outcomes. Specific deviations (in the form of waived deliverables) were also associated with negative performance consequences. Results also supported the lessons from Phase 1. Variation on different process dimensions was associated with different performance outcomes. Disaggregation was important, with many insights lost when deviations were aggregated.

This project enhanced our understanding of the performance impacts of product development process standardization. The case studies highlighted the importance of disaggregating to individual process dimensions to correctly evaluate the effects of standardization. The systematic literature study resulted in a

framework for organizational decision making about process standardization and a summary of the current state of knowledge – elements, established links, contested links, and unexplored links. The detailed empirical study at one company examined one set of contested links – between process standardization and project performance – and found that process variation in the form of both customization and deviation was associated with net negative effects on project performance.

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1. Introduction and Overview

1.1 Research Motivation

1.1.1 Importance of Product Development

“Product development is the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product” (Ulrich and Eppinger 2000). A broader definition, focused on the creation of a stream of multiple products over time, is provided by Wheelwright and Clark (1992: Chapter 1). They define product development as “the effective organization and management of activities that enable an organization to bring successful products to market, with short development times and low development costs.” This definition of product development also helps to highlight three critical aspects of product development project performance: cost, schedule, and quality.

Product development is critical because new products are the basis for competition in many firms. In a wide range of industries, firms that quickly and economically develop good products are likely to succeed. For this reason, product development is a source of competitive advantage for many firms. Product development is also important because it is a mechanism by which companies diversify and adapt themselves to match evolving environmental conditions. Thus, product development is among the essential processes that influence the success and renewal of organizations. (Brown & Eisenhardt 1995, Clark & Fujimoto 1991)

1.1.2 Importance of Process in Product Development

A process is “an organized group of related activities that work together to create a result of value” (Hammer 2001). Processes are a fundamental aspect of design and management theory and practice.¹ They are at the

¹ An important and closely related organizational construct is that of an organizational routine. Organizational routines can be defined as repetitive, recognizable patterns of interdependent actions, carried out by multiple actors (Feldman & Pentland, 2003). Seminal organizational studies have recognized routines as an important element of organizational behavior (Cyert & March, 1963; Nelson & Winter, 1982). Examination of the definitions of organizational processes and routines reveal that they share much in common. In fact, in much of the literature the terms have been used quite interchangeably. There have been some attempts to distinguish between routines and processes. For example, Bingham et al. (2007) argue that routines are one form of knowledge (the other being heuristics) that can be learned through experience with organizational processes. They also distinguish between processes and routines on the grounds that a process need not be routinized (it can be ad hoc) and that a single process may include many routines. However, when we look at examples of routines that have been studied in the literature (Feldman, (2000) examines hiring, training, and budgeting, among others) we see that they are quite broad and could just as easily be called organizational processes. In one example that illustrates the interchangeable use of these terms, Benner and Tushman (2002), in their study of the influence of process

heart of broadly adopted management approaches such as Total Quality Management (TQM), Lean, Six Sigma, reengineering, ISO 9000, and CMMI. Focusing on the organizational activity that forms the focus of this dissertation, one can define a *product development process* as, “the sequence of steps or activities which an enterprise employs to conceive, design, and commercialize a product” (Ulrich and Eppinger 2000). An example of a high-level product development process is shown below.

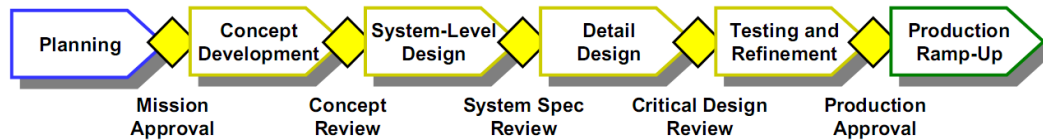


Figure 1 - Generic Product Development Process
(based on Ulrich and Eppinger 2000)

The processes used in product development have been found to have important effect on performance outcomes and been the focus of a wide range of research (Browning and Ramasesh 2007, Gerwin and Barrowman 2002). An important premise of this dissertation is that processes themselves can be designed. “Processes can be regarded and treated as systems that should be engineered purposefully and intelligently, facilitated by useful models.” (Browning et al. 2006)

1.1.3 Multi-Project Organizations

Today, much product development occurs in large firms that have several business units, each with multiple PD projects running in parallel and each producing a stream of new products over time. For any multi-unit organization, a natural question arises: should all units do things the same way, or should they do things differently? (Hammer and Stanton 1999) This research project addresses that general question in the specific context of product development in multi-project organizations.

management on innovation, repeatedly state that process management reduces variation in organizational routines. Pentland and Rueter (1994) lay out two contrasting views of routines – effortful accomplishments and automatic responses. The understanding used in this research is that routines are effortful accomplishments, rather than automatic responses. Building on this view, and considering that both processes and routines are centrally based on repeated patterns of action, I will use the terms processes and routines interchangeably and draw upon organizational routines literature in this work.

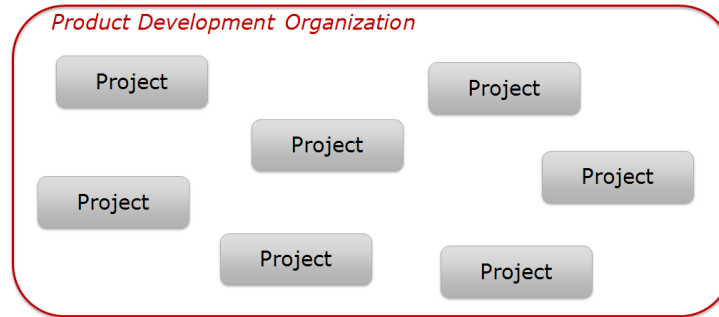


Figure 2 - Multi-Project Product Development Organization

If different PD projects across an organization do things in largely the same way and execute the same sets of activities to take products from idea to market, we say that the organization is characterized by a high degree of *process standardization*. If projects across the organization do things differently (execute very different sets of activities, in different orders, using different tools etc.) we say the organization is characterized by a high degree of *process variation* or *process diversity*. To consider if different projects across an organization should do things the same way or do them differently, we need to understand the performance impacts of process standardization. Thus we start with the overarching question: What is the impact of process standardization on performance?

1.1.4 Process Standardization in Multi-Project Organizations – Explanation and Effects

Previous research indicates that process standardization has many positive and negative performance effects. On one hand, process standardization has been argued to offer several benefits in terms of increasing efficiency (Adler et al. 1999, Morgan and Liker 2006); enabling decision-making and resource allocation (Garvin 1998, Hammer and Stanton 1999, Sobek, Liker, and Ward 1998); and aiding knowledge transfer across projects (Adler and Cole 1993, Argote 1999). On the other, it has been argued that process standardization may prevent widely varying individual projects from effectively meeting their performance goals (Shenhar 2001, Krubasik 1988, MacCormack and Verganti 2003); reduce creativity (Tilcsik 2008); curb an organization's ability to innovate (Benner and Tushman 2002); hinder an organization's ability to learn over time and adapt to changing environments (Benner 2009, Levinthal and March 1993); and alienate employees (Hackman and Oldham 1980).

Even limiting consideration to specific performance outcomes, the influence of process standardization is debated. For instance, Tatikonda and Rosenthal (2000) show that process standardization actually improves project performance even across widely varying projects. Adler and Borys (1996) argue that standardization can be enabling or coercive, and if implemented in an enabling manner, can improve employee satisfaction.

Spear and Bowen (1999) explain that the standardization of processes at Toyota accelerates learning and adaptation by providing a steady baseline against which improvements can be measured and implemented.

It is apparent that researchers agree that process standardization impacts various performance outcomes, but the exact nature of this influence is often debated. We see that process standardization is both a powerful and complicated organizational lever; powerful because it impacts several different aspects of performance, complicated because there is debate about the direction of many of these impacts. As a matter of practical importance, it is even less clear how process standardization is to be implemented in an organization in a manner that best supports harnessing the benefits and controlling the costs.

For a complex organizational phenomenon such as process standardization, it can be difficult to make headway in understanding performance effects. Eminent organizational routines researcher, Sid Winter, puts it well in a recent piece (Adler et al. 2008) when he says “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.”

1.2 Overarching Research objective

The goal of this research is to provide companies with guidance for effectively managing standardization and variation of their product development processes across multiple different projects. To do this, the initial overarching question motivating this research was: What is the influence of process standardization on performance? In light of what has been shown above about the powerful and complicated nature of process standardization, this initial driving question might be better adapted to: Under what conditions and how does process standardization influence performance on project-level and organization-level outcomes? Using this question as a starting point, this research acknowledges the complexity of process standardization’s influence in organizations and seeks to improve understanding of some mechanisms and contingencies through which process standardization influences performance.

1.3 Overview of Study

The project consists of three research activities, which are described in this document. An overall map of the research project, with the insights that connected and motivated the different research phases is shown below.

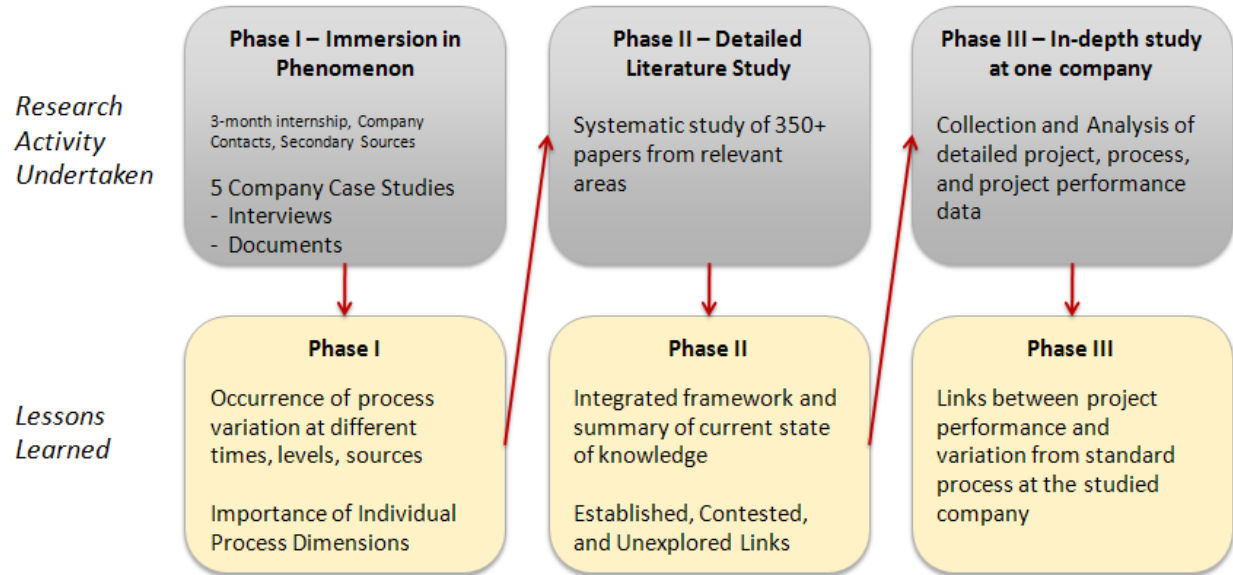


Figure 3 - Map of the Research Project

This dissertation is organized as follows. Chapter 2 describes the case studies and the conceptual insights gained from them. Chapter 3 outlines the detailed literature study and provides a summary of the current state of knowledge. Chapter 4 describes detailed empirical study and its findings. Chapter 5 concludes by discussing the lessons learned across all phases, the contributions of the work, and suggestions for future work.

2. Phase I - Immersion in Phenomenon and Case Studies

2.1 Overview of Immersion in Phenomenon

The goal of this research is to better understand how standardization influences performance. In light of the fact that standardization is complex, a way to achieve this goal is by beginning to sort out the mechanisms through which standardization influences performance and by understanding the contingencies that affect those influences.

To begin this process of improving current understanding, a well supported research strategy is to actively engage with the phenomenon in the field. Theory-building research using real-world cases is particularly useful for answering “how” and “why” questions about phenomena of interest (Eisenhardt & Graebner 2007). In this chapter, I will describe the steps I took to actively engage with the phenomenon of process standardization. These steps include:

- an internship studying product development processes at a large auto supplier,
- studying secondary literature and initial conversations with process managers to understand process standardization approaches at various companies, and
- five in-depth company case studies.

2.2 Description of Internship at a large auto supplier

I performed a three month internship at one of the world’s largest automotive technology suppliers. The goal of my internship was to study the product development process of a newly initiated business unit and to make recommendations for its improvement.

The company consisted of several different business units, each focusing on a particular technology class. Each business unit had its own standard product development process. The newly initiated unit, within which I was stationed, was one that crossed several technology classes and was therefore composed of people drawn from many different units. In the development of the new system, these employees were each using their former home unit’s product development processes as a reference. This led to some coordination difficulties within the new unit. My supervisor was responsible for developing the product development process for the new unit. In the course of my internship, I studied the development processes for several different units within the company to understand their similarities and differences. I also interviewed people in a variety of

roles (engineers, project managers, and business unit managers) to understand how they interacted with the process and what features they would like included in the standard process for the new unit.

This internship was invaluable in providing me a grounded understanding about how product development processes operate in multi-division, multi-project organizations, how various stakeholders interact with the process and use it in their work, and also simply to convey the complexity of the entire system.

2.3 Secondary Data Sources describing Process Standardization

After this initial grounding, I was interested in understanding how companies currently managed the tradeoffs of process standardization and customization. Towards this goal, I utilize secondary literature as a data source. There exist a few published descriptive case studies depicting how particular organizations manage process standardization. I include here the main insights gleaned from these secondary sources.

2.3.1 Motorola

Tailoring of the Software Development process at Motorola is the subject of one descriptive study (Fitzgerald et al. 2003). The authors describe how the Organizational Standard Software Process (OSSP) at Motorola's facility in Cork, Ireland is "micro-tailored" for individual projects. Certain elements of the OSSP are chosen based on project-specific characteristics. The Project level software process includes "software standards, procedures, tools, methods, and templates." The decision about what elements of the OSSP are applicable to the project is taken by the project manager. Some of these tailoring decisions are made at the start of the project and recorded in the project plan. Others are made dynamically in the course of the project. For both types of tailoring, attempts are made to define and capture "tailoring criteria" and rationale, which then form the base of knowledge for future tailoring.

2.3.2 Pratt and Whitney

(Bowen & Purrington 2006) is a Harvard Business School case that provides a description of the implementation of Engineering Standard Work at Pratt & Whitney. P&W is widely regarded as one of the leading industrial implementers of ESW. "Underlying the creation of ESW was a recognition that designing a complex system required the creation of a prescriptive process that made all work as foolproof as possible and caused learning to be automatic." The idea was that, "Pratt's product development resources would be organized as an engineering factory in which complex work flows traveled along predetermined paths and across engineering groups and each engineering activity was defined by prescriptive procedures."

ESW consisted of workflow maps and activity pages that together "carefully documented 1) what needed to be done, 2) how it needed to be done, and 3) when the task needed to be started and completed on the

critical path.” Organizational standards of *Technology Readiness Levels, Tools and Methods, Design Criteria*, and *Design Standards* support the implementation of the actual steps. *Practitioner Proficiency Assessments* and *Standard Resource Plans* allow the efficient allocation of resources to tasks.

Importantly for our purposes, an online system allows transparent tracking of all approved deviations from the standard work. Deviations can only be approved by someone with the necessary certified Proficiency Level.

The implementation of this ESW architecture at P&W has been a resounding success, with a 2002 assessment finding that \$1 spent on ESW achieved a cost savings of nearly \$4.

2.3.3 Toyota

Another description of process standardization comes from Morgan and Liker’s 2006 book on the Toyota Product Development System (Morgan & Liker 2006). The authors describe extensive standardization at Toyota in three areas - Design, Process, and Engineering skill-set.

They describe process standardization as involving standardizing tasks, work instructions, task durations, and the sequences of tasks in the development process itself. To address how each program creates its own process, the authors offer: At Toyota, “macrolevel milestones and timing are utilized across different programs and each individual functional organization level controls the detailed, working-level processes. By leveraging both of these standardized structures, detailed, program-specific schedules at the working level are developed.” p. 105

We should take away one key difference between Toyota’s process standard and that of most other organizations. “Whereas Toyota’s various engineering organizations each standardizes the *means* to engineer the product based on requirements of a central framework,” most other companies “attempt to standardize *only the ends* for the entire product development enterprise.” [Emphasis added, p.105]. We can see that Pratt and Whitney’s approach to Engineering Standard Work is quite close to Toyota’s. Unfortunately, neither the study of Toyota nor P&W includes much detail about how customized program plans are created for individual programs.

2.4 Case Studies

After studying secondary sources for descriptions of how companies manage standardization, I conducted in-depth case studies at five companies.

2.4.1 Theory Building from Cases

Case studies are rich, empirical descriptions of particular instances of a phenomenon that are typically based on a variety of data sources (Eisenhardt and Graebner 2007, Yin 2008, Eisenhardt 1989). Case studies are well suited to answering “how” and “why” questions and are a particularly appropriate research approach when previous research may have addressed the question in a way that is inadequate (Eisenhardt and Graebner 2007). Given the state of the previous research, and that my goal was to begin to ‘sort out the mechanisms and contingencies’ through which process standardization impacts performance, I chose a research approach of theory-building from case studies.

Much of the previous research on product development processes has focused largely on understanding the impact of process design on performance at the individual project level (see Browning & Ramasesh 2007 for a review of model-based work; Gerwin & Barrowman 2002 for review of empirical work at the individual project level). “Little research has been completed on the links between the operations at project level, the portfolios of projects at the organizational level, and central routine activities of the firm as a whole” (Engwall 2003). Work that does address the effectiveness of process standardization in product development and focuses at the level of the portfolio or the organization has often been prescriptive, aimed at practicing managers to promote the use of process standardization in organizations (e.g. CMMI, Cooper 2005) or, in the case of work published in academic journals (Benner & Tushman 2002, Tatikonda & Rosenthal 2000), has taken a very high level approach to measuring process standardization (ISO 9000 certification, survey question asking for rating of ‘process formality’). In Chapter 1 we saw that researchers studying process standardization in a variety of organizational functions have found it to have a several different performance effects and results from studies have often even contradicted each other. To develop a more fine-grained understanding, grounded in real-world product development practice, I conducted five theory-building case studies.

I chose a multiple case study approach because it would allow me to create robust theory grounded in varied empirical evidence from the different cases. The multiple cases also make it possible to compare and contrast between them and more precisely understand constructs and relationships at appropriate levels of abstraction (Eisenhardt and Graebner 2007).

2.4.2 Selection of Cases

To choose my five cases I employ theoretical sampling i.e. I select cases because they are particularly suitable for describing the phenomenon and illuminating the constructs in which I am interested. This is the standard

and appropriate approach for sample selection in theory-building case studies (Eisenhardt 1989, Eisenhardt and Graebner 2007) and should not be confused with random or stratified sampling.

The selected cases that comprise the sample are five large companies that develop electromechanical assembled products. The smallest company in the sample had annual revenue of approximately \$5B in 2009. I chose large companies because I was interested in studying organizations in which process standardization is an important issue. I wanted to study companies that had multiple product development projects ongoing at one time and that developed a steady stream of products. I chose companies (or at least focused on divisions within companies) developing electromechanical assembled products because I wanted to be able to meaningfully compare across cases and therefore wanted the companies to be undertaking essentially comparable product development activities. For this reason, I did not choose companies that primarily developed software, chemicals, pharmaceuticals etc. because product development in these contexts is quite different. While the companies in the sample are similar in that they are large and develop electromechanical assembled products they also differ in some important respects. The companies all operate in different industries (computer hardware, aviation electronics and communication equipment, automobiles, electronic equipment). They also have different approaches to process standardization (this will be explained in detail later in this chapter). Of course, one important determinant of case selection was company interest. It was essential for me to get access to process data, so the willingness of companies to share their time and information with me was an important criterion in the formation of the final sample.

2.4.3 Approach and Data Collection

I visited each of the selected companies for data collection. The visits lasted from three days to a week. Two of the companies were visited twice, and the other three were visited once. Across the cases, my data collection and analysis was driven by seeking to understand three basic questions:

- a) how do product development processes differ across projects?
- b) why do product development processes differ across projects i.e. what factors drive these differences?
- c) how do differences or standardization across processes impact performance on project-level and organization-level outcomes?

At each of the companies I focused on two broad sources of data – interviews and process documentation.

Interviews

The first source of data was interviews. I conducted semi-structured interviews with a wide variety of stakeholders within the companies who all interacted with the development process in a different manner

(project managers, engineers, process managers, business unit managers, functional managers). The set of interviews I conducted at each of the companies included at least one process manager, project manager, and portfolio manager. When possible, I also included additional informants who were engineers and functional managers. In all, I conducted 48 interviews across the five companies (see distribution below).

	Project Manager	Process Manager	Portfolio Manager	Project Engineer	Functional Manager	Total by company
Company A	1	1	3			5
Company B	2	2	1			5
Company C	3	1	1	1		6
Company D	1	3	1	2		7
Company E	7	4	6	4	4	25
Total by Role	14	11	12	7	4	48

Table 1 - Interviews by Company and Role

The interviewees were chosen by a snowball sampling method. My first point of contact at each of the companies was a process manager. Once I had explained my research focus and requested to connect with people in various roles, they pointed me to people within their organizations. Often those interviewees recommended other people for interviewing.

The interviews ranged from 45 minutes to three hours (and in one case a full working day). I took detailed notes at each interview. For those interviews where I received permission (less than half), I recorded the conversation. Within a few days of almost all interviews, I sent a summary of the interview notes to the interviewee, asked if I had captured the essence of our conversation, and sometimes asked for clarification.

In each of the interviews, I asked informants a subset of the following questions:

- How do you interact with the product development process in your daily work?
- What for you are the three biggest benefits of a standard process?
- What for you are three biggest costs of standard process?
- What are the biggest benefits and costs of a standard process to the organization?
- On a project, what factors cause you to modify or deviate from the process?
- How do the projects in your organization differ from each other?
- How do you see product development processes varying across projects in your organization?
- What are the main reasons driving the differences in product development processes across projects?

Reflecting the semistructured nature of the interviews, not all questions were discussed with all interviewees.

In each conversation, the interviewees and I directed attention to areas that seemed interesting.

Process documentation

The second broad source of data was company documents pertaining to the product development process. At each of the companies I primarily studied PD process documentation at the central level. These documents described the standard process to be applied across the portfolio and also provided guidance for how the standard process could be customized for different projects. The types of documents I accessed at the central or portfolio level included: websites and binders of process description and flows, process overview presentations and pamphlets, and web repositories of project portfolio information. Together, these formed several thousand pages of process documentation. When possible, I also studied process documentation at the level of the individual projects (describing each project's instantiation and execution of the standard process). However, at this stage of the research, the project-level process information was a secondary source of information.

Scope of Study

The primary focus of this research is on standardization and variation in product development processes across projects within a company. The variation in the form of standard process from one company to another (e.g. waterfall, spiral etc.) is important only inasmuch as it helps to understand the within-company variation. Unger (2003) and Slaughter et al. (2006) are two studies that focus on variation across companies.

Variation in process can occur at multiple levels. For example, at the highest level (shown in Figure 1), development processes can be almost entirely common. At the lowest level of abstraction, for example in the details of how individual engineers accomplish particular subtasks, there might be a lot of variation. It is important to define the level at which variation in processes is being studied. In this research, I asked respondents to describe the highest level of abstraction at which interesting variation in development processes occurred in their organizations. Across the companies, this level turned out to be one level down of abstraction down from highest level described in Figure 1. At this level, the process might consider of a set of activities on the order of 100 in number. Variation in activities executed, sequence, tools, etc. occurred at this level and formed the focus of this study.

2.5 Case Write Up – Company A – Computer Hardware

2.5.1 Description of Company Unit and Product Portfolio

Company A is a large provider of computer products and services. At this company, I focused my study within one business unit. The business unit provides products and solutions to retain and manage large volumes of digital information. The product portfolio consists of a broad range of disk and tape storage

systems and software. The unit also provides server systems that are typically the core technology in data centers for client institutions. The business unit had revenues of about \$15 billion in 2009.²

2.5.2 Description of Interviews

At this company I conducted five interviews – three with portfolio managers, one with a project manager, and one with a process manager. I include here a summary of the lessons learned about how this company unit manages its process standardization.

Separation of Project Management and Technical Development Activities

There was a clear distinction in this organization between project management and technical development activities. The standard process that was laid out for the organization focused on the business case and management activities. Technical development activities ran in parallel to the management process, and were not standardized. Each product line, or even each team often differed in the manner in which they performed the technical development activities.

“The standardized [NPD]³ is about management and the business case. Technical development is not standardized – not across [Company], [Unit], or even product lines or brands” – Process Manager

“The technical development process runs in parallel to [NPD]. The Gates used are the same for [NPD] across all products and brands. [NPD] opens or closes the funding.” – Portfolio Manager

Management of variation from standard

As a standard existed for the NPD, it was useful to ask how variation from that standard was managed within the organization. The unit did recognize that there was variation across the projects in their portfolio and provided some central guidance for how the process should be customized to fit the different projects.

“We have 8 different project archetypes. Then we have a matrix with each of the project types as a column and the checklist deliverables as rows. The matrix shows the not applicable items, and also shows why. It gives reasons for different products.” – Project Manager

“The unit has an overall defined process checklist of approximately 75 items which acts as a superset process for all projects. Certain parts of this checklist may not be applicable to certain projects, therefore we provide guidance by selecting the subsets which they do not need to execute.

The checklist deliverables are the heart and soul of NPD.” – Portfolio Manager

² Annual revenues for all companies are approximated to maintain anonymity. The revenues are provided only to give a sense for the size of the companies or business units.

³ To maintain anonymity, I substitute the acronym NPD (New Product Development) for the name of the standard process used at this organization. I will use NPD as the standard process name for all the companies in my study.

	Product Type							
	Hardware	Software (not MNL, not ABC)	Hardware & Software	Software OEM-in	Hardware OEM-in	Hardware Reseller	ABC Software	ABC XYZ Software
Examples:	AB4000, AB5000, some Tape	none, except RST going to PQR	SVC		AB3000, Brokeman 20	Sysco PQR	Note: These are special in that are closely tied to system software of which ABC is a part	
Development								
Accessibility Checklist(s) Anti-Smike - HW only							NA - handled by pDA	NA - done at major release. Not required for SPE maint
		NA - not HW		NA - not HW			NA - not HW	NA - not HW
Cost of Originality (COO & VOO)						NA - not required for reseller	NA - handled by pDA	NA - done at release level
Chemical Emissions Data								
Finance								

Figure 4 - A mock-up of the matrix used to manage customization for different project archetypes

However, the matrix of checklist deliverables for each project type only provided a guideline or a starting point for the process executed on each project. There is much more variation in processes across projects than is outlined in the matrix. For instance,

“An item isn’t really always required, even if checklist says it is. Depending on the product – for example, if the review is for a different distribution channel and the product hasn’t changed – there may be no need [for an item].” – Project Manager

For these additional variations on the process, we found that even within the business unit there were differences in the way in which variation from the NPD standard was handled. There were two different variation approaches used by different product lines within the business unit.

In one approach, process variation decisions were made and documented upfront. Teams were asked to submit a document called the ‘Process Customization Declaration’ outlining which of the stipulated NPD steps were applicable to their project and therefore what subset they were going to perform. These documents were reviewed and approved at the start of the project and then acted as the plan for the projects.

“Each project team creates a ‘Process Customization Declaration’ for their project. It outlines - out of the NPD steps and process artifacts, which ones are applicable to this particular project? PCDs have to be approved within the product line. They are reviewed by the product line leader or NPD leader. The PCDs are then maintained at the project level.” – Portfolio Manager

“The PCD requires them up front to say what items they are doing and aren’t doing.” – Portfolio Manager

In the other approach, variation decisions were made and documented by project managers and then a subset of the projects in the product line were audited to check their compliance with the process or their reasons for variation.

“The customization of processes is reviewed by the product line leader and maybe by corporate. The review is not an upfront signature to sign-off and approve each customization. Teams can self declare what is not applicable. Instead the review is a post-hoc random testing or an audit. In the audit they test for compliance and reasons provided for customization.”

“Processes are driven by audit. Can I meet the audit?” – Project Manager

“In our product line it is not upfront. The executed process is reflected in the checklist log. Along with sometimes the reason why they didn’t do it for some items. The teams self-declare that it is not applicable. Then about 10% of the items are spot checked later.” – Portfolio Manager

Individual projects have to provide and document reasons for why they did not execute certain elements of the NPD. The auditor has to judge if the reasons provided are valid or not. When asked how these judgments were made, a portfolio manager offered the following response:

“Some reasons for requiring or not requiring a project to do something come down to history and previous experience. I make a value judgment about what is a good reason based on my knowledge and experience.” – Portfolio Manager

The process variation in this unit is a mixture of centrally guided customization and additional variation decided upon by project teams.

Characteristics on which projects vary

One important characteristic on which the projects within the unit varied was the balance of Hardware and software in development. This was one of the characteristics considered in developing the 8 product archetypes. Another important project characteristic that also had enough variation to warrant its consideration in the development of the 8 archetypes was the extent of development performed in-house versus at a supplier.

However, projects within the unit varied on many more characteristics than just hardware and software balance and extent of in-house development.

“Eight archetypes are not enough to capture all variation in products. There are always exceptions to 8 product categories.” – Portfolio Manager

“Even after all this, it doesn’t capture the complexity of the real products.”- Project Manager

I asked interviewees to describe the characteristics on which the products in the portfolio varied. In addition to the two characteristics mentioned above, respondents cited these factors:

“Some products are thirty years old, some are very new. The technology that underlies these products is different.” – Portfolio Manager

“Type of release - Release 1, 2 or 3 in a product family. Some could be entirely new products introducing a line, other could be follow on releases that differ very little from previous releases.” – Portfolio Manager

Dimensions on which processes vary

I also asked interviewees to describe how processes varied across projects in the organization. An important set of answers highlighted that the process standards imposed some uniformity in the activities that were performed, but the manner in which they were performed (fidelity, tools, time, etc.) varied a great deal.

“The NPD tries to determine the 'What' of the process. The 'How' is determined on a project-to-project basis by the project teams. Attempts to dictate the 'how' have not worked well in the past.” – Project Manager
“This is all 'what'. No 'how'. There's tremendous variation on how.” – Process Manager

Another closely related lesson was about the levels of granularity in the process.

“Processes start diverging at lower levels of abstraction. We have tried to keep Phases and Activity level of the NPD common. The decision points are below that, i.e. 'Task' level. It depends, it varies.” – Process Manager

As the subactivity or task level describes the 'how' of performing the activities, this point is well aligned with the previous one.

In addition, as mentioned before, there is also variation in the less standardized technical development process. For software components of the projects, these differences were highlighted:

“There are different coding practices. Standards are not set. Methodologies have changed over time. For example Waterfall, Rapid Prototyping, Modified Waterfall, Agile – they are all different and have a different set of artifacts.” – Portfolio Manager

Reasons for which Processes vary

When asked about the factors driving differences in the development processes across projects, interviewees highlighted the role of project characteristics.

“Development process variation is considered necessary because of project differences.” – Process Manager
“It's all about what is appropriate for different products.” – Portfolio Manager
“Most variation is driven by the tier of product released - In-house or OEM e.g. product entirely developed in-house or resell from [supplier].” – Portfolio Manager

Project characteristics also played a role in determining the form of the technical development process (in addition to the NPD).

“There is an attempt to match process to project depending on project characteristics. For example, if Time-to-Market is key, an agile process is chosen, if Quality and Stability are the key, then a more structured, more formal process will be implemented. Other important project characteristics that are considered in process choice are size and complexity, co-location, market maturity, and horizon (1,2, or 3).” – Portfolio Manager

Respondents also drew attention to factors other than project characteristics. An important set of answers addressed the mental models, history, and culture of the teams executing the process.

“A big driver of variation is historical experiences and personal interpretation of the process. In reality, the process is not an algorithm. It is more general. It is not nearly as precise or prescriptive. Many things are open to interpretation. This leads to variation across projects.” – Process Manager

“Part of it has to do with how development team came up. Product teams have their own internal culture. Some thrive on change, others prefer old ways. A good part of variation has to do with profile of team.” – Portfolio Manager

“A number of different factors drive the methodology and process choice for a particular project. There are all the on-paper drivers, but a lot of the variation in processes comes from other factors like history, culture, and the team's familiarity with a methodology. These other factors explain at least as much variation in the process as the on-paper drivers.” – Project Manager

Effects of Process Standardization

When asked about the effects of process standardization in their organization, most respondents at Company A accepted the benefits of standardization as a given. They chose to discuss more challenging aspects or to highlight the limitations of simple stories about standardization.

“In terms of consequences of process standardization – simply standardizing processes across software is not enough to ensure a seamless transition of people between groups. The standardization of process helps, but there is much to be said for the people really understanding the technology and how to do the job. This understanding is often beyond the scope of just the standard process.” – Portfolio Manager

“Having more precise documentation that is less open to interpretation could lead to less variation. However, it would also be less flexible and less applicable in a wide variety of situations that could arise. It is very difficult to predict all possible situations and write them in to the process. Thus there is a tradeoff between more precise and less precise documentation.” – Portfolio Manager

2.5.3 Schematic Description of Process Standardization Approach

For each company, I will represent the process standardization approach in a simple schematic table. By process standardization approach, I mean the manner in which central guidance is provided to navigate the tradeoff between process standardization and variation. I will list the project characteristics considered in making customization decisions as an input, the process dimensions about which guidance is explicitly centrally provided as an output, and the method that is used to translate from the inputs to the outputs as the algorithm.

Inputs	Algorithm	Outputs
<ul style="list-style-type: none"> • Hardware/Software balance • Extent of In-House Development 	Table - each product archetype column, activities as rows. yes/no indicated.	<ul style="list-style-type: none"> • Activities
8 Product 'Archetypes'		

Table 2 - Schematic of Process Standardization Approach at Company A

2.6 Case Write Up – Company B – Avionics and Communications Equipment

2.6.1 Description of Company and Product Portfolio

Company B is a provider of aviation electronics and mobile communications products and systems for commercial and military applications. The company had revenues of about \$5 billion in 2009.

2.6.2 Description of Interviews

At this company I conducted five interviews – one with a portfolio manager, two with project managers, and two with process managers. I include here a summary of the lessons learned about how this company manages its process standardization.

Separation of Project Management and Technical Development Activities

Company B also separated its Project Management and Technical Development Activities. At this company, the same level of standardization was applied to and the same tool was used to manage both sets of activities.

Management of variation from standard

Company B had a wide portfolio of products. The company recognized the variation in their portfolio and the need to customize their development process to fit different projects. At the time of this study, the company had just developed a new tool to manage the standardization-variation tradeoff and was beginning to roll it out across the organization.

The company had invested a substantial amount of effort in the development of this new tool. The idea of the tool was to allow project and product characteristics to drive process needs, but still allow a common development process model to be shared by business units and between disciplines. To develop this tool, a small team of process experts and former project managers interviewed 90 different people in the company (project managers, business unit leaders, functional managers) through focus groups and asked questions about process.

“We took the original process and beat it up. After that we began to integrate the [NPD] and pull it together.” – Process Manager
“We didn’t want separate processes, there was so much in common.” – Process Manager

The tool that resulted from the effort was quite sophisticated. It addressed the wide variation in projects in their portfolio by asking project managers to answer a set of 32 questions describing their project at the start of a new development effort. These 32 questions addressed various aspects of the project including size, newness, technology readiness, certifications, supplier capability, production needs, maintenance needs, performance priorities and many others. Answering these 32 questions resulted in a detailed portrait of the project’s characteristics. The tool then outputted the process activities that needed to be performed on the project.

A	B	C	D	E
	Q1		What is the projected cost of this project?	Select one.
<input type="checkbox"/>	a		At or Above \$ABC	
<input checked="" type="checkbox"/>	b		Below \$ABC	
	Q2		Please indicate maturity of technology on the project	Select one.
<input type="checkbox"/>	a		Risky technology - unproven or limited application; emerging within market	
<input checked="" type="checkbox"/>	b		Mature technology - proven and applied in similar applications; established within market	

Figure 5 - A mock up of the spreadsheet used to collect inputs on Project Characteristics

A	B	C	D	E
"X"=YES	Req/ Audit	Cust Req'd	ACTIVITIES AND TASKS	DELIVERABLE
<input checked="" type="checkbox"/>			Capture Originating Requirements	
<input checked="" type="checkbox"/>		<input type="checkbox"/>	1. Capture stakeholders needs	stakeholder needs
<input checked="" type="checkbox"/>		<input type="checkbox"/>	2. Capture source requirements.	source requirements
<input checked="" type="checkbox"/>		<input type="checkbox"/>	3. Capture architectural context.	architectural context(s)
<input checked="" type="checkbox"/>		<input type="checkbox"/>	4. Define most important	most important requirements
<input checked="" type="checkbox"/>		<input type="checkbox"/>	5. Define technical performance	technical performance measures (TPMs)
<input type="checkbox"/>			Define Concepts	
<input type="checkbox"/>		<input type="checkbox"/>	1. Define concept.	concept
<input type="checkbox"/>		<input type="checkbox"/>	2. Perform conceptual analysis.	conceptual analysis document
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		Define Requirements	
<input type="checkbox"/>		<input type="checkbox"/>	1. Perform requirements trade	trade studies
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	2. Define product requirements.	product requirements
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	3. Conduct traceability analysis from	requirements trace/ analysis
<input checked="" type="checkbox"/>		<input type="checkbox"/>	4. Perform functional hazard	functional hazard assessment

Figure 6 - A mock-up of the spreadsheet displaying process activities required for a particular project

The linkages between project characteristics and the process activities necessary was included in the back-end of the spreadsheet, and was based on the input collected from the focus groups and interviews.

“The new NPD eliminates redundant tasks, as well as refines the tailoring questions based on project characteristics, such as size, complexity, and third-party dependencies. The new NPD has eliminated approximately 250 redundant tasks from the current version, reducing the learning curve and improving the understanding of the tailored outputs.” – Company Document

Characteristics on which projects vary

All the characteristics on which projects varied in the organization were well represented in the tool. None of the respondents added any additional project characteristics on which there was significant variation.

Dimensions on which processes vary

Once again, the new NPD provided only the ‘what’ of the activities to be performed. In this company it provided the ‘what’ for both technical and management activities, but still did not include much of the ‘how’.

“The actual steps to execute the project are identified in the methods, guidelines, templates, checklists and procedures of a particular Business Unit. The Business Unit specific methods combined with the [NPD] provide the plan by which the product is developed.” – Portfolio Manager

As a result of the NPD not specifying the how, there was much variation on other dimensions of the process.

“The [NPD] currently works at the level of specifying ‘what’ activities need to be performed. It does not specify with what level of fidelity these activities should be performed, in what order they should be performed, with how many iterations and with what frequency they should be performed, with what tools they should be performed etc. There is substantial variation in these aspects of the process across projects and across business units. These decisions are made by project leadership based on their expertise and knowledge.” – Process Manager

However, the company did not plan this as a final state. They planned to include other aspects of the process in their NPD tool, so that guidance for customization could be provided explicitly at the central level.

“Beginning to think about some other important process dimensions is one of the next steps of our group.” – Process Manager

“An objective of the on-going [NPD] project is to accumulate a repository of process assets. While this repository grows, use of approved process material, whether at the corporate engineering or local business unit, is preferred.” – Company Document

In fact, at the time of this study, the team responsible for the new NPD had already begun to think about how they could link deliverables and templates to the output of activities from the NPD tool.

Reasons for which processes vary

Respondents all cited project characteristics that were included in the NPD tool as factors driving process variation. One factor that was mentioned could be interpreted as a little different from the questions in the tool.

“Technical Reviews are decided on a project-by-project basis. The timing of the technical reviews is often driven by dates imposed by other companies.” – Project Manager

This response shows how the need for coordination with other companies can introduce variation in the process (the timing of technical reviews). This factor could fall under the questions addressing suppliers and customers, but it was different enough that I highlight it separately.

Effects of Process Standardization

The respondents provided many expected effects of the new tool imposing a common structure across units and projects. One expected effect was that it would be easier for people to move between units.

“Only seldom do our people move across disciplines. They often move between business units, which was addressed by the development of this tool. It should now be much easier for people to move between business units.” – Portfolio Manager

Another important set of expected benefits had to do with providing a measurable and comparable baseline, from which improvement could be gauged. This would also allow comparisons across projects. The expectation was that the tool would lead to improved decision making and resource allocation, as well as spur productivity improvements in individual process elements.

“We expect that the process becomes basis of planning, also the basis for the WBS.” – Process Manager

“We can now collect consistent metrics across projects, because the work they do is now comparable.” – Portfolio Manager

“We can assess if individual process items are set up correctly - how long does it take, how much does it cost to do step X? It'll provide us a big boost in our goal of improving our productivity and cycle time, because we can now measure it.” – Project Manager

2.6.3 Schematic Description of Process Standardization Approach

Inputs	Algorithm	Outputs
<ul style="list-style-type: none"> • Complexity • Newness • Cost • Certifications • Technology Readiness • Business Unit • Testing Requirements • Support Requirements • Hardware/Software • Extent of Outsourcing • Supplier Quality • Production Needs <p>32 questions</p>	<p>Logic Table – each activity decision made by referring to answers for pertinent questions</p>	<ul style="list-style-type: none"> • Activities (required and suggested) • <i>Deliverables</i> • <i>Templates</i> <p>~80 technical activities ~50 management activities</p>

Table 3 - Schematic of Process Standardization Approach at Company B

2.7 Case Write Up – Company C – Automotive Manufacturer

2.7.1 Description of Company and Product Portfolio

Company C is one of the world's largest automotive manufacturers with a wide portfolio of cars and trucks. It had revenues of over \$100 billion in 2009.

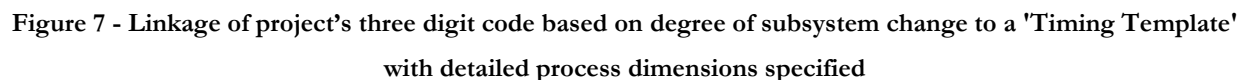
2.7.2 Description of Interviews

At this company I conducted six interviews – one with a portfolio manager, three with project managers, and one with a process manager, and one with a project engineer. At this company, I did not record any of the interviews, so my descriptions below include no quotes. I include here a summary of the lessons learned about how this company manages its process standardization.

Management of variation from standard

The products in this company's portfolio, while highly complex, did not differ greatly from each other. Each development effort was one to create a new model of car or truck, and so was quite comparable. There could be variation in products depending on whether the new model being developed was simply an upgrade of an existing model (slight tweaks for the new year) or one based on an entirely new platform. To capture this one

“The Goal is to provide a standard method for describing the degree of product change, generic development timing, and generic development logic of a vehicle program as well as the linkage between them. Specifically, this method supports the development of the product cycle plan and the development of the Vehicle Program Plan (VPP).” – Company Document



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processes for sourcing and supplier interaction, technology development and sharing, and manufacturing planning that interface with the NPD at many points.

Characteristics on which projects vary

As indicated above projects varied primarily in the degree of change in three key product subsystems. Respondents pointed to other characteristics on which the products varied, but stated that these were not characteristics that impacted the development process at the level I was studying.

Dimensions on which processes vary

Respondents indicated that processes for each program varied greatly in terms of the actual detailed tasks performed within them. However, at the level I was studying, all the important variation was captured in the NPD customization process described above. Processes did vary in activities, reviews, time spent on activities, sequence of activities, templates, deliverables, and roles, but all of these were specified in the timing templates.

Reasons for which Processes vary

The respondents did not indicate any reasons other than product characteristics that drove variation in the process at the level I was studying.

Effects of Process Standardization

Respondents indicated that the Company had invested a substantial amount of resources in the development of its NPD plan. They expected that having a standard development plan would allow them to reduce their development time while still performing all necessary activities and maintaining quality.

2.7.3 Schematic Description of Process Standardization Approach

Inputs	Algorithm	Outputs
"Degree of Product Change" in three key subsystems Rated from 1-6	Three digit code maps to a "timing template"	<ul style="list-style-type: none">• Activities• Sequence• Timing• (Reviews)• Deliverables• Templates• Roles

Table 4 - Schematic Description of Process Standardization Approach at Company C

2.8 Case Write Up – Company D – Electronic and Subsystems Solutions

2.8.1 Description of Company Unit and Product Portfolio

Company D is a leading military contractor. At this company, I focused my study within one business unit. The business unit that I studied focuses on electronic and subsystems solutions for the defense and intelligence markets, as well as commercial sectors. The unit offers a diverse set of products and services including electromagnetic signal technologies, such as radio frequency apertures, transmitters, receivers, and infrared sensors; mission-specific defense IT and network systems management; aircraft flight and engine controls, cockpit displays, and vehicle management systems; and maintenance of maritime resources. Its order book comprises several thousand contracts, with diverse delivery periods ranging from months to multiple decades. The revenue of the business unit was about \$10 billion in 2009.

2.8.2 Description of Interviews

At this company I conducted seven interviews – one with a portfolio manager, one with a project manager, three with process managers, and two with a project engineers. I include here a summary of the lessons learned about how this company manages its process standardization.

Management of variation from standard

Company D is a defense contractor. As a result, external standards popular in the defense industry, such as CMMI and the MIL-STDs, play an important role in its process architecture and management.

“A lot of our commonality is driven by external factors such as MIL-STDs, regulatory standards, and DoDs demand for CMMI” – Process Manager

To understand the manner in which process standardization and variation is managed in this company, it is useful to understand its organizational architecture. The company has four business units. I studied one of the four business units. The business unit I studied has four divisions. Each division has a few ‘business areas’ within it. Each ‘business area’ may have a few different projects ongoing at a time.

At the level of the whole company, there are high level process mandates that simply lay out the necessary phases and reviews (for both design reviews, which address technical issues and bid reviews, which address business issues) for any project. These apply across the entire company and are mandates. They specify the ‘what’ but not the ‘how’ for the phases and reviews. At the level of the business unit and the division, there is not much additional information added. There may be slight modifications or tailoring to the company-wide standard model, but they are not very substantial. At the level of the ‘business area’ there is substantial addition. At this level the phases and reviews are supplemented with detailed functional processes that lay out much of the ‘how’. These include activity descriptions, deliverables, templates, and specifications of roles.

At the beginning of each project, the project leadership team follows the company-wide phase and review model and supplements it with the detailed information from the functional organizations to create an engineering plan and a project management plan. These two plans describe in great detail the process that is planned to be executed on that project. In addition to the process dimensions mentioned above at the level of the business area, the engineering plan and project management plan also include the sequence of activities and iterations, the time to be spent on activities, resource allocations, and tools. These are created by the project leadership team and approved by the business area or division leadership.

If there are any aspects of the engineering plan or project management plan that conflict with prevailing process for the business area, then the project can submit a 'Process Change Request'. The goal is to document the rationale for the deviation. These 'Process Change Requests' are reviewed by process managers and business area leaders to gauge their validity and also to update the standard process if necessary.

Characteristics on which projects vary

Across the business areas, there is much variation in customer groups and technology. This is why the business areas have their own detailed processes to fill out the high-level company-wide standard. Within the business areas, each project still has to create its own engineering and project management plans. There are important variations in project characteristics that guide the development of engineering plans and project management plans. A company document lists some important attributes for consideration in project level choices - size, cost, and length of time of the projects. Another company document (a guideline for developing engineering plans) states that to choose an engineering development lifecycle (the philosophy governing iterations and the sequence of activities on the project e.g. waterfall, prototype, spiral etc.), the project leadership team should consider "availability of resources, complexity of program, level of understanding of user requirements, familiarity or newness of product technology, requirements volatility, and schedule constraints."

Dimensions on which processes vary

We have outlined above the dimensions on which project-level processes (as outlined in engineering plans and project management plans) vary. Different process dimensions are controlled at different levels of the organization (phases and reviews at company level; activity descriptions, deliverables, templates, and specifications of roles at the business area level; and sequence of activities and iterations, the time to be spent on activities, resource allocations, and tools at the project level).

Reasons for which Processes vary

Much of the variation in processes is driven by project characteristics. As outlined above, projects in the business unit's portfolio vary on a number of characteristics. These project characteristics are taken into account while creating the project-level engineering plans and project management plans. A company document describes how variation in tools may be driven by project characteristics that are not explicitly listed above:

"At many points in the engineering development lifecycle, a selection must be made among several options of available tools. This selection is typically based on cost, staff experience, availability of training, and interoperability with other tools being considered for use on the project." – Company Document

A presentation made by a Process Manager within the company outlines barriers to process commonality. We can interpret these barriers to commonality as factors that drive process variation.

"Barriers to Process Commonality:

- Inertia
- Lack of proper infrastructure
- Misconceptions about meaning of common process
- "Not invented here" (turf wars)
- Different names for essentially common roles
- Misconceptions about constraints to creativity
- Unwillingness to trade off short term cost versus long term gains"

Slide from a presentation on Process Commonality by a Process Manager

Effects of Process Standardization

Respondents discuss a number of different effects of process standardization. A portfolio manager weighs costs and benefits of standardization:

"The way I think of it is - Commonality drives efficiency. Diversity facilitates innovation. How should we balance these?" – Portfolio Manager

"The cost of maintaining process is different when the process is diverse and standard" – Portfolio Manager

A process manager outlines how process standardization can lead to improvement in performance.

"The need to standardize is driven by our goal to get to CMMI Level 4. We have to collect data on a lot of projects, so we can create baselines and statistical models. These will then allow us to predict and improve our time and cost performance." – Process Manager

A presentation by a different process manager outlines many positive effects of process standardization:

"Advantages of Process Commonality:

- Common face to the customer
- Long term cost savings
- Support for 'borderless engineering' – better communication between functions/sites/divisions
- Reduce variance to replicate successes
- Reduced training costs"

Slide from a Presentation on Process Commonality by a Process Manager

2.8.3 Schematic Description of Process Standardization Approach

Inputs	Algorithm	Outputs
Size Cost Staff Experience Availability of Training Interoperability	<ul style="list-style-type: none">• Overall company-wide lifecycle model• Business Unit has 'tailored' lifecycle• Project further tailors and records in 'Engineering Plan'	Phases Reviews Roles Deliverables Tools

Table 5 - Schematic of Process Standardization Approach at Company D

2.9 Case Write Up – Company E – Electronic Equipment

2.9.1 Description of Company and Product Portfolio

Company E makes electronic equipment with embedded software. It has annual revenues between \$10 billion and \$20 billion.

2.9.2 Description of Interviews

Of our sample of five companies, Company E was studied in greatest depth. At this company I conducted twenty-five interviews (about half of the total number) – six with portfolio managers, seven with project managers, four with process managers, four with functional managers, and four with project engineers. The detailed empirical study described in Chapter 4 was also undertaken at this company. I include here a summary of the lessons learned about how this company manages its process standardization.

Management of variation from standard

Company E has an organization-wide standard process. The standard process [NPD] has six reviews or gates. At each gate, there is a set of deliverables expected. Across all gates, there are ~100 deliverables. The entire process with the gates and deliverables is represented on one A3 sheet. At this level, the process is standard across the company. The [NPD] has both technical and business elements, but the emphasis is on business objectives.

“Historically, [NPD] had more technical parts. Now emphasis is more on business and market.” – Technical Project Manager

Diving down one level deeper, one can get explanations of the deliverables and the activities that should create those deliverables.

The company acknowledges that there is variation across its projects. The two project characteristics it uses in its internal decision making are complexity and newness. The company allows project leadership teams to combine some of the [NPD] gates based on assessments of complexity and newness. This decision to combine gates is not governed by a formal process but is made by a project leadership team in consultation with the business unit leadership.

“Partly the philosophy of [NPD] is to have a superset of all activities, so [NPD] itself is aimed more at larger projects. The idea is that we don’t want to miss key things.” – Process Manager

“For tailoring [of NPD], VPs and Program Managers have open communication and lots of dialogue. There are verbal agreements - this program will be run similarly to this other program. We’re going to combine gates. There is no formal approval process.” – Process Manager

“The delivery team with business partners would look at what [NPD] would fit the project at the beginning. Have that discussion with [NPD] manager and us. Are there phase combinations that make sense? The [NPD] manager and I try to make sure that they’re not taking shortcuts that are going to result in business risk.” – Portfolio Manager

This combination of gates as described above reflects a customization of the standard process that is planned at the beginning of a project. However, not all process variation is planned up front.

“Sometimes it’s like “gee we slipped here, can’t we just combine these gates or waive this deliverable? Other times a supplier isn’t ready, so they can’t submit a deliverable. Variation is not always a pre-planned and intentional outcome.” – Portfolio Manager

These variations of the process that happen during the course of the project and are not pre-planned are still approved by the business unit leadership at the reviews. Projects report variation from the planned process and the reviewers decide if they should receive a ‘waiver’ and move on to the next phase or not.

Characteristics on which projects vary

In addition to complexity and newness, which the company uses in its decision making, projects vary on other characteristics.

The delivery model - internal, OEM-in, partnered etc. is a big dimension of variation. Working with fully OEM-in and fully in-house are two extremes. – Portfolio Manager

“The main factors of variation are how complex the product is, how fast are you turning it around (6 months to many years), amount of software vs. hardware development, and third party vendor vs. in-house.” – Project Manager

Dimensions on which processes vary

Once again a common theme in the responses is that the standard process provides some uniformity in ‘what’ activities need to be performed and ‘what’ deliverable need to be created, but not in the manner in which they are performed or developed.

“At the end of the day, when you step back, the critical few things to launch a product are the same across. The steps that you do might vary in the how.” – Project Manager

“I’m not a believer in specifying hows. Even if they give you secondary benefits. The reality is that it’s going to depend on the organization. Different managers will manage through their own belief system, different systems engineers are going to do things their

way, so on for software engineers, etc. If you want consistency, then have consistency of organization. Consistency of Outputs. That's basically what [NPD] asks for – consistency of outputs.” – Portfolio Manager

As a result of not specifying the ‘hows’, there is variation on many dimensions of the process. Some dimensions of variation include the roles performing activities, the amount of prototyping and testing, the format of the deliverables, the methods used to perform activities, the tools used to perform activities, and the stringency with which activities are performed. The responses below point to some of these differences:

“Who is involved? If it's a small project and you're defining strategies at [Gate 1]. Involve the right stakeholders, such as sales and marketing etc. If you have short delivery time, say less than 6 months, involve [operation companies] – the people selling and implementing early at [Gate 1].” – Process Manager

“One of the most significant customizations is Testing Cycles. Do we need an external customer test? Can I get info another way? It's related to how new is this? Do I really have a lot of risk?” – Process Manager

“A process dimension that varies across projects is the prototype delivery schedule. This is decided by [Gate 2]. It's a serious plan – the number of prototypes, a schedule, who, in terms of the OpCos, gets what prototypes and when.” – Process Manager

“The slide decks for reviews can vary – [Gate 1] packages look different from each other.” – Technical Project Manager

“There's lots of differences. If you want me to highlight some of the common ones...

- Customer Requirements – there are difference in how we gather VoC. It depends on how much time we have and how much money. Should we do QFD, should we do it quicker, should we have surrogate analysts, talk to the sales people? If it's a follow-on or variant, then we won't go through entire QFD.
- There are differences in how you decide on 'Integrated Test Plans'.
- There are differences in financial modeling to determine business forecasting and business case. The method with which we collect and create the inputs for our sales and business forecasting varies across projects.
- Looking across products, I've seen a lot of customization in how goals are communicated to teams. No two programs do it the same. It's an area of opportunity. A management 'Summary of Goals'.
- How we do the competitive analysis by features of the product etc. There are lots of variations. There could be some benefits to taking the best of all and having one standard.” – Portfolio Manager

“There's variation especially in area of tools. It's an especially hard one. Tools vary across organization because there's a big cost of change. Sunk cost you've got in those tools. You could have 15 years of experience and history.” – Portfolio Manager

“The templates for activities and deliverables are increasing, but they aren't common yet. We don't have very good infrastructure to share templates right now. We don't have data management systems etc. It's more of a word-of-mouth sharing.” – Portfolio Manager

“Even though the macro-level processes aren't supposed to differ because we have [NPD], for all effects and purposes, they do based on how much risk is in the project. We'll do things a lot differently at the gates. For example, take a clean sheet program [Name X], loaded with new technology. The scrutiny of organization differs. The rigor with which you go through steps differs. It all depends on the risks. The rigor is really in terms of data demand. Compare [Gate 2] on cleansheet vs. small projects. Amount of evidence needed to produce is really high.” – Project Manager

Reasons for which Processes vary

Many respondents pointed to differences in project characteristics that drove process variation. These project characteristics include complexity, newness, extent of in-house development, sales and distribution channels, customer demands, extent of hardware vs. software, and supplier needs and process.

“If the project is a variant, with just a small number of improvements, then can we streamline the generic product delivery process. If we're doing design work, then we'll focus more on design metrics - drawings completed, lines of code. If the project is a partnered one, we'll focus on making sure the interfaces are validated.” – Portfolio Manager

“Process should fit the program. For a project of 3 months, \$200K, don't need to put \$50K of process. Lots of criteria don't apply to it.” – Process Manager

“A project factor driving variation is implementation complexity. Getting out to market complexity. It’s about sales and distribution channels. Projects should state if they have a bunch of novel stuff, in terms of implementation channel use, in the first gate itself.” – Process Manager

“Project factors that drive variation are:

- Total [development] investment. Is it 10s of millions of dollars a year? The little ones do a lighter process. What’s the business value of the thing? Risk of screwing up is smaller.
- Customer – for example selling to Federal Govt. you have to do certain things. Those are non-negotiable.” – Process Manager

“Reasons for need of process change are:

- Development models. Is it Turnkey, Partnered, or Organic Proprietary. Roughly corresponds to length of program, but it’s actually about the proportion you do in-house.
- Length of the program. Some super long projects need to add more checkpoints in the middle. Shorter projects combine [1a] and [1b]. Or they combine [2] and [3], have [4] literally weeks later.” – Process Manager

“Some change is driven by need to match the vendor’s process. The vendor of the engine will have different models. This drives some variation. An example is financial guidelines. Global purchasing has to deal with vendor differences. Certain programs who deal with certain vendors, always need an exception. Senior management and Finance want every project to do the same budget etc. so they’re concerned. Sooner or later they’ll see that vendors drive variation.” – Project Manager

“The type of project – if it’s pure software, then you customize [NPD], no hardware testing. Lots of projects have total life of a few months. They combine phase gates. They use customized version.” – Project Manager

However, respondents also mention factors other than project characteristics, such as individual taste, history, and organizational culture.

“A general reason for differences is different people, different backgrounds. They put their own spin on things. They need to customize because they can do something better. It’s a common theme. Everything is customized. Only sometimes for good reasons. They all do it with good intentions, but they don’t consider the tradeoff. Do we really need that? Can we get away with the standard way? It’s more that differences in individuals and their experiences that really drive differences in process. It’s not so much about product attributes.” – Portfolio Manager

“Realities of the culture of the organization and its history. An example [Company Unit in Location A] used to have their own delivery process. So they still want to do things a little differently.” – Portfolio Manager

“People may be very comfortable about checkpointing and displaying certain aspects, but they want to keep other aspects hidden within the team – for example test results, or intermediate test results. Oversight is really a big part of it. What am I going to be inspected on? What am I used to being inspected on? I could make that decision before, why do I have to bring it to you now?” – Portfolio Manager

“There are technical, political, and inertia barriers to having commonality in process.” – Project Engineer

Effects of Process Standardization

Respondents cite many performance effects of process standardization. The benefits are much more frequently mentioned than the costs. Some of the benefits that respondents mention are ease of movement of people between projects, improved decision making with standardized information, improved communication and coordination leading to efficient product development, learning across projects, corporate learning over time, reduced training costs.

“We have a lot of movement at [Company E]; through reorgs and other opportunities. Lots of people going into new jobs. It would be more efficient if we had standardization. – Portfolio Manager

“The main use of [NPD] process is to have business discussions with a predefined set of information and the right artifacts.” – Process Manager

“[NPD] used to be a ‘how to’ and ‘who does’ but now it’s a one-pager. The program managers have discretion to do the how to, who does. Now this results in difficulty moving between projects.” – Process Manager

“The value of standard process, in order of importance is:

- People working on multiple projects can easily shift projects. At [Company E] people don’t move between programs a lot. But they work on multiple projects at once. Ease of movement gets talked about. You constantly hear it in the hallways.
- Second thing is consistency. “Talk the same language”. It’s easy to know when a red flag comes up because of the same deliverables. Senior Management know what they’re agreeing to. – it allows better decision making.
- Lessons learned on one program are easily integrated into other program. And yes, in fact lessons are learned. An example is an Air Freight issue. Now a fix is folded into the engineering and transition to manufacturing subprocess. Since then, we have avoided air freight. [NPD Gate 3] is forcing function consistency. Without it errors might have occurred.” – Process Manager

“Now PMs see value in it. They like structure, they like not having to explain to Cross Functional teams what to do repeatedly.” – Process Manager

“People try to cut corners, think they’re going to get faster. They usually don’t get away with it. The project wasn’t successful. Almost always it’s a shortage of a business case understanding.” – Portfolio Manager

“The benefits of standardization are felt for investments. We’re working from the same gradebook. We can evaluate projects against each other. [NPD] is not about necessarily making product delivery easier. The secondary benefit is that we can compare across projects so we can see common failure modes, common critical paths – it’s about learning across projects.” – Portfolio Manager

“The relationship between [NPD] and market performance is that if good process is followed, it’s not ensured that market performance will be great. It’s possible, yes, but not ensured. If bad process is followed, it is ensured that great market performance will not happen.” – Portfolio Manager

“The benefits of standard process are about first, reusability of process. There’s no need of training, no need of developing new process every time we start a project. Second, it’s proven to deliver quality. It helps protect [Company E]’s investment – actually this is the biggest reason. And then, everyone is aligned. Product team and field team is ready together. In Sync.” – Functional Manager

“Benefits are that it helps you get organized, it gives basis to language we use, and organizations are connected. It’s about synchronization.” – Technical Project Manager

“There are costs of customization. It’s more meetings, more churn, more explanation. It’s education of people. Senior Managers could really benefit from a common view. An example is for Goals, we had Red, Yellow, Green, but everyone did it differently. 3 columns or 1 column? Definitions of what’s red, what’s yellow, what’s green? All the differences, it takes time to internalize. It’s a little bit of a cost.” – Functional Manager

“There’s time-savings at the team-member level. They may or may not result in improved time to market. But at least you’re not trying to reinvent wheel at each time. There’s clarity in decision making. Hopefully it leads to better decisions. Transitioning in new people coming on board. They can come on with less overhead, ramp-up time.” – Functional Manager

“For people coming in and out of project team, the objective of the phase gate is something that enables people to be aligned. Gate 1 and 2 - committing what and when will be delivered, gate 3 -product ready to early customer, Gate 4 - ready to launch. It’s a strong framework for people to walk into. It sets a common context. The expectations ground everybody.” – Portfolio Manager

“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

“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.” – Project Engineer

“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

“The [NPD] is a way to pass on corporate learning. Reminders from those that came before you.” – Project Manager

“The benefits are to get everybody on same page. To move seamlessly from Program A to Program B. “We’re in Gate 1 we need to get to Gate 1 exit” I don’t need to figure out what that means. There isn’t every program variation. Lots of debate about what’s expected at what gate. It’s a common framework, common language.” – Project Manager

“The benefits are that diverse teams (backgrounds, resources, skill levels) can still do all things that are needed. It forces hard and fast linkage to schedule. It defines deliverable sets.” – Portfolio Manager

Respondents also highlighted some potential costs of standard development processes. These include stifling innovation, the process becoming overly cumbersome over time, the effort associated with preparing for reviews and the effort devoted to inspection or ‘checking’, and sacrificing speed for small projects.

“There are some tradeoffs. Maybe we’re sacrificing innovation. Somebody could have come up with an innovative product delivery approach. Sometime’s we’re also sacrificing speed. If there’s a small project going through 100-step process.” – Portfolio Manager

“A cost is that processes could become ‘flypaper’, everything added just sticks to them. A collection agency for everyone with a cause. One guy thinks all machines should be green. Write it into [NPD]! People have ideas, personal agendas. It got baked into [NPD] in the past. Getting through gates was pretty onerous. Costly in the sense that program bar was going up. Over past few years, we’ve gone back to streamlining. An assessment team that worked with us. We worked with the checklist. “critical” “maybe”. We asked who cares. A lot that got taken out was flypaper.” – Project Manager

“Actually, the process is not inflexible, so there are no real costs.” – Functional Manager

“The costs are that sometimes simpler projects have to do process documentation/reviews. Some level of cost associated with that. There’s also the costs of having ‘checkers’, people who check. This doesn’t happen very often, but there is a risk associated with it. In the wrong environment, it could be stifling creativity. We don’t get the improvements in delivery process that we might when people are given even more latitude.” – Portfolio Manager

“Costs? Well, it’s work that has to happen anyhow. So it’s not a waste. For the PM + TPM it can be a cost in the preparation for phase gates, so I guess there’s a cost to some people personally.” – Technical Project Manager

2.9.3 Schematic Description of Process Standardization Approach

Inputs	Algorithm	Outputs
Newness Complexity	Decision made by Project Core Team based on project characteristics	• Reviews • Phases
Each is rated 1-3		

Table 6 - Schematic of Process Standardization Approach at Company E

2.10 Cross Case Analysis and Lessons Learned from Cases

In this section, I will compare across cases and discuss the lessons learned from immersion in the phenomenon.

2.10.1 Importance of Individual Dimensions

An important insight is that to appropriately consider the impact of process standardization on performance it is essential to disaggregate the process into its individual ‘dimensions’. This is important because standardization on different dimensions of the process impacts disparate performance outcomes quite differently. To illustrate this, let us consider a simple example. When I asked a process manager at company E about the benefits of process standardization, she said

“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.”

This is a story of how standardizing on the deliverables at the reviews/gates improves decision making by senior managers because it allows for comparison using the same information and a common baseline. At the same company, when I asked an engineer and then a project manager the same question, here is what they told me.

Engineer - “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.”

Project Manager - “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.”

This is a story of how using standard tools allows ease of movement of personnel, or a story of standard tools increasing efficiency. Thus we see that standardization on these two different ‘dimensions’ of the process (deliverables or tools) impacts very different performance outcomes (decision making and ease of movement of project personnel). If we were to simply consider the aggregate process and ask how standard it was, it would conflate these two effects. Standardization on the tools used (e.g. CAD systems or thermal analysis templates) has no impact on decision making by senior management, and standardization on review deliverables has only a weak effect on ease of movement of personnel between projects. However, if we were simply measuring process standardization at the aggregate level, without considering the individual dimensions, we would consider a set of processes that used entirely standard tools and no standard deliverables to display the same level of standardization as a set that outputted standard deliverables for the reviews but used very different tools. We would then expect these sets of processes with the same level of standardization to show the same performance effects, but in fact one would fare well in easing personnel movement between projects and quite poorly on senior management decision-making and the other would be exactly the opposite. Through this example we see that disaggregating or unbundling the process into its individual dimensions matters when evaluating the performance effects of process standardization. Going back to review the answers of respondents to benefits and costs of standardization, it is evident that many of the benefits and costs cited are actually results of uniformity or variation on particular dimensions of the process.

This insight is also well aligned with commonality in the product space. Product platforms can involve sharing common components across a family of products. However, not all components are equally good candidates for commonality. Customer tastes are heterogeneous on some product attributes and quite homogenous on others. It makes sense to standardize those components that affect the product attributes on which customer tastes are homogenous and customize components that affect product attributes on which tastes are heterogeneous. In the same way that standardizing different components across a product platform

can have different performance effects, standardizing different process dimensions across an organization can have different performance effects. The analogous problem of product platforms was very useful in helping to develop and flesh out the insight about individual process dimensions. This is also a useful connection to make because tools for decision making about product commonality are well developed. If they can be adapted to address the question of process commonality, faster progress in understanding and improved decisions may be possible.

2.10.2 Importance of Stakeholders executing processes

The second insight from the case studies is that to correctly understand the impact of process standardization on performance, in addition to the routine-based aspects of the product development process system (i.e. the process design itself), it is very important to consider the decisions of the individual stakeholders in enacting the process and the decision rights allocated to them. The reason it is important to consider the decision making or ‘cognition’ of the stakeholders is because projects are not carried out by an automatic execution of the ‘ostensive routine’ (Feldman & Pentland 2003) or centrally documented process. On each project, the product development process is in fact mindfully executed by goal-seeking individuals. It is this ‘performative routine’ (Feldman & Pentland 2003) or enacted process that actually leads to the performance outcomes on the project. A project manager might vary or tailor a process to suit the individual needs of her project and to meet her own project’s cost, schedule, and quality targets. An engineer might choose not to execute an activity in the manner stated in the central documentation because she believes she has figured out a better way to perform that activity. Much of the variation in product development processes across projects can in fact be explained by the decision making of mindful actors overseeing and executing the processes. Some examples from the cases are presented here.

“A general reason for differences is different people, different backgrounds. They put their own spin on things. They need to customize because they can do something better. It’s a common theme. Everything is customized. Only sometimes for good reasons. They all do it with good intentions, but they don’t consider the tradeoff. Do we really need that? Can we get away with the standard way? It’s more that differences in individuals and their experiences that really drive differences in process. It’s not so much about product attributes.” – Portfolio Manager, Company E

“Realities of the culture of the organization and its history. An example [Company Unit in Location A] used to have their own delivery process. So they still want to do things a little differently.” – Portfolio Manager, Company E

“In terms of consequences of process standardization – simply standardizing processes across software is not enough to ensure a seamless transition of people between groups. The standardization of process helps, but there is much to be said for the people really understanding the technology and how to do the job. This understanding is often beyond the scope of just the standard process.” – Portfolio Manager, Company A

This insight may seem quite commonsensical, but it is only now beginning to seep into the literature about process standardization and organizational routines. It is in line with current research from the strategy field on routines and capabilities, which encourages incorporating stakeholders’ cognitive (Gavetti 2005, Levinthal & Rerup 2006) and the organization’s hierarchical (Gavetti 2005) aspects into studies of organizational routines and capability development. The lessons from the company case studies support this move in the

literature. Considering stakeholder interests explicitly adds complexity to our design of the product development process system, but it is useful to acknowledge this complexity and bear it in mind when making recommendations for the improvement of the system. No recommendation of improvement to the product development process system can be usefully implemented without consideration of the objectives and reactions of the various stakeholders that interact with the process.

2.10.3 Different types of variation – Customization and Deviation

Another insight is that variation in product development processes comes in different forms. First, there can be differences in organization-level choices of the standard product development process. The standard development process can take the form of a phase-gate process, or a spiral process, or evolutionary development and prototyping. This is not the focus of my study. Unger (2003) addresses the question of how an organization can choose a standard PDP to address its risk profile. All five companies in this study used some form a phase-gate process.

I am interested in variation in product development processes across projects within an organization. This variation also comes in different forms. All the companies in the study acknowledged that there was variation across the projects in their portfolio and that the standard process should be customized to fit the variation in project characteristics. Therefore they all provided some central guidance on how to customize the process for a particular project. This process customization decision was made explicitly at the start of a project, and formed the basis for the project plan. I call this centrally-guided process variation that occurs at the start of a project – *customization*. Processes also varied during the execution of a project because things happened that caused changes to the plan agreed upon at the project start. I call this variation that occurred during project execution – *deviation*. *Customization* is centrally directed and planned. It is the embodiment of the organization's approach to managing the standardization-diversity tradeoff. *Deviation* is a result of local adaption and decisions by agents as projects unfold.

2.10.4 Reasons for variation

Across the companies, process variation is driven by variation in project characteristics. The project characteristics cited include: complexity, newness, hardware vs. software, extent of in-house development vs. supplier development, supplier capability and processes, technology readiness, regulations, customer needs and demands, sales and distribution channel, team composition and capability, project goals, length of time, availability of resources, and the level of uncertainty about various project characteristics (technology, market, resources, competition).

Another set of answers also drew attention to factors other than project characteristics - stakeholder interpretation, objectives, and cognition; history; organizational culture; and existing organizational technology and infrastructure.

2.10.5 Costs and Benefits felt differently by stakeholders

Another insight that emerged from the case studies is that the costs and benefits of standardization on different process dimensions are felt differently by different stakeholders. For example, the benefits of *standard deliverables* for reviews are felt largely by senior managers as they get to see the same information in the same format over time and across projects and can thus make better decisions. The costs of creating standard deliverables for the reviews are felt largely by project managers and engineers, as they have to invest (sometimes considerable) effort to prepare status reports for the periodic reviews. In contrast, the benefits of *standard tools* may be felt in large part by project managers and engineers, as standard tools allow them to move easily between projects and across the organization⁴. The costs of standard tools may often be felt centrally by senior managers, as they have to invest organizational resources in a push to enforce tool commonality across the enterprise. This is just a simple example to illustrate that the costs and benefits of standardization on different dimensions are felt differently by different stakeholders.

The information gathered in the course of this research was not enough to systematically examine which parties felt the costs and benefits of standardization on particular dimensions. However, it did point to this differential distribution of costs and benefits as an interesting avenue for further study. Considering the distribution of costs and benefits across different stakeholders is particularly useful when considering how to implement standardization. It can provide an indication as to where resistance to a standardization effort may emerge from and therefore what parties might need to be assuaged.

2.10.6 Dynamics of Process and embedded knowledge

An interesting aspect of the standard process that was alluded to by several respondents was about its dynamics. The standard process does not stay stagnant over time. There is variation in its enactment each time it is executed. After each execution, it is possible that lessons could be learned or improvements in the process could emerge. For the process to remain useful and relevant it needed to be updated with these lessons and improvements.

“I’m now working with Project Managers who are running the new [NPD] tool, to ask them how well its doing, and what changes and additions need to be made to it.” – Process Manager at Company B

If any aspects of the engineering plan or project management plan conflict with prevailing process for the business area, then the project can submit a ‘Process Change Request’. The goal is document the rationale for the deviation. These ‘Process Change Requests’

⁴ I do not consider here the possibility that having experience with multiple tools could increase the employability of engineers and managers, as I am restricting my analysis to costs and benefits within the organization.

are reviewed by process managers and business area leaders to gauge their validity and also to update the standard process if necessary. - Description of Process Change Requests at Company D

It is with these dynamics in mind that Feldman and Pentland (2003) write of organizational routines as sources of flexibility and change. This is also why the standard process carries wisdom:

“The [NPD] is a way to pass on corporate learning. Reminders from those that came before you.” – Project Manager at Company E

Salvato (2009) studies product development processes at an organization over the course of 15 years and shows that “timely managerial interventions aimed at encoding successful experiments into higher-level organizational [product development capability]” result in a permanent increase in performance. D’Adderio (2008) also studies similar dynamics in the context of an engineering freeze process at a leading auto manufacturer.

However, this updating of the process is not straightforward and without downside.

“A cost is that processes could become ‘flypaper’, everything added just sticks to them. A collection agency for everyone with a cause. One guy thinks all machines should be green. Write it into [NPD]! People have ideas, personal agendas. It got baked into [NPD] in the past. Getting through gates was pretty onerous. Costly in the sense that program bar was going up.” – Project Manager at Company E

The above quote points to the fact that people have ideas and personal agendas and that these can dictate the changes to the process standard. Howard-Grenville (2005) studies “how actors and contexts shape both individual performances of routines and contribute to their persistence or change over time” and points to the relative power of individuals as a reason why the actions of some individuals, but not others, can change routines. Even more importantly, we see that the process can become overly burdensome, weighed down by constant additions to requirements.

“Over past few years, we’ve gone back to streamlining. An assessment team that worked with us. We worked with the checklist. “critical” “maybe”. We asked who cares. A lot that got taken out was flypaper.” – Project Manager at Company E

The same project manager describes how his company has gone back to streamlining the development process. In fact, a detailed study conducted at this company in the past examines this and finds that there is a repeated long term cycling in the length of the process standard. This dynamic of increasing knowledge being encoded into the standard process until it becomes overly burdensome followed by some amount of streamlining plays itself out every few years in this company. Bingham, Eisenhardt, and Davis (2007) study the internationalization process at six companies and find that the processes “undergo *simplification cycling* where they first become elaborated with new experiences, but then are made purposefully simple.” These process dynamics are a fruitful avenue for further research in organizational learning. Is this cycling dynamic widely present? Is it useful? What is the optimal frequency and degree of cycling? These are all questions that can be addressed in future research.

2.10.7 Differences across companies in process standardization approach

As we have seen, all companies acknowledged variation in their project portfolios and provided some central guidance for process variation, and left some aspects of the process free to the discretion of project teams.

The companies differed on:

- the project characteristics they took into consideration to customize their process
- the process dimensions that were centrally specified and those left to project team's discretion

These two aspects are represented in the schematic table of process standardization approach at the end of each case study.

We see that the only project characteristic Company C considers for its customization decision is the degree of change in three key subsystems, whereas company B uses 32 questions to determine a wide array of project characteristics. As for the process output, Company A only outlines what activities are to be performed on a particular project. Company C dictates what activities are to be performed, the sequence in which they are to be performed, the time to be spent on each of the activities, the reviews necessary, the deliverables needed at each of the reviews, the tools and templates to be used to create the deliverables, and the roles that are responsible for each activity.

It is reasonable to ask why there is difference in the process standardization approach across companies.

From putting that question to some interviewees and from sensemaking across the cases, I conclude that the companies differ in their process standardization approach because they differ in:

- The project characteristics across which there is variation in their portfolios
- Their strategic priorities across performance outcomes

For instance, Company B considers so many project characteristics in making its customization decisions because it has a broad portfolio. Projects in its portfolio vary on all the characteristics it considers. The portfolio of Company C, the auto manufacturer, doesn't feature important variation on most characteristics. The company only needs to consider degree of change in three key subsystems to capture most of the important variation in its portfolio. The variation of project characteristics in turn drives process variation on specific dimensions. For example, if projects vary greatly in their complexity, or in the time of development, this will drive variation in the number of reviews in the process. Therefore a company with variation in complexity across its portfolio will usually provide guidance for how one should customize the number of reviews to match the complexity of a project.

However, it is not only the degree of variation in project characteristics across the portfolio that guides what process dimensions to standardize. Another important consideration is the priorities in performance outcomes. If a company places very high importance on development time as a strategic priority, it will provide central control over how much time should be spent on an activity (see Company C). If a company cares tremendously about development cost, it will provide central guidance for the allocation of resources for different activities.

To distil these observations into advice for decision making about process standardization for a company, we can say the following: to determine the process standardization approach for a company, one should first consider the variation in its portfolio and its strategic priorities in performance outcomes. Together these will provide guidance as to what project dimensions to consider when making customization decisions and what process dimensions to centrally control and which to leave to the discretion of project teams.

The idea that the right process standardization approach is contingent on company characteristics is quite a new one. A recent study by Benner & Veloso (2008) explores how technology coherence moderates the performance effects of process management practices (measured by ISO 9000 certification). The authors “find that firms that have a very narrow or very broad technological focus have fewer opportunities for complementary interactions that arise from process management practices and thus benefit less than those with limited breadth in technologically related activities.” This is one of the first studies to show that the performance effects of process standardization can be contingent on portfolio characteristics. The results from the case studies indicate that not only technological breadth, but the level of variation on many other project characteristics – target customers, regulations, and technology newness for a few examples – will moderate the effect of standardization on performance, i.e. they will influence the right standardization approach for a particular company.

Another portfolio dimension that influences the process standardization approach is the number of projects in the portfolio and the relative importance of each one.

“In our group we have 120 [reviews] a year. These are an order of magnitude more than any other group. This means we have a lot more projects going at any one time. We put a lot less effort into identifying the absolute perfect process for a project.” – Portfolio Manager at Company A

Company D spends a great amount of time putting together a detailed engineering plan and project management plan for each project. This is because each project is typically very large (often hundreds of millions of dollars) and therefore it is worth the effort to identify the perfect process for each project.

In sum, we see that portfolio characteristics and strategic performance priorities play an important role in determining the right process standardization approach for an organization.

3. Phase II – Framework to think about PD Process Standardization and Detailed Literature Study

3.1 Reasoning for Detailed Literature Study

The case studies described in the previous chapter led to a renewed understanding of process standardization. An important insight was that standardization on individual process dimensions impacts different performance outcomes differently.

Previous literature has also established that the right product development process is contingent on project characteristics i.e. projects that vary widely in factors such as complexity, newness, etc. will need different product development processes to effectively meet project goals of cost, schedule, and quality (Shenhar 2001, (Krubasik 1988). Knowing these things, we have turned to the literature to create lists of project characteristics, process dimensions, and performance outcomes (at both the individual project and organizational levels), and importantly to uncover existing evidence on links between these elements. Much of the previous research on product development processes, project management, learning in organizations, and capabilities and routines is applicable here. There is substantial work that has focused on the impact of individual dimensions on individual outcomes and this work can be leveraged to draw our links. However, the relevant literatures I must draw on are large and fragmented, and tying the individual streams together to create cogent understanding for our problem is the output of the literature study.

This chapter presents lists of project characteristics, process dimensions, and performance outcomes dimensions (considered at the level of an individual project and the level of a portfolio of projects in an organization) and a distilled understanding from existing literature of the links between individual elements. Together, these elements and links form the basis for a framework to help organizations with decision making about process standardization.

3.2 Method for Literature Study

I adopted a loosely structured method for surveying the literature. As a first step, I began with four general review papers in the area of product development. Two highly-cited, broad reviews of product development literature are Brown & Eisenhardt (1995) and Krishnan & Ulrich (2001) – these represent promising starting points. The other two review papers used as starting points were Gerwin and Barrowman (2002) – a meta-

analysis of existing empirical studies to evaluate relationships between aspects of product development process and performance; and Browning and Ramasesh (2007) – a survey of activity based process models for managing product development projects. I supplemented these four broad reviews with two journal-specific product development review articles - Krishnan & Loch (2005) from *Production and Operations Management* and Shane & Ulrich (2004) from *Management Science*. I followed the reference trees related to product development process that emerged from these review articles. Another set of starting points was provided by the articles cited in Chapter 1. I had found these articles using simple keyword searches for ‘process’ followed by standardization, variation, commonality, diversity, tailoring, customization, and formality. These articles provided another broad set of references. Following the leads of the references from these papers led us to many different literatures. There were the obvious candidates for fields such as project management and product development, but there were also streams of literature on some of the individual outcomes (e.g. organizational learning and knowledge transfer) and even some individual process dimensions (e.g. templates). A search for tailoring led to a rich vein of work in software development published in journals such as *MIS Quarterly* and *IEEE Software*. I was also led deeply into the strategy literature on capabilities and organizational routines. Presentations of my research work at a few conferences led to discussions with researchers in the area, who pointed to me other relevant work. All in all, I reviewed more than 350 relevant papers. Twenty-five different journals contributed more than one paper to the set: *Academy of Management Journal*, *Academy of Management Review*, *Administrative Science Quarterly*, *ASME Journal of Mechanical Design*, *California Management Review*, *Harvard Business Review*, *IEEE Software*, *IEEE Transactions on Engineering Management*, *Industrial and Corporate Change*, *Journal of Engineering Design*, *Journal of Marketing*, *Journal of Marketing Research*, *Journal of Operations Management*, *Journal of Product Innovation Management*, *Management Science*, *MIS Quarterly*, *Operations Research*, *Organization Science*, *Production and Operations Management*, *Project Management Journal*, *Research in Engineering Design*, *Research Policy*, *Sloan Management Review*, *Strategic Management Journal*, and *Systems Engineering*.

Not all 350 papers are cited here. Many of them were redundant, particularly because we already had access to excellent review articles and meta-studies. I only cite the relevant subset here. For each of the papers, I coded into a spreadsheet all project characteristics, process dimensions, project performance outcomes, organizational performance outcomes addressed. I also coded links from one item to another addressed in each article, along with the support provided. After the sets of elements had been assembled, I worked to consolidate items by removing redundant and overlapping elements. The goal was to create parsimonious sets that still spanned the space. To give you a sense of the degree of consolidation that was possible – the list of project characteristics went from over 300 in its raw form down to 22 after consolidation. The list of process dimensions went from more than 400 in raw form down to 18.

3.3 Framework Description of Categories and Links

In the course of this literature study that was informed by the case studies, an overarching framework to characterize the problem space began to emerge. This framework emerged through an iterative process driven by the goal of conceptually organizing and connecting the research I was reading.

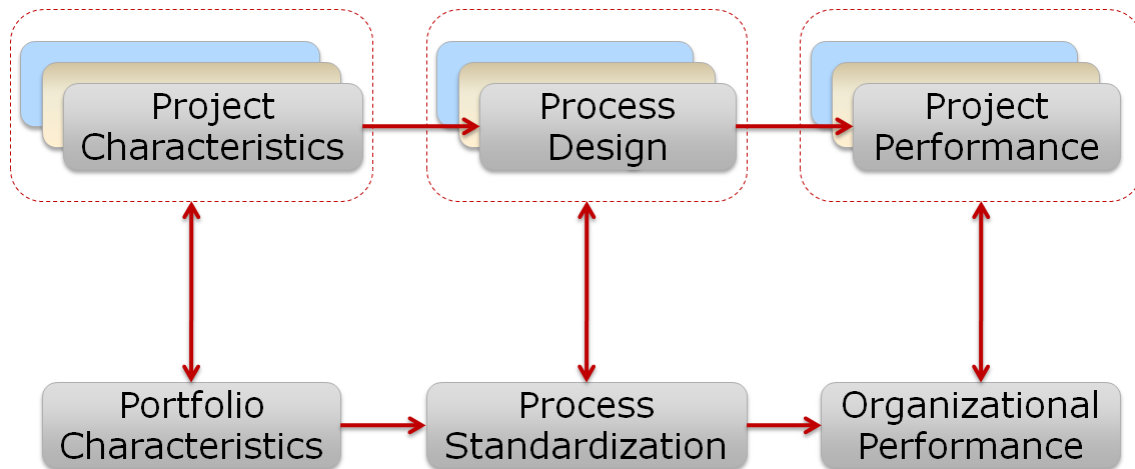


Figure 8 - Framework to describe problem space for Process Standardization

In the top row of the framework, we have the individual project level. Each individual project has its own characteristics (*Project Characteristics*). Each individual project executes its own instantiation of the development process (*Process Design*). In many cases the project characteristics inform the process that is executed; therefore we have a link between Project Characteristics and Process Design. The executed development process (and its fit with the Project Characteristics) influences *Project Performance*. This framework is not meant to imply that Process Design is the only input that influences Project Performance, or that Project Characteristics are the sole influence on Process Design. There are certainly other important inputs. This framework is only meant to lay out the broad relationships between the constructs that are the focus of this study.

In large organizations, there are not only individual projects. It is useful to move beyond the level of a single project and consider multiple projects. The boxes in the background in the top row are meant to represent multiple ongoing development projects. When one considers multiple development projects together (indicated by the sets contained in the dotted red lines), one moves from the level of the individual project to the level of the portfolio. The portfolio level is addressed in the bottom row of the framework. Multiple projects considered together create a portfolio with its own characteristics (*Portfolio Characteristics* e.g. size and distributions of project characteristics). Multiple processes considered together result in a set of processes that can be similar or different. The degree of similarity in multiple processes is called *Process Standardization*. At the

level of the portfolio, one is concerned not only with individual project performance, but organizational or portfolio-level performance (*Organizational Performance*). Organizational Performance includes an aggregate of individual project performance outcomes, but also includes performance outcomes not encapsulated in project-level performance measures, such as learning, knowledge transfer, improved decision making and resource allocation. As we have seen in previous chapters, Process Standardization can influence many organizational performance outcomes. Another link that has only recently begun to be explored is how Portfolio Characteristics influence the Process Standardization approach in an organization.

It is useful to note the scope of the framework. I am considering the portfolio of development projects in an organization as a given. I do not address portfolio strategy or how an organization should choose the set of projects it undertakes. My question is, given a set of projects in an organization, how does process standardization impact performance? We can imagine a box labeled *Portfolio Strategy* feeding into the left of the framework shown in the figure above (out of the scope of my research). On the right side of the framework, I am interested in operational outcomes (even when discussing organizational performance), not financial outcomes like market share, sales, or growth. Intermediate operational outcomes (such as development time and product quality, or even knowledge transfer across projects, decision making and resource allocation) will certainly contribute to strategic and financial outcomes such as market share and growth, but my research does not directly address those outcomes. We can imagine a box labeled *Financial and Market Performance* on the right of the framework outlined above. These outcomes are important, but distant. The relationship between process design or process standardization and these outcomes will likely be noisy and weak, therefore hard to identify.

3.4 Fleshing Out the Categories

3.4.1 Project Characteristics

Project Characteristics are simply attributes that describe a project. A number of project characteristics were referenced in the case studies. It is important to note that project characteristics can include aspects of the product itself (e.g. complexity, technology class), but can also include aspects of the organization (e.g. extent of in-house development, resource availability, team capability). I include both types as project characteristics. Occasionally, it might be difficult to identify if some organizational project characteristics are aspects of the project or the process. For example, project leader capability could be considered an organizational project characteristic but it could also fall under the process dimensions of agents or roles. In this study, I have used my own judgment to classify individual items as project characteristics or process dimensions. I have tried to err on the side of including more items as project characteristics than as process dimensions. I choose in this manner so as to be conservative about the influence of process design on performance.

The exercise of collecting a long list of project characteristics from the papers, and then consolidating that list, resulted in the following set of project characteristics:

1. Complexity (number of parts, interconnections, functions)
2. Newness
3. Hardware vs. software development
4. Extent of in-house development vs. development at suppliers
5. Supplier quality
6. Production Requirements
7. Testing Requirements, Cost of Tests
8. Maintenance and Support Requirements
9. Certifications, Regulations
10. Resource Availability and Uncertainty
11. Project Priorities (Criticality, Quality, Speed etc.)
12. Team Capability and Tenure
13. Budget or Cost
14. Technology Uncertainty or Technology Readiness
15. Consumer or Market Uncertainty
16. Competitive Environment
17. Size of Team
18. Requirements Stability
19. Intended Sales or Distribution Channel
20. Team Dispersion
21. Team Composition or Cross Functionality
22. Project Leader strength, vision, skill

Many of these project characteristics are quite broad and some of them are partly overlapping. The decision about whether to bundle to aspects of a project into one characteristic or whether to list two related aspects separately was made using a judgment call. An important input that formed the basis of that judgment was the frequency with which the items were mentioned in the literature. The idea of this exercise is not to offer a finalized list of project characteristics, but to identify the sets of factors across which companies see important variation in their projects. This list can then be useful as a starting point for any organization that is trying to identify and characterize the variation in its project portfolio.

3.4.2 Process Dimensions

An important lesson from the case studies was that it is important to consider individual dimensions when discussing the influence of standardization on performance. The body of research in product development at the individual project level had already studied various dimensions of the process. Our goal is to bring the fine-grained resolution up to discussions of process management at the portfolio level. To simply catalog the dimensions of development processes, it was reasonable to lean heavily on literature at the individual-project level.

The exercise of collecting a long list of process dimensions from the papers, and then consolidating that list, resulted in the following set of process dimensions:

1. Activities
 - a. Reviews
 - b. Supplier Involvement
 - c. Prototyping
 - d. Testing
 - e. Planning
 - f. Internal/External Communication
2. Sequence or order of activities and the flow or dependencies between them
3. Overlap
4. Time spent on activities
5. Proficiency, stringency or fidelity of activity performance
6. Iterations (number, breadth, frequency of feedback)
7. Deliverables
8. Tools
9. Templates
10. Roles
11. Metrics
12. Documentation

The dimension Activities has a subset. The activities listed in the subset are often cited separately as important dimensions in process design. They were mentioned enough times and carry enough performance implications to be listed as separate dimensions. However, since they can all be classified as specific types of activities, I list them as a subset.

Browning (2010) lists 56 attributes of process activities and deliverables assembled from his research at companies. These attributes provide very detailed resolution at the level of individual activities and deliverables. Many of these attributes are not useful to us at our level of discussion. An important note is that process differences must also be observed at the level of a collection of activities or deliverables e.g. differences in the sequence of activities.

It is interesting to note that various aspects of the development process are discussed under the label 'project management styles' in the project management literature.

3.4.3 Project Performance Outcomes

Product development projects have multiple performance outcomes. The commonly mentioned categories of project performance outcomes are the project management trio of cost, schedule, and quality. Ulrich and Eppinger (2000) list five project performance outcomes - product quality, product cost, development time, development cost, and development capability. We see that cost can be usefully considered in two distinct areas - development cost and product cost. Development capability is an interesting performance outcome because it is largely felt at the organization or portfolio level (or for future projects) and is not felt at the level of the individual project under completion. For this reason, development capability might be subsumed under organizational performance outcomes like 'knowledge transfer across projects' or 'learning over time'. At the very least, it is tightly linked to those outcomes. Finally, product quality has several flavors. Quality can usefully be categorized as either performance quality (technical performance, customer satisfaction) or conformance quality (high reliability or low defects, meeting of functional specifications).

The exercise of collecting a list of project performance outcomes from papers, and then consolidating that list, resulted in the following set of project performance outcomes:

1. Development Cost
2. Schedule
3. Unit Product Cost
4. Quality
 - a. Technical Performance
 - b. Customer Satisfaction
 - c. Reliability or defects
 - d. Meeting of Functional Specifications

I consider development capability related outcomes under the category Organizational Performance Outcomes.

3.4.4 Portfolio Characteristics

Aggregating up from the level of individual projects, we get to the portfolio level. Product portfolios can be most directly characterized using distributions of characteristics of the projects that comprise them. We identified 22 different project characteristics, the distribution (heterogeneity or uniformity) of each of these project characteristics – both product and organizational – is useful information to characterize the portfolio. This is the information that addresses the important question – ‘what characteristics does my portfolio vary on?’ Benner and Veloso (2008) build on Steinemann (2000) to measure the degree of technological coherence in a firm’s portfolio using data from firm SEC reports. They are essentially characterizing the distribution of technology classes across the portfolio. Silverman (1999) uses a similar measure of technology coherence using patent data. To characterize portfolios comprehensively, we need to build such measures for each important project characteristic.

In addition to the distribution of project characteristics, we also have other attributes that characterize the portfolio. Building on Tushman and Nadler (1978) and applying the ideas to the context of data integration in organization, Goodhue et al. (1992) point to cross-unit interdependence as an additional important aspect. “...if interdependence is high...the formalized language of integrated data will allow large amounts of information to be easily shared...This suggests that data integration would probably be most useful where subunits were very interdependent...” In our context, we can ask if there is interdependence between projects in the organization. Do projects compete for and share resources? Do people move often between projects? Addressing questions like these will give you an idea of the level of project interdependence. Engwall (2003) highlights project interdependence as an important aspect to consider in studying project management.

Two final characteristics referred to in the literature are also discussed earlier in the case studies – the size of the portfolio and the relative importance of each project. These two are related to each other, but are distinct enough that I consider them separately. If we continue to think of the idea of distributions of project characteristics, the size of the portfolio provides the number of points in the distribution, and the relative importance of each project provides a weighting to each point.

Summarizing, I present this list of portfolio characteristics:

1. Distribution of each project characteristic (uniformity or heterogeneity)
2. Interdependence between projects

3. Portfolio Size (number of projects)
4. Relative importance of individual projects

3.4.5 Process Standardization

In a manner similar to aggregating up from individual projects to the portfolio, aggregating up from individual process designs to a family of processes can be usefully represented by considering distributions of process dimensions across the organization. As discussed earlier, most process management and process standardization research so far has bundled various dimensions of the process together to create one single measure for process standardization or variation. In Chapter 2, I show why this can be problematic. To correctly understand the impact of process standardization, it is useful to consider distributions of process dimensions separately.

At this point it is useful to discuss how the level of process uniformity or variation has been measured in previous literature. Unger (2003) offers iteration and review based metrics to classify high-level product development processes. This is a simple distribution method. Pentland (2003) shows how sequential variety in work processes can be quantified, building on optimal string matching techniques developed by Abbott (1990). Salvato (2009) and Sabherwal & Robey (1993) supplement these methods with clustering analysis to identify clusters of similar processes. Van de Ven et al. (2000) describe the building of event sequence files and list various methods such as markov analysis, phase mapping, and time series analysis to uncover the structure in organizational processes and to enable comparison across them. Finally, Langley (1999) reviews various strategies for theory building from process data and offers visual mapping, and a case-based synthetic approach as useful strategies for comparing across a number of processes.

Reasons for Process Variation

Another useful side-discussion is to understand reasons for process variation as well as constraints to process variation that are discussed in the literature. These will complement the lessons we learned from the case studies to help build a holistic understanding of the phenomenon.

Agency and Cognition:

As we learned from the case studies, the agency of the individual stakeholders in enacting the process is an important driver of process variation. This insight is in line with current research from the strategy field on routines and capabilities, which is now encouraging the incorporation of stakeholder agency and cognition (Gavetti 2005, Levinthal and Rerup 2006, Pentland and Feldman 2003) into studies of organizational routines. Empirical studies of organizational processes are now beginning to take agency into consideration. “First,

individuals and groups approach routines with different intentions and orientations, suggesting that agency shapes particular routine performances. (Howard-Greenville 2005).

Christiansen & Varnes (2009) point to the importance of sensemaking in the implementation of product development practices, "...structured approaches are translated through a number of interpretations into daily practices." The importance of interpretation is consistent with Feldman and Pentland's (2003) statement that it is "...impossible to specify any routine in sufficient detail that it could actually be carried out." Bendoly & Cotteleer (2008) study behavioral sources of process variation and find that users will circumvent the process if they perceive it to be a misfit for their tasks.

Miner et al. (2001) conduct an inductive study of improvisation in new product development activities in two firms and discovered many instances where agents improvised to solve problems. These improvisations were sometimes valuable because they could point to new useful ways of doing things. Salvato (2009) studies how "timely managerial interventions aimed at encoding successful experiments" resulted in permanently higher performance in a product design organization. However, not all variations in the routine become encoded into standard organizational practice. Routines are updated through a contested political process. Power is important to determine which changes become part of the standard and which leave no trace. (D'Adderio 2008, Howard-Greenville 2005). Miner (1994) and Miner and Haunschild (1995) address the issue of how useful variations should be selected to be retained, whereas other variations should be discarded. Adler et al. (1999) offer the answer of metaroutines as an established manner in which to update routines for improved performance. (Brunner et al. 2009) offer a related idea of planned perturbations as a mechanism by which to continuously improve routines.

Project Contingency

As we have seen from the cases, an important factor that drives variation in processes is variation in project characteristics. This is supported in the literature too. The studies that address this reason are discussed in detail in the section on the link between Project Characteristics and Process Design.

Organizational Context

A final set of factors that drives variation in processes is related to context. Howard-Greenville (2005) emphasizes the importance of organizational context by writing, "...routine performances are embedded in an organizational context that, while it may not restrict the flexible use of a routine, may constrain its ongoing adaptation." Edmondson et al. (2001) find that routines are reinforced by technological and organizational context and that substantial changes in these routines require a special team learning process. Engwall (2003) and Feldman & Rafaeli (2002) point to the importance of interactions and coordination with other projects. Ansari et al. (2010) study how practices are modified in the course of diffusion. This idea of change in

practices during diffusion is consistent with the difficulty of replication because errors are introduced in the course of copying a routine from one place to another (Szulanski 1996, Rivkin 2001).

3.4.6 Organizational Performance Outcomes

As discussed in Chapter 1, we know that several organizational performance outcomes are influenced by process standardization. To develop an understanding of the problem space, it is useful to create a broad list of these organizational performance outcomes that are affected by process standardization. Browning (2010) points to several aspects of organizational performance that are impacted by process standardization when he discusses the ‘purposes’ for which process models are used.

The exercise of collecting a list of organizational performance outcomes from papers, and then consolidating that list, resulted in the following set of project performance outcomes:

1. Efficiency
 - a. Training Costs (Ease of bringing people on)
 - b. Ease of movement of people between projects
 - c. Operational Coordination between projects (handoffs, synchronizing)
2. Knowledge Transfer
 - a. Communication across subunits
3. Organizational Learning
 - a. Avoid failure modes that best earlier projects (eliminate duplication of efforts)
 - b. Process learning curve, Improvement from repetition and access to knowledge of activities (time saved, errors reduced)
4. Adaptation to changing environment
5. Innovation
6. Creativity
7. Decision Making and Resource Allocation
 - a. Estimation of project time, project resources etc.
8. Employee Satisfaction
9. Showing Customers and Auditors

In the discussion of project performance outcomes, I indicated that I would discuss development capability related outcomes under this category. Development capability related outcomes are subsumed under the headings knowledge transfer and organizational learning. This set of organizational performance outcomes provides a broad set of factors which may be affected by process standardization.

3.4.7 Categories with consolidated lists of elements

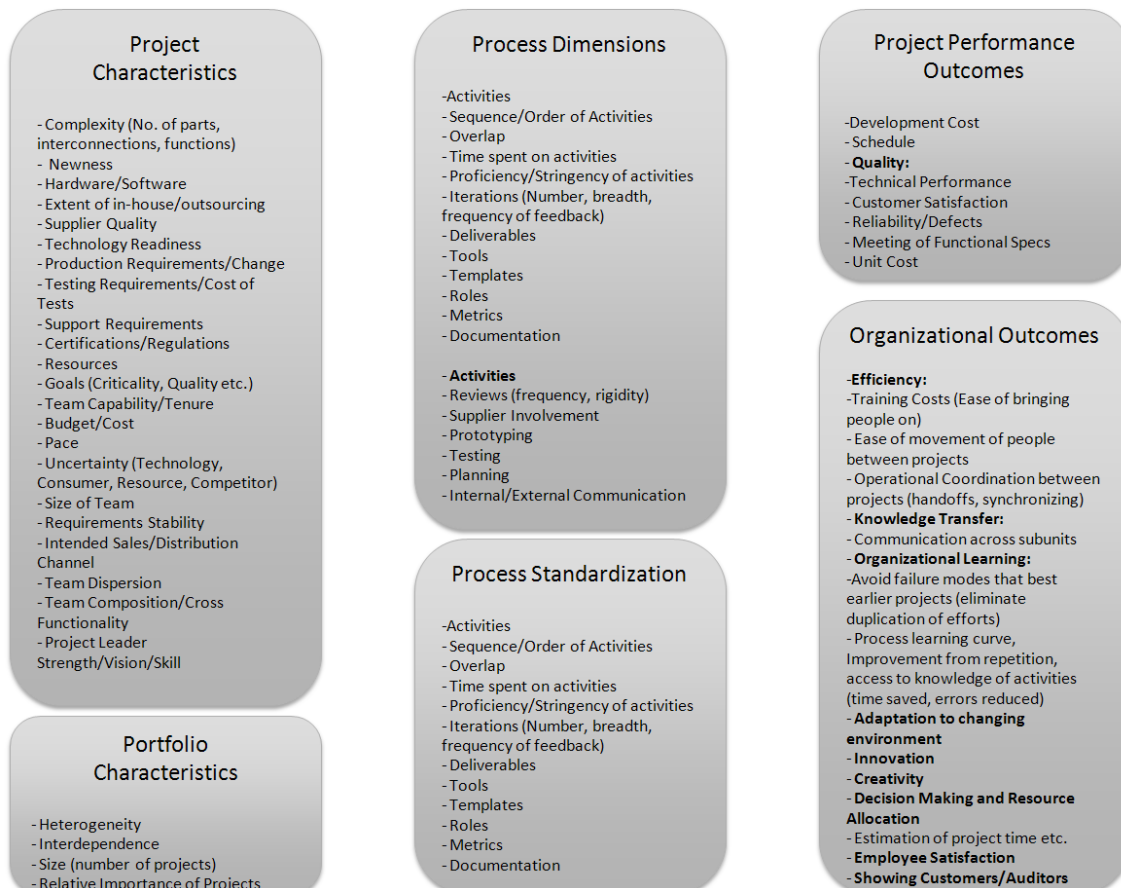


Figure 9 – Framework categories with consolidated lists of elements

3.5 Fleshing Out the Links

3.5.1 Project Characteristics – Process Dimensions

The literature supports what we learned from the case studies – that variation in project characteristics is an important factor that drives variation in processes. The studies that address this link are discussed in this section.

Krubasik (1988) offers an early, practitioner-oriented call for customization of product development processes. He states, “The best way to develop a product depends on the opportunity cost and the entry risk in that instance.” “The context varies for each individual product. Therefore, managers should treat each product differently and choose the strategy that fits best.” Shenhar (2001) is a study which uses qualitative

and quantitative information to “show how different types of projects are managed in different ways”. The author describes the study as exploratory, which suggests that the idea that development processes should be contingent on project characteristics is not very academically mature. The study classifies projects on two dimensions (technological uncertainty, and scope) and finds that “higher-technology projects required more design cycles, later design freeze, and increased attention to design considerations, risk management, systems engineering, and quality management.” and “As scope increases, projects are managed with additional attention to planning, control, and coordination...and are generally characterized by increased bureaucracy and documentation.”

Eisenhardt & Tabrizi (1995) conduct a study on acceleration of product development efforts. “The results indicate that...the compression strategy of supplier involvement, use of computer-aided design, and overlapping development steps describes fast pace only for mature industry segments.” MacCormack & Verganti (2003) classify projects on two dimensions – market uncertainty and uncertainty about amount of new design work and find that the performance impact of development practices is mediated by project characteristics. They conclude that “...managers carefully must evaluate both the levels and sources of uncertainty facing a project before designing the most appropriate process for its execution.” Lewis et al. (2002) also find that uncertainty moderates the relationship between project management style and performance. Pich et al. (2002) create a model to investigate how projects should be managed in the face of uncertainty, ambiguity, and complexity. They conclude that “The appropriate strategy is contingent on the type of uncertainty present and the complexity of the project payoff function.”

Schmidt et al. (2009) use a survey to study NPD project review techniques. They find that “...more review points are used for radical NPD projects than incremental ones, and...more criteria are used to evaluate incremental NPD projects than radical ones... At each review point, technical criteria were found to be the most frequently used type for incremental projects, and financial criteria were the most commonly used type for radical ones.”

At the level of company choices of product development process structure, Unger (2003) finds that company choices of PDP structure are directed by the risks in their projects. Slaughter et al. (2006) find that many “firms match their software process choices to product characteristics, customer volume, and business unit strategies.”

Together we see that there is plenty of evidence supporting the fact that product development processes should be contingent on project characteristics. However, the evidence is not yet mature enough to

concretely indicate exactly what dimensions of the process should be impacted by particular project characteristics.

3.5.2 Process Dimensions – Project Performance Outcomes

There has been a tremendous amount of research, both empirical and modeling, on the impact of process design on project performance at the level of an individual project. To report on the established links from this research, we will rely on three review articles. These articles have done the hard work of combing through the extensive literature to summarize the findings. For model-based work, we will use Browning and Ramasesh (2007). For empirical work we will use primarily Gerwin and Barrowman (2002) as it includes a formal meta-analysis of much of the literature, but we will also use some conclusions from Brown and Eisenhardt (1995).

Gerwin and Barrowman show that the project outcome that has been studied in greatest depth is development time. They use that as one development outcome. They combine all other outcomes into a combined measure of performance called ‘goal failure’. This aggregation of performance outcomes goes against the lessons we’ve learned about the importance of disaggregation, but they do it because of the limitations of available data.

The results of their meta-analysis indicate that:

- Task overlapping is an effective process characteristic and works to reduce both development time and goal failure. (Analysis also indicates a lack of moderators, which means this process dimension has impact over a broad range of situations.)
- Cross-functional teams reduce development time in a broad range of situations. Cross-functional teams have no impact on goal failure.
- Team leader’s organizational influence is effective in reducing both development time and goal failure in a broad range of situations.

Brown and Eisenhardt’s (1995) summary of past research in product development is generally in agreement with Gerwin and Barrowman’s review. They add that past research robustly supports that internal and external communication reduce development time and increase productivity.

Browning and Ramasesh review the model-based work on product development processes. A number of their insights are about the limitations of current models and areas for future research. They also offer useful insights to help managers with using and interpreting output from the models. Here, I only highlight their insights that directly relate process design to performance outcomes.

- “Iterations are often undesirable, except where they provide high amounts of uncertainty reduction (e.g. rapid prototyping) or can be used to pull activities off the critical path.” “A significant portion of PD project duration and cost stems from iteration and rework.”
- “Activity overlapping becomes less advantageous as risk (uncertainty that has an impact) increases - i.e., as activities are performed with more assumptions and less firm information.”
- “Although ‘speed costs more’ is a common assumption, this intuition may not always be true, and the full set of reasons why has not been formalized.

3.5.3 Portfolio Characteristics – Process Standardization

The relationship of portfolio characteristics to process standardization is a relatively unexplored set of links. As such it is a potential fruitful avenue for research. We have seen from the case studies that portfolio characteristics do in fact drive the process standardization approach adopted by companies. One of the few studies to acknowledge that portfolio characteristics can moderate the influence of process standardization on performance is Benner and Veloso (2008). They find that companies with a moderate level of technological coherence (as compared to high or low) show the most benefit of adopting process management approaches in terms of improved financial performance. This study has some problems because of the high level measure it uses for process standardization (ISO 9000 certification) and because it uses financial performance, which is only indirectly affected by process, as opposed to operational performance outcomes. However, it is still an insightful study because it highlights the importance of considering portfolio characteristics to determine the influence of process standardization.

Sullivan (1999), in his MIT masters thesis, also indirectly addresses the relationship between portfolio characteristics and process standardization. He studies three aircraft engine manufacturers and finds that the size of their standard process documentation is proportional to the cost of development of a cleansheet program in that company. This is an indication that a company’s process standardization approach may be related to the nature of the products in its portfolio.

3.5.4 Process Standardization – Organizational Performance Outcomes

As we have seen in Chapter 1, several streams of prior research have examined process standardization and found it to be quite powerful. Let us examine the available literature moving through performance effects. First I will consider project performance, and then I will move through the organizational performance outcomes one by one.

Project Performance

It should also be noted that process standardization does not directly impact project performance. It influences project performance only by constraining or guiding the process design choices made at the project level. Given the importance of project performance outcomes, and the fact that process standardization can play an important role in influencing them even if the influence is indirect, we consider project performance here.

As outlined in the section on the link between project characteristics and process design, it is quite well established that project performance is influenced by the fit between project characteristics and process design. Several researchers make the argument that “one size does not fit all” and product development processes should be explicitly designed to match project characteristics (Shenhar 2001, Krubasik 1988, MacCormack and Verganti 2003). If this is the case and a company has a portfolio with widely varying projects, then imposing a standard process could prevent individual projects from effectively meeting performance goals. This is a common argument against standardization.

However, there is also a counter argument. This is well represented in a study by Tatikonda and Rosenthal (2000). The authors use “a cross-sectional survey sample of 120 completed new product development projects from a variety of assembled products industries” to study the effect of process formality on project performance. They found that process formality is associated with improved performance and that “...effectiveness of these methods is not contingent on the product or process technology novelty inherent in a given development project. The findings suggest that a variety of projects can be managed using broadly similar project execution methods.” They suggest that a potential mechanism might be because having a standard process prevents individual projects from taking detrimental shortcuts. It is important to note the limitations of this study. They used a very broad measure of process standardization (two survey questions about the degree of process formality) and also a single measure for project performance (survey question about project execution success). However, it does represent some empirical evidence for an argument that is often presented as a counter – namely that process standardization prevents projects from taking harmful shortcuts.

We see that the effect of Process Standardization on Project Performance is a *contested* set of links.

Efficiency

Efficiency has many forms. It can manifest itself as lower training costs (ease of bringing people on), or the ease of movement of people between projects, or as reduced waits at handoffs by making sure all parties are coordinated and synchronized.

In their study of the Toyota Product Development System, Morgan and Liker (2006) state: “[process] standardization enables true concurrent engineering and provides a structure for synchronizing cross-functional processes that enables unmatched vehicle development speed.” “Process standardization is a potent antidote to both task and inter-arrival variation discussed in the previous chapter.” This is an accurate reflection of the arguments in the literature linking process standardization with increased efficiency. As Adler et al. (1999) describe, these arguments have a long and full history beginning with studies of bureaucracy and reflected in many areas of management and organization studies. Efficiency is associated with bureaucratic forms of organization with high levels of standardization and formalization.

However, even this long held association of standardization with efficiency is not without challenge. Sobek et al. (1998) describe situations in which adopting a standard process can reduce efficiency because the standard is burdensome, infrequently updated, creates additional work, and is thus mostly circumvented by employees. They specifically cite the case of GM in the mid-90s saying, “the more they attempt to define the process of product development, the less the organization is able to carry out that process properly.” These arguments are echoed by other researchers. Browning et al. (2006) write “...many organizations’ standard processes tend to be detached from the way work is actually done. Many of those doing so-called ‘real work’ may see the standard process as irrelevant, too generic to be helpful.” Cooper (2005) writes, “Standard process is often bureaucratic and cumbersome, lacks buy-in from employees, and project teams often circumvent the process or only pay lip-service to it.”

The long history of the association of standardization with efficiency and the presence of several successful examples leads me towards calling this set of links established. However, it is useful to note that examples of standardization being clearly associated with efficiency in the context of product development processes are a lot less prevalent than in the context of some more repeatable processes. It is also reasonable to accept that process standardization may be beneficial up to a certain point and may become burdensome beyond that point. Despite these caveats, I consider the link between process standardization and efficiency an *established* set of links.

Knowledge Transfer

Knowledge transfer is applying the lessons learned in one unit in the organization to another unit. In our case, it would mean incorporating the lessons learned on one project into the development effort on another project. Process standardization is associated with increased knowledge transfer. Adler & Cole (2000) and Argote (1999) explain why this association holds. Standardization increases the relevance of knowledge acquired in one part of an establishment for another part and documentation serves as a conduit for

knowledge to flow from one part of the organization to the other. Prencipe & Tell (2001) build on the rich literature on knowledge codification and apply the ideas to the context of inter-project learning. They conclude that codified manuals and procedures such as project management processes are a useful method support inter-project learning.

Knowledge transfer is one of the rare performance outcomes for which studies exist to establish the association with standardization on an individual process dimension. The influence of templates on knowledge transfer has been studied empirically in Jensen & Szulanski (2007). Through an eight-year, in-depth field investigation of Rank Xerox they find empirical support for the claim that template use enhances the effectiveness of knowledge transfer.

I consider the link between process standardization (particularly in the form of standard templates) and knowledge transfer an *established* set of links.

Organizational Learning

Organizational learning has a rich literature of its own and the term has many definitions. For the purposes of this paper, I will consider organizational learning as composed of two different types:

- Knowledge passed on across projects over time, i.e. learning to avoid failure modes that beset earlier projects, an elimination duplication of efforts to solve the same problems repeatedly. In this way there is an accumulation of wisdom in the organization. Such effects have also been called organizational memory (Moorman & Miner 1997).
- Learning curve phenomena – improvement in performance from repeated performance and access to knowledge about activities (common measures include productivity increases, time savings, errors reductions).

Spear & Bowen (1999) explain that the standardization of processes at Toyota accelerates learning and adaptation by providing a steady baseline against which improvements can be measured and implemented. Various authors including Morgan and Liker (2006) have also argued that standard processes serve as stores of organizational memory and that therefore are an important mechanism through which the organization learns. "...organizational learning is only possible with living standards that are seriously followed and regularly updated." These arguments support the idea that process standardization is associated with increased organizational learning.

However, there are some interesting counterpoints to the arguments above. Schilling et al. (2003) find that learning is maximized by experience with tasks that offer related variation. Neither pure specialization

(focusing on the same task), nor experience with unrelated variation resulted in as much learning. This leads us to ask – does executing aspects of a product development project for different projects over time count as related variation, unrelated variation, or specialization? Also, how well do the results of this study generalize out of a laboratory setting with a computerized card game as the task? Narayanan et al (2009) address the question using real organizational data in the context of maintenance tasks for software systems. They also find that a balance between specialization and exposure to variety leads to the highest productivity. This leads us to question if complete standardization of development processes may stifle opportunities for learning over time. Also, strict adherence to a standard may reduce experimentation and improvisation, therefore reducing opportunities to find improvements. The arguments about the influence of process standardization on ability to adapt to a changing environment (discussed in the next subsection) are also quite closely related and further complicate the issue.

I think of the link between process standardization and learning over time as a *contested* set of links.

Adaptation to changing environment

There currently exists an underlying conflict in research about whether organizational routines help or hinder firms' evolution and adaptation. A long stream of research suggests that routines give rise to inertia and harmfully constrain the nonincremental organizational changes required to respond to a radical changes in the environment (e.g. Leonard-Barton 1992, Levinthal and March 1993, Tushman and Romanelli 1985). Recently however, research on dynamic capabilities (Eisenhardt & Martin 2000) and organizational routines has pointed to routines as sources of flexibility, renewal, and change (Feldman and Pentland 2003). The empirical research in this area is quite limited. Benner (2009) offers a relevant recent example of an empirical study addressing this question. Using the empirical setting of the photography industry during the shift from silver-halide chemistry to digital technology, "the study explores how the increasing use of process management practices affected organizational response to a major technological change through new product developments." The study does not settle the debate on the effect of routinization (measured as process management) on adaptation. The findings are nuanced and "suggest that the increasing process management practices (ISO 9000 certifications) were more harmful for the responsiveness of incumbent firms with capabilities in the old technology than for the nonincumbent firms entering the digital camera market from other industries." This indicates that the effect of process management on adaptation depends on existing capabilities of organizations. This is a point similar to the moderating effect of portfolio characteristics discussed in Benner and Veloso (2008).

The above discussion highlights that the link between process standardization and adaptation to changing environments is a *contested* set of links.

Innovation

Another closely related discussion is about the effect of process standardization on innovation. Brunner et al. (2009) summarize the idea contained in much of the literature when they say, “Routinization creates a risk: when organizations are guided by old knowledge, they do not create new knowledge.” Benner & Tushman (2002) offer one of the first empirical (and highly-cited) studies of the effect of process management on innovation. “In a 20-year longitudinal study of patenting activity and ISO 9000 quality program certifications in the paint and photography industries, [they] found that increased routinization associated with process management activities increases the salience of short term measures and triggers selection effects that lead to increases in exploitative technological innovation, at the expense of exploratory innovation.”

In a study of six product development organizations, Brown & Eisenhardt (1997) find “that successful multiple-product innovation blends limited structure around responsibilities and priorities with extensive communication and design freedom to create improvisation within current projects.” They call this act of enforcing structure on certain aspects of development but not others the use of *semisttructures*.

While the available empirical evidence points to the idea that process standardization leads to reduced exploratory technological innovation, the available studies have many limitations and there is not yet an accumulation of evidence to support this link as established. I think of the link between process standardization and innovation as an underexplored or contested set of links.

Creativity

The effect of process standardization on creativity of individuals is an important link, which is closely related to the performance outcomes discussed above. Browning et al (2006) argue that process standardization actually facilitates creativity by standardizing many mundane aspects of development, thus opening up attention and time to be creative on problems that really matter. Tilcsik (2008) argues that process standardization reduces creativity. He finds that going through six sigma training reduces the creativity of employees of a large corporation. Gilson et al. (2005) examine relationships between creativity, the use of standardized work practices, and effectiveness (measured as both performance and customer satisfaction) among 90 empowered teams of service technicians. They find that creativity and standardized procedures can be complementary. Specifically, they find that standardization moderates the relationship between creativity and both team performance and customer satisfaction. They describe nuanced relationships between standardization, creativity, customer satisfaction, and team performance.

Does process standardization impact creativity positively, negatively, or are they complementary? The above discussion shows that the link between process standardization and creativity is a *contested* set of links.

Decision Making and Resource Allocation

A large amount of practitioner and academic literature (Garvin 1998, Hammer & Stanton 1999, Sobek et al. 1998, Browning 2010, Browning and Ramasesh 2007, Morgan and Liker 2006, Bowen and Purrington 2002) indicates that process standardization leads to improved decision making and resource allocation. Defining standard work allows comparison across projects, it also allows estimation of time and resources necessary for a project and therefore allows decision makers to assess where the process stands compared to where it should be.

The link between process standardization and improved decision making and resource allocation is an *established* set of links.

Employee Satisfaction

Research on work design argues that process standardization reduces employee satisfaction because employees are not empowered to solve problems or perform work in the manner that they see fit (Hackman and Oldham 1980, Mintzberg 1979). Adler & Borys (1996) argue that standardization can be enabling or coercive, and if implemented in an enabling manner, can improve employee satisfaction. Adler et al. (1999), then follow this up in their study of model changeovers in the Toyota Production System, showing that standardization, applied intelligently, can indeed be neutral or even positive for creativity and employee empowerment.

The link between process standardization and employee satisfaction is a *contested* set of links.

Showing Customers and Auditors

Researchers widely agree that the benefits of process standardization include a common face to customers (Hammer and Stanton 1999) and a display of capability to auditors (Browning 2010). However, the legitimacy conferred by adopting a process standard may also lead to some perverse effects. Westphal et al. (1997) show that early adopters of Total Quality Management actually customized it to their contexts and reaped efficiency gains; later adopters adopted normative forms of TQM programs to gain legitimacy, with little or no benefits in terms of increased efficiency. This also explains why many organizations adopt certifications such as ISO9000, CMMI and other standards without actually implementing them effectively.

The idea that process standardization results in a common face to customers and a display of capability to auditors is an *established* set of links

3.5.5 Project Characteristics and Portfolio Characteristics

I will now address the vertical links of the framework. All the vertical links are bidirectional. This is meant to indicate that influence acts in both directions. Portfolio Characteristics are determined by aggregating up individual project characteristics, but individual projects are usually undertaken because they fit with a sense of portfolio strategy (which lays out a desired set of portfolio characteristics). The nature of this link has already been discussed when the category Portfolio Characteristics was described.

3.5.6 Process Design and Process Standardization

Once again, this link is indicated as bidirectional because influence flows both ways. The level of process standardization in an organization is calculated by aggregating individual process designs, but a key influence also flows in the other direction. Individual process designs are constrained by the existing standard process in the organization. Projects are not free not execute any set of activities in any manner they choose. They must generally follow the standard process or at least acknowledge and often provide reasons for variation. In this way, the standard process acts to constrain individual process designs.

3.5.7 Project Performance – Organizational Performance

As we have seen, there are multiple performance outcomes at both the individual project-level and the organization-level. Many of these performance outcomes are interrelated. A number of the organizational-performance outcomes actually serve to improve project-performance on future or concurrent projects. If one considers the performance of the entire portfolio of projects over a long enough time horizon, then many of the organizational-performance outcomes will be captured simply by considering changes in project performance. For example, knowledge transfer across projects may serve to reduce cost or schedule, or maintain quality on future or concurrent projects. In another example, improvements in decision making and resource allocation are captured as a higher percentage of correct calls on whether to kill a poorly performing project or allocate more resources to it. In this way, a large part of improvement in organizational performance outcomes actually serves to improve the project performance over the long run and across the portfolio of projects.

3.6 Lessons Learned from Literature Study

From examining the previous research it is clear that process standardization is both a powerful and complicated organizational lever; powerful because it can impact several different aspects of performance, complicated because the influence of standardization on many performance outcomes is yet contested. Most

of the research has addressed links between process standardization in the aggregate and performance outcomes. As we have seen from the case studies, standardization on individual dimensions of the process will have different performance effects. Thus we see that a substantial number of links - between standardization on individual process dimensions and performance outcomes are yet *unexplored*. Even for some of the established performance links, it is useful to consider which individual process dimensions are doing much of the heavy lifting. For example is the fact that process standardization leads to better decision making and resource allocation driven by standard deliverables, standard activities, standard metrics, or all of them together?

3.6.1 Towards a Decision Making Framework for Process Standardization

From the case studies we learned that to determine the right process standardization approach for an organization, one needs to consider variation in portfolio characteristics and strategic priorities across performance outcomes. Using these two sets of factors as inputs and combining them with an understanding of the links between project characteristics, process design, and performance outcomes (at both the project and portfolio level) could tell one what process dimensions to standardize and what dimensions to leave to vary.

This literature study was undertaken with the intention of building that necessary understanding of the links. I created an organizing framework to describe the problem space, identified the sets of elements in each category of the framework and then surveyed the current understanding of the links between categories and individual elements. Eventually, after a great deal more research has been completed and a greater proportion of the links have been established to a reasonable degree of certainty, this framework can become a decision tool for companies. One can envision the following: A manager would input the variation across a number of project characteristics in her organization's portfolio and the organization's strategic priorities in performance outcomes. The links between elements would already be encoded into the tool. Based on the inputs provided, the tool would output what process dimensions the organizations should standardize and to what degree. The current state is far away from this. The literature study reveals many contested links and also many unexplored links, especially at the level of individual elements. The current framework can still provide some useful guidance to organizations for decision making about process standardization. It can point them to lists of factors to consider and it has summarized the current state of the research, in which a few links are established. Taking this knowledge and converting it into a useable decision framework for organizations could be a valuable focus for future work.

4. Phase III – Detailed Study at Company E

4.1 Reasons for the Detailed Study

In the previous chapter I described how I laid the groundwork for the creation of a framework to support organization-level decision making about process standardization. As part of that process, I summarized the current state of knowledge on process standardization. Focusing on relationships with performance outcomes, we see that there are sets of established links, contested links, and unexplored links. To move our understanding of process standardization forward, I choose to further explore one set of contested links.

The set of links I choose to examine addresses the relationship between process standardization and project performance. I choose to focus on project performance because as described in Chapter 3, the direction of the influence of process standardization on project performance is contested. The idea that process standardization prevents individual projects from achieving ideal performance is an oft-cited negative effect of process standardization, in literature and practice. However, we have seen that the evidence from the literature is inconclusive on the direction of the influence. Another reason why I choose to focus on this set of links is because it is salient. Project performance outcomes (development cost, product cost, schedule, and quality) are very familiar to managers and directly relevant to their day-to-day work. Project performance outcomes are also important – most companies actively manage them and organizational performance outcomes often translate into improvement on project performance. A final reason for choosing to focus on this set of links is data availability. Companies track project performance, so objective data are available. Data on many organizational performance outcomes are unavailable and would have to be collected through subjective assessments. For reasons of salience, importance, and data availability we choose to focus on this contested set of links.

The case studies emphasize the importance of focusing on individual process dimensions and their links with individual performance outcomes. This points to a need for in-depth data. I need detailed information on project characteristics, process design, and performance outcomes at the level of individual projects. Because of the need for detailed data, I choose to conduct the study at one company. This represents a classic research tradeoff of depth versus breadth in scope.

4.2 Selection of Company

The company selected for the study is Company E – a maker of electronic equipment with embedded software. The reasons that company E was selected for the detailed study are simple – it displays the features necessary for the study, it is representative of the other companies in the sample in terms of size, market share, and portfolio variation, and importantly because it was willing to grant me access to various company resources that enabled me to gather the detailed data needed for the study. When I say that the company displayed the features necessary for the study, I mean that it had:

- some variation in its project portfolio (newness, complexity, and extent of in-house development),
- a reasonably well established standard development process, and
- some customization of the standard process to fit project characteristics

4.3 Variables of Interest

I was interested in studying the relationship of process standardization with project performance outcomes. A standard process for product development existed at this company and was studied in detail in Phase 1 of the research. To understand the effect of process standardization on project performance, I needed to collect data at the level of individual projects. First, I needed data on development processes executed by individual projects. These executed processes would have been constrained and guided by the standard. The idea was to infer the effect of the standard process by studying the effect of variations from it. Secondly, I needed data on project performance. I was interested in measuring project performance holistically, so ideally I'd collect data on all project performance outcomes - development cost, product cost, development time, and product quality. Finally, it was important to acknowledge that projects in the organization varied on a number of characteristics, as these difference themselves might drive differences in performance outcomes. Therefore, I needed to collect data to characterize the projects in as much detail as was reasonable. Together we see that I needed to collect data on the categories project characteristics, process design, and project performance, while keeping in mind the organization's process standardization approach and context. In Chapter 3, we identified lists of elements in each of these categories. All of these elements form variables of interest. Constrained by considerations of data availability and time, I was interested in collecting data on as many of these elements as possible.

4.4 Data Collected and Description

The raw data collected at this Company was extensive and detailed. The primary sources of data were electronic project repositories. The repositories contained slide decks from every review presentation together with a substantial amount of supporting documentation. I was able to access this information for 15 different projects. On average, a review presentation contained approximately 40 slides. The company's standard

development process included six reviews from concept approval to release for shipping the product. With fifteen projects, and using rough numbers of six reviews per project and 40 slides per review presentation ($15 \times 6 \times 40 = 3600$), it becomes evident that the raw data includes thousands of pages of information. This only counts the review presentations and none of the supporting documentation, which included deliverables like project schedules, meeting minutes, product data sheets and requirements documents, supplier agreements, prototype plans and customer satisfaction and reliability data. The data available were detailed enough to characterize the projects, their development processes, and performance outcomes in substantial depth. The additional qualitative information available also meant that there would be the possibility of uncovering mechanisms and reasons behind patterns that became apparent.

I was able to collect data on a number of project characteristics, process dimensions, and project performance outcomes. The lists of elements on which I was able to collect data are presented here.

Process dimensions: reviews/gates, deliverables, testing (prototypes and software builds), proportion of time spent in phases

Additional dimensions include (with serious data limitations): attendance at reviews, cross functionality of team, and key risks identified in the course of the project

Project Performance: Development Cost – Engineering Spend and Engineering Spend Overrun, Development Time and Schedule Overrun, Quality (Reliability) – Service Cost Overrun, Product Cost - Unit Manufacturing Cost and Overrun

Project Characteristics: Newness, Complexity, Extent of development in-house vs. at supplier, Resources, Project Manager

Looking at the categories on which I had focused for the detailed study, I highlight the elements for which I was able to collect data out of the list of all elements identified from the literature study.

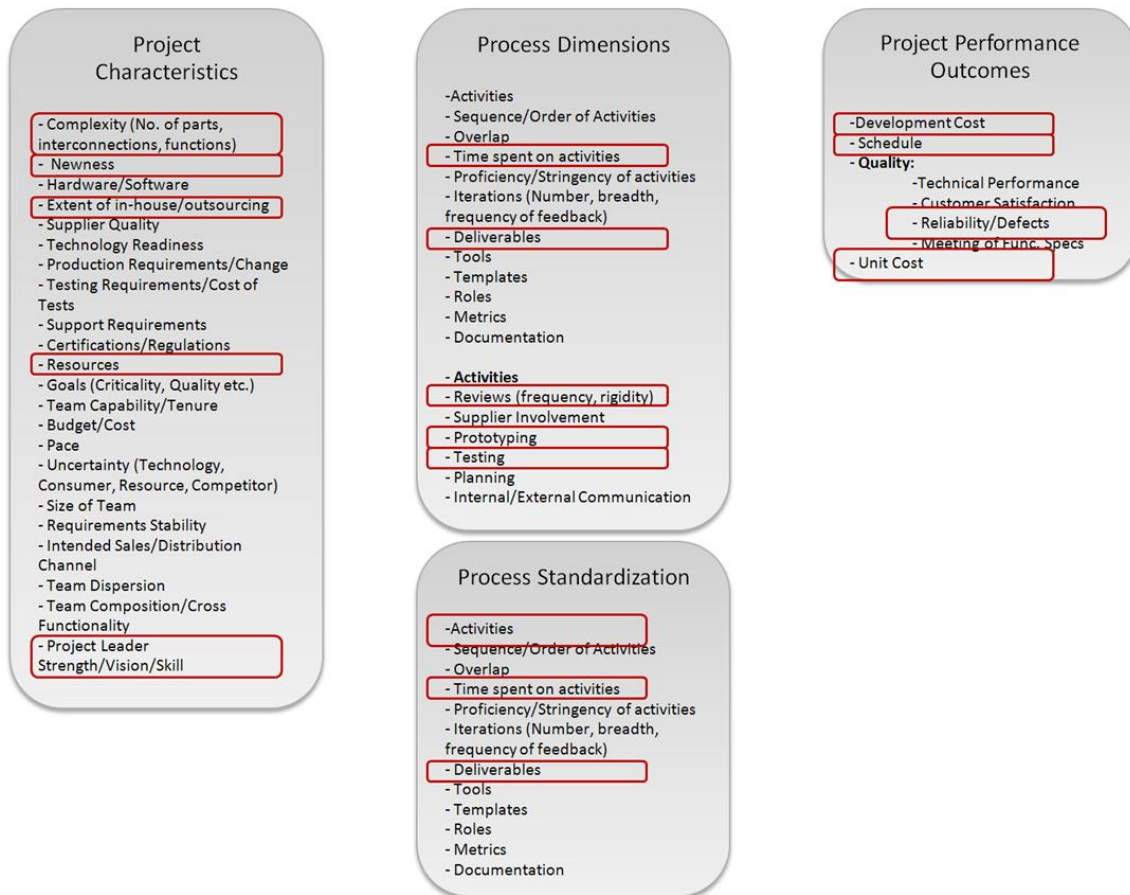


Figure 10 - Elements for which data was collected in detailed empirical study, compared to full set of elements identified in literature study

4.5 Data analysis approach

We have seen that the data available are extensive and detailed. Our approach to analyzing the data was informed by the guidance for research strategy presented in papers by Edmondson & Mcmanus (2007) and Langley (1999).

Edmondson and McManus address the topic of methodological fit in management field research. They define fit as the “internal consistency among elements of a research project – research question, prior work, research design, and theoretical contribution.” They present a framework to relate the design of a research project to the state of prior work. Now that we have a sense of the available data, research question of interest, and the state of prior work, it is appropriate to consider their recommendations and use them to guide our approach to analyzing the data.

State of Prior Theory and Research	Nascent	Intermediate	Mature
Research questions	Open-ended inquiry about a phenomenon of interest	Proposed relationships between new and established constructs	Focused questions and/or hypotheses relating existing constructs
Type of data collected	Qualitative, initially open-ended data that need to be interpreted for meaning	Hybrid (both qualitative and quantitative)	Quantitative data; focused measures where extent or amount is meaningful
Illustrative methods for collecting data	Interviews; observations; obtaining documents or other material from field sites relevant to the phenomena of interest	Interviews; observations; surveys; obtaining material from field sites relevant to the phenomena of interest	Surveys; interviews or observations designed to be systematically coded and quantified; obtaining data from field sites that measure the extent or amount of salient constructs
Constructs and measures	Typically new constructs, few formal measures	Typically one or more new constructs and/or new measures	Typically relying heavily on existing constructs and measures
Goal of data analyses	Pattern identification	Preliminary or exploratory testing of new propositions and/or new constructs	Formal hypothesis testing
Data analysis methods	Thematic content analysis coding for evidence of constructs	Content analysis, exploratory statistics, and preliminary tests	Statistical inference, standard statistical analyses
Theoretical contribution	A suggestive theory, often an invitation for further work on the issue or set of issues opened up by the study	A provisional theory, often one that integrates previously separate bodies of work	A supported theory that may add specificity, new mechanisms, or new boundaries to existing theories

Table 7 - Three Archetypes of Methodological Fit in Field Research.
From Edmondson and McManus (2007)

This table presents the essence of the Edmondson and McManus paper. The current phase of the research project fits best under the 'Intermediate' category. Certainly some constructs are established in product development literature, but as we have seen, there are several contested and unexplored links. Also moving the consideration of process standardization down one level of abstraction to the level of individual process dimensions represents the creation of new constructs. The research falls quite neatly into the intermediate category. In this category, their recommendations are that the data collected be a hybrid of qualitative and quantitative information and these data be analyzed using exploratory statistics and preliminary tests. These are useful recommendations, and ones that I will heed in the course of my analysis.

Another paper that informed my research approach is Langley (1999). Langley describes and compares a number of alternative strategies for the analysis of process data, and evaluates the strengths, weaknesses, and

applicability of individual strategies. She suggests that multiple strategies are often advisable. Of the strategies she identifies, my research approach combines elements of ‘quantification strategy’ and ‘synthetic strategy’.

Let us move from a discussion of the general strategies of data analysis to the particular. For my project, how did I go about analyzing the data? Once again, I remind you that my goal is to uncover relationships between process designs (particularly variation from the standard process) and project performance. I acknowledge that project characteristics play an important role, so they must be included in the analysis and appropriately accounted for. Following this goal, I conducted analysis to relate variation on several process dimensions (reviews/gates – *customization*; deliverable waivers – *deviation*; testing, represented by prototype cycles and software builds; and proportion of time spent in phases) with project performance outcomes (development cost – engineering spend and engineering spend overrun; development time and schedule overrun; quality in terms of reliability – service cost overrun; and product cost – unit manufacturing cost overrun). I conducted this analysis while accounting for variation in project characteristics (newness, complexity, extent of development by supplier, resources, and project manager).

It is useful to note a number of things.

- I only report analysis for the process dimensions on which I was able to collect enough data of high fidelity. Data was gathered on other process dimensions, but this data had serious gaps and limitations and ultimately turned out to be unreliable. I do not report any analysis on these dimensions.
- Project characteristics analyzed include both product characteristics (newness and complexity) and organizational project characteristics (extent of development by supplier, resources, and project manager).
- As described in the case study on Company E in Chapter 2, the process variation at this company includes both customization and deviation. In the collected data set, the planned variation decided at the start of the project (customization) is on number of gates/reviews. The variation that occurs during the project because of unfolding events (deviations) is on deliverable waivers. The nature of process variation on both gates and deliverable waivers will be explained ahead.
- The set of project performance measures does not include technical performance or meeting of functional specifications. These outcomes are not included in the analysis because of the context of the company. The particular way in which this company manages its product development (at least for the 15 projects in our sample) is to define the functional specifications and necessary technical performance at the start of a project. These targets are then held fixed. The project must deliver to these goals to release the product. As a result, there is not much variation across projects in terms of

meeting functional specifications or technical performance targets. For this reason, they are not included in the analysis.⁵

4.6 Operationalization of Constructs

In this section I will describe how I created measures for each of the variables of interest. This activity involved going through the thousands of pages of available raw data and extracting meaningful measures of project characteristics, process dimensions, and project performance outcomes. I will go through the categories in the order listed above and describe the creation of measures for elements in each category.

4.6.1 Project Characteristics

The company acknowledged variation across projects in its portfolio and used the project characteristics of complexity and newness in its internal decision making. The company considers these two characteristics to capture important variation across projects. The company has documents to guide managers on how to assign complexity and newness ratings for their projects. Project Managers are asked to rate both complexity and newness on scales of 1 to 3. I was able to access the guideline documents and learn how complexity and newness ratings are assigned. The complexity and newness ratings assigned by project managers were not available for the projects in my sample. For this reason, I had to create my own measures of complexity and newness and verify them with company stakeholders.

Complexity

From the guideline documentation, I learned that the characteristic the company addresses as ‘complexity’ is primarily about scope and the size of the effort. If one considers a common definition of complexity as including number of parts and number of interconnections between parts, then the company definition of complexity focused entirely on the number of parts, and not on the interconnections. Project Managers were asked to estimate the number of parts to be developed, number of product features to be worked on, and number of lines of code to be written and use these as inputs to assign their complexity rating. Complexity, as defined in this organization, was really about the size of the development effort. This is consistent with what Hölttä-Otto & Magee (2006) find in their study of five firms. That study “found that the scale of a project and the amount of ‘stretch’ are the two most widely used characteristics for estimating project complexity.” They did not find that companies utilized either component or task interactions as inputs to estimate project

⁵ The manner in which companies manage the product development operations – what performance outcomes they hold fixed and what they outcomes they are willing to trade against each other – is an interesting aspect of product development project management. It is possible that companies have unique ‘fingerprints’ in terms of how they manage against performance outcomes. This is an interesting avenue for further exploration.

complexity. They also indicate that this was a reasonable approach, because they found no evidence of interactions being associated with difficulty of development.

Bearing these in mind, I developed a measure of Complexity by counting the number of ‘Key features/areas of work’ from the *Product Data Sheet*. Each project created a document, for internal use, that was an approximately five page overview of the product, focusing on its key features and technical specs. These documents were called Product Data Sheets. Product Data Sheets included a section titled ‘Key features/areas of work’. I counted the number of these key features/areas and used them as a measure of project complexity (Low → 3 to 5 areas of work, Medium → 6 to 8 areas of work, High → More than 8 areas of work). Across the 15 projects the number of key areas varied from 3 to 11, with an average of 6.2 areas of work listed. I used a three category scale because the organization itself assigned complexity ratings on scales of 1-3. I also calculated measures by only using two complexity classes, and by drawing the lines between classes at different numbers of key areas. The results obtained were substantively similar using these alternative formulations.

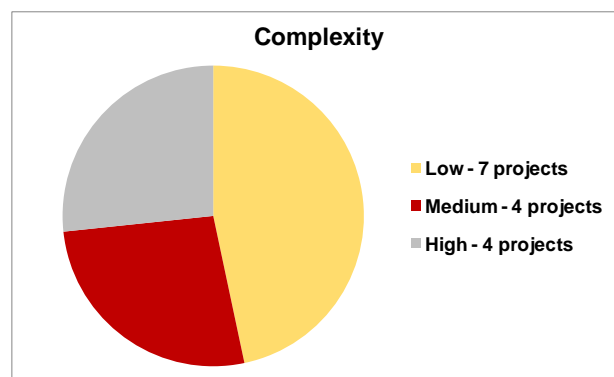


Figure 11 - Distribution of Projects by Complexity

To maintain anonymity, the examples of different projects and their calculated complexity rating presented below have been masked and modified. These should still give you a sense for the kinds of key features/areas of work listed in the Product Data Sheet.

Example 1: Complexity = Low (3 Key areas of work): Front panel, [Subsystem A], Reliability

Example 2: Complexity = High (9 Key areas of work): Front panel, [Subsystem A], [Function] Quality, [Function] Speed, [Function] modes, Reliability, Input Media Handling, Driver software, EH+S Regulatory compliance

[Function] is the main function of the product. For example for a washer, the function could be wash; for a dryer, the function could be dry; for a printer, the function could be print; for a camera the function could be image.

Newness

For newness, I once again studied the internal guideline documentation. Here the definition of newness was about how new the technology and product were for the company. It included some measure of what Hölttä-Otto and Magee (2006) call stretch – the perceived difficulty of meeting objectives, but primarily it was a simple characterization of the newness of the technology and product compared to what the company had developed or released in the past. In our sample of 15 projects, complexity and newness were correlated with $r = 0.5$.

I created a very simple measure for newness. Once again, I relied on the *Product Data Sheet* to create this measure. The Product Data Sheet included a one-paragraph description of the product at the very beginning (similar to the abstract of a paper). I characterized products as having low, medium, or high newness depending on the words used to describe the product in its one-paragraph overview. The product was categorized as low newness if the description included the words “Follow-on” or “Derivative”. Products were characterized as high newness if the description included the word “new”. For products that did not include any of these words, some interpretation was necessary. Many of these products fell into the category medium and had descriptive phrases such as “Upgrade of” “Shares features with”.

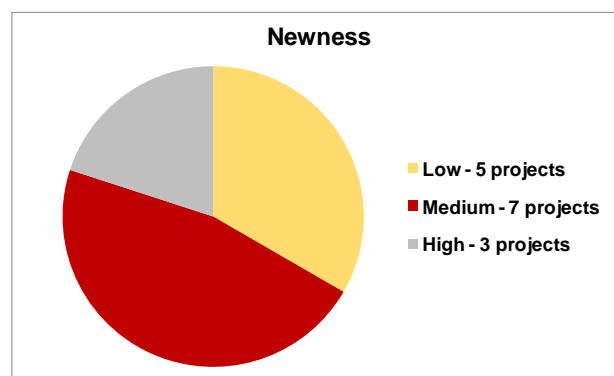


Figure 12 - Distribution of Projects by Newness

Example 1: Newness = Medium: “[Product Name] will launch as a refreshed and upgraded version of the [earlier product]. The main updates will be seen in the [product] interface, drivers, and meeting compliance requirements in Europe as well as for [energy use certification].”

Example 2: Newness = High: “[Engine name] is a new engine and [Product name] will be [its] first product.”

To check robustness, I also calculated newness by separating it into only two levels and the results obtained were substantively the same for this alternative formulation.

Extent of Development by Supplier

Another important project characteristic across which variation existed in the portfolio was the extent of development by supplier (or what the company often referred to as delivery model). Some projects at the company were developed entirely in-house, some were sourced almost entirely from suppliers with a label added at the end to sell it as a ‘Company E’ product, and others were developed partly by suppliers with some features developed in-house. Within the company, these three modes were called In-house, OEM-in, and Partnered respectively.

To classify products as In-house, Partnered, or OEM-in (which correspond with low development by supplier, medium development by supplier, and high development by supplier), I once again used the one-paragraph descriptions from Product Data Sheets. Low – In-house development. Medium – “based on” engine provided by Supplier. High – turnkey or “fully OEM-in”

Example 1: OEM-extent = High: “[Product name] is a turnkey OEM-in [technical specification] [product class] [product] using the [supplier product] engine.”

Example 2: OEM-extent = Medium: “[Product name] is a [technical specification] [product class] [product] based on the [supplier product] engine with controller software and user interface features added in-house.”

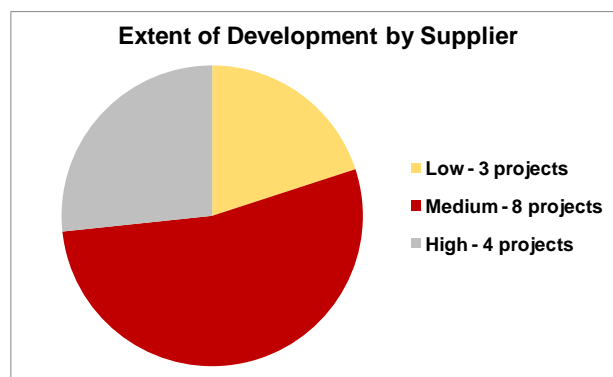


Figure 13 - Distribution of Projects by Extent of Development by Supplier

Resources

An important project characteristic is the resource availability and allocation to a project. To create a measure of resources allocated (in terms of people or full-time equivalents) to a project, we used the following method.

For three of the projects in our sample, budgets were available. These budgets indicated that almost all engineering spend (consistently greater than 90%) is spent on people. These budgets also showed that the company uses a fixed amount (*Person Cost*) per person per year for its engineering spend calculations. Given this information, and the fact that I had data on total engineering spend for each projects, I used the following formula to calculate the number of full time equivalents allocated to a project.

$$\frac{(\text{Engineering Spend}) \times 52}{(\text{Development Time in Weeks}) \times (\text{Person Cost})}$$

For the 3 projects for which budgets were available, with actual numbers for FTE, the calculated FTE matched up quite well. This gave me the confidence to use this calculation to estimate FTE on all 15 projects.

Project Manager

Another important project characteristic is project leader skill. In our sample, three project managers managed multiple projects in the group of 15. Two managers had led three different projects each and one manager had led two projects. To create a measure for Project Manager, I assigned each multiple-project-manager their own category using a dummy variable. All other project managers (who had managed only one project each – seven total) would be used as a baseline against which to compare the multi-project-PMs.

4.6.2 Process Dimensions

Gates

The standard development process at the company indicates that all projects go through six total gates. These gates are 1a – Concept Approval, 1b – Requirements Defined, 2 – Technology Demonstrated, 3 – Implementation and start of Testing, 4 – Testing, Refinement, and Production Ramp-Up, PSR – Product Shipment Release.⁶ In practice, 11 (out of 15) projects combined two of the gates. Combining gates means that the project performed two reviews together instead of separately. The most frequent gates to be combined were gates 2 and 3. 9 out of 11 combiners combined those gates. This combination of gates was

⁶ Note that these gate labels are not used by the company. I compared the activities performed in each phase between gates at the company, with the generic product development process from Ulrich and Eppinger (2000) and assigned the gate labels accordingly to provide a sense of the flow of activities and the locations of the reviews.

planned at the start of a project. Project leadership teams made the decision according to the complexity and newness of the product and combined gates when they saw fit. As this was a planned variation in the process, I call this a ‘customization’. Examining the factors that influenced managers to make the decision to combine gates, I found that complexity had a role to play. If a project was low complexity, managers always combined gates (for all 7 projects), whereas if a project was medium or high complexity, managers sometimes combined gates and sometimes didn’t (for both medium and high complexity 2 projects combined gates and 2 didn’t). Newness does play an evident role in determining gate combination. To operationalize gate combination, I create a dummy variable. If project combined gates, I set dummy variable = 1. If project did not combine gates, I set dummy variable = 0.

Deliverable Waivers

The standard development process laid out what deliverables were expected at each gate. Some projects did not submit particular deliverables at the reviews because of events that occurred or problems that were discovered during project execution. The gate review teams could exercise their judgment and grant projects a ‘deliverable waiver’, allowing projects to pass through gates and move on to the next phase, even without submitting a particular deliverable. The meeting minutes from review meetings include mention of any deliverable waivers at that gate. I use this information to gather data on deliverable waivers.

For each project, I create a measure that is the count of total deliverable waivers, which provides an aggregate measure of deviation from the standard on the dimension of deliverables. However, I also categorize waivers into different types depending on the performance outcome they are most closely tied with. Thus, I bin waivers into Engineering Spend Waiver, Reliability and Performance Waiver, Schedule Waiver, Unit Manufacturing Cost Waiver. I count waivers in each category separately and create measures for each type. The reason I bin waivers is because it is reasonable to expect that waivers of a certain type may affect certain performance outcomes. This is consistent with the lessons about disaggregation from previous research phases.

I include here two examples of deliverable waivers along with their categorization. These are actual excerpts from review meeting minutes, with sensitive information covered up.

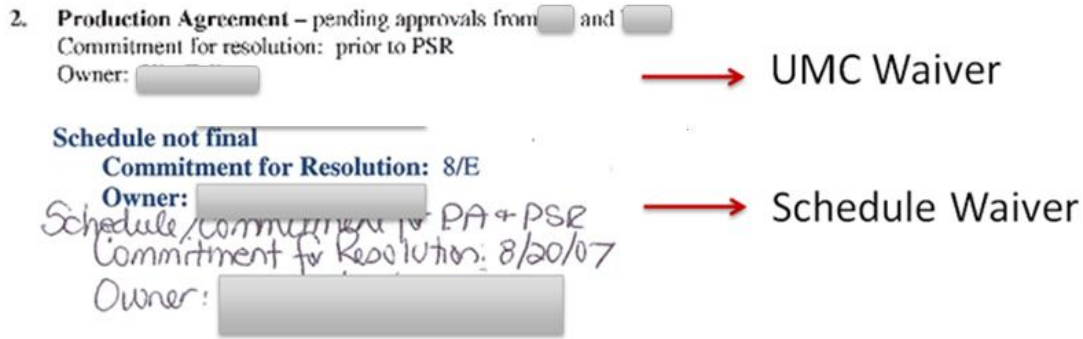


Figure 14 - Examples of Deliverable Waivers

I categorize a Production Agreement that has not yet been signed as a UMC waiver because matters of production are most closely associated with the outcome Unit Manufacturing Cost. A detailed activity-level schedule that has not yet been created is categorized as a schedule waiver, because it is closely associated with the outcome Schedule. An example of an Engineering Spend Waiver is “Design and Development Agreement not signed with [supplier]”. An example of a reliability and performance waiver is “[Technical performance measure] in [particular operating situation] are ~5 times slower than that of current shipping product.” This is a waiver because each product is supposed to have reached certain technical performance targets (set early in the project) by certain gates and provide evidence to show that it is meeting those targets.

Testing

Testing occurs in both hardware and software. For hardware, the extent of testing is reflected in the number of prototype cycles incorporated into the process. For software, testing is reflected in the number of ‘integration releases’ – times when different modules of software are integrated and tested. The planned number of both prototype cycles and software build cycles is reported in the project schedule. To create measure of testing, I count the number of each type and sum them together. The number of total tests ranges from 4 to 9 across the sample of projects, with an average of 6.1. I also calculated software and hardware builds separately and considered them individually in the analysis - the results obtained were the substantively the same but with lower statistical significance. It makes theoretical sense to sum hardware and software builds together to create a composite measure of testing because the reliability output measure (service cost) is influenced by both hardware and software.

Proportion of Development Time spent in Phases

The review presentations each include the date on which the review occurred. This date marks the end of one phase and the start of the next. Using these dates it is straightforward to calculate the time spent in each

phase. Taking this time for each phase and dividing it by the total project development time, gives the proportion of time spent in each phase.

4.6.3 Project Performance Outcomes

Development Time in weeks

Total project development time is calculated as (Date for PSR from review presentation) – (Date for 1b from review presentation). Development times for projects in the sample range from 24 weeks to 65 weeks, with an average development time of 45 weeks (about 10 months). I use gate 1b (and not 1a) as the starting point to calculate project development time, because Gate 1b represents the point when projects actually have resources allocated to them and development starts in earnest. Gate 1a is only concept approval. The idea for the project is approved, but sometimes development does not begin immediately. In a few cases in our sample, a project was approved and made it through 1a but was then shelved for a few months. This dynamic is revealed by examining the content of review presentations. When business unit leaders decided to initiate actual development on the project, they gathered resources and had the project prepare for 1b. 1b is also when product requirements are defined. This is why 1b represents a much better starting baseline for many measures.

Engineering Spend in \$m

Engineering Spend on projects is extracted from information contained in the financial case at review for Gate 4. This represents total spending for acquiring the product, including in-house development expenditure, plus payments made to suppliers for design and development. Gate 4 is used because it is the last gate at which financial information is reported. This represents the final engineering spend report on the project. Engineering spend for projects in the sample ranges from \$1.6m to \$17m, with an average of \$7.2m.

Schedule Overrun (weeks and %)

Schedule overrun is calculated as (PSR actual date obtained from review presentation) – (Planned date for PSR from schedule at 1b). This gives the schedule overrun in weeks. To translate this into a percentage schedule overrun the number calculated above is divided by projected total development time at Gate 1b. The average project overruns schedule by 3.6 weeks, with a range from essentially on time (1 day early) on the low end and a delay of 32 weeks on the high end (or from -1% to 112% with an average overrun of 13.6%).

Planned schedules are reported at each gate. Therefore at Gate 1b, I can see what the planned dates are for all upcoming reviews. Then the actual date that the reviews happen can be obtained from the review presentations themselves. In this manner, I can track slip in the project at the resolution of individual gates. I can see until what point projects were moving according to plan and when they started getting delayed.

Engineering Spend Overrun (\$m and %)

Engineering Spend Overrun is calculated as (Reported Engineering Spend from Financial Case at review for Gate 4) – (Planned Engineering Spend from Financial Case at Gate 1b). To calculate percentage overrun, the above number is divided by (Planned Engineering Spend from Financial Case at Gate 1b). The average project overruns budget by \$0.8m, with a range of \$1.4m under budget on the low end and \$3.6m over budget on the high end (or from -24% to 128% with an average overrun of 19.7%).

Service Cost Overrun (\$ and %)

At this company, after testing is complete the company makes a projection of service cost per machine per year. This projection is informed by the testing data and benchmarking against comparable products already in the field. This projection of service cost per machine per year is reported at PSR.

Four to five months after the product has been shipped, the project holds a review to evaluate customer satisfaction and reliability. At this point, there is actual data from the field on how much it is costing to service the machine. This data, based on four to five months of field operations is normalized to report it in consistent format as service cost per machine per year.

Data from these reviews to evaluate reliability and customer satisfaction was only available for 12 of the 15 projects in the sample. Therefore for all analyses that address service cost overrun, the sample size is 12 projects.

I calculate service cost overrun as: (Service cost per machine per year reported at Customer Satisfaction and Reliability Review) – (Projected Service Cost per machine per year at PSR)

To calculate the percentage service cost overrun, the above number is divided by (Projected Service Cost per machine per year at PSR). The average service cost overrun is \$33/machine/year, with a range of \$56/machine/year under projected cost on the low end and \$391/machine/year over projection on the high end (or from -49% to 111% with an average overrun of 8.3%).

Unit Manufacturing Cost Overrun (\$ and %)

To address the performance outcome Product Cost, I collect data on Unit Manufacturing Cost (UMC). The projected UMC is reported in the financial case at each gate. UMC Overrun is calculated as (UMC from Financial Case at Gate 4) – (UMC from Financial Case at Gate 1b). To calculate percentage overrun, the above number is divided by (UMC from Financial Case at Gate 1b). The average project overruns UMC by

\$12, with a range of \$243 under projection on the low end and \$237 over budget on the high end (or from -12.1% to 29.3% with an average overrun of 1.7%).

I use data from Gate 4 in the calculation of UMC overrun because it is the last time at which financial case data is available. However, this presents a challenge. Gate 4 represents ramp up to production. Actual production has not yet been undertaken. A good amount of the uncertainty in production costs has been resolved by gate 4 (material and parts have been sourced, production agreements have been signed etc.) but it is still not the final data on unit product cost. This is an acknowledged limitation of the data. However, it is the best available information.

4.7 Analysis of Data and Results

4.7.1 The Modeling and Analysis Process

As described earlier, the goal of the analysis is to relate variation on process dimensions (especially variation from the standard) with project performance outcomes, while accounting for variation in project characteristics. Following this goal, I conduct simple statistical analysis (OLS regressions) using process dimensions as the independent variables of interest, project performance outcomes as dependent variables and project characteristics as control variables.

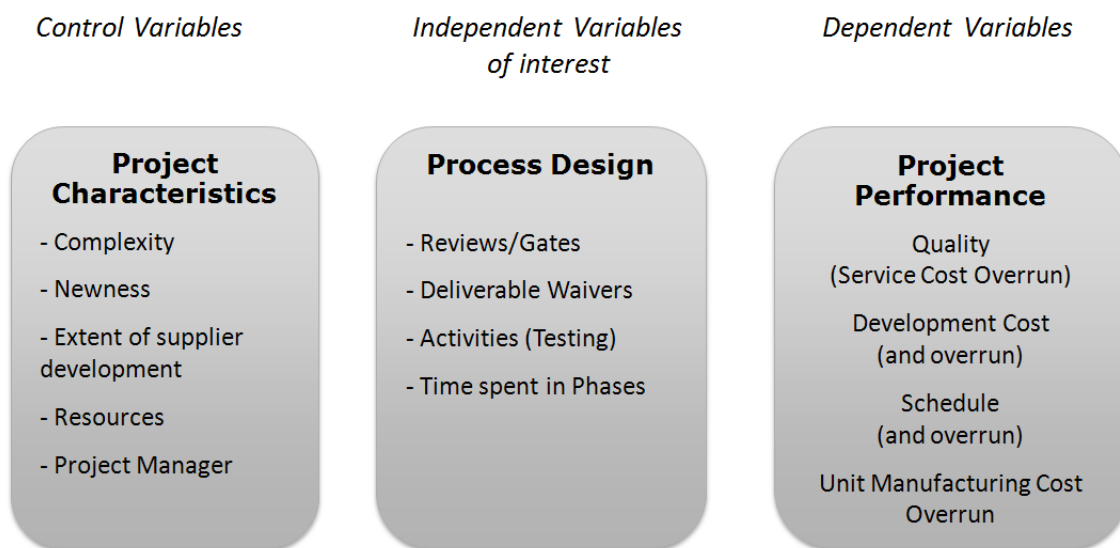


Figure 15 - Strategy for Statistical Models

This analysis is performed in the following manner. For each performance outcome, I start with the key Project Characteristics that the company uses in its own decision making – newness and complexity. These variables stay in the regression throughout as they are used to level across different projects and make them

comparable. I then add organizational project characteristics (extent of development by supplier, resources, project manager) to the model, one by one. If the variables provide explanatory value, I keep them in the model, otherwise I drop them. I gauge if the additional variables add explanatory value by tracking Adjusted R^2 . Adjusted R^2 corrects the R^2 statistic for degrees of freedom i.e. the number of regressors included in a model. It is a standard and widely utilized metric to trade off parsimony of models against goodness of fit (Kennedy 2003). Thus if adding organizational project characteristics increases Adjusted R^2 then I retain them in the model, otherwise I discard them. Finally, I add process variables (gate combination, waivers as theoretically appropriate, testing, proportion of time spent in phases). The coefficients obtained from these models indicate the effect of a particular element on the performance outcome that is being studied. I add process dimensions last, so as to be most conservative in estimating their effects. Only after we have controlled for all relevant project characteristics, do we examine the effect of process dimension on performance. Described here is the general process I followed in conducting the analysis. However, this process was not followed mechanically. As is appropriate for 'Intermediate' research (Edmondson and McManus 2007), when available theory, case information, or analysis results pointed to an interesting avenue for exploration, I followed it. I will show how these explorations yielded interesting insights. Finally, where possible I supplemented the quantitative data with available qualitative information to uncover stories and mechanisms. I will also show examples of this process yielding useful insights.

4.7.2 Descriptive Statistics and Correlation Table

The following page contains a table summarizing all the variables in the study including descriptive statistics and correlations between variables.

	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
[1] Newness	1.87	0.74	1	3	1																			
[2] Complexity	1.80	0.86	1	3	0.50	1																		
[3] Ext. of Supplier Dev.	1.07	0.70	0	2	0.16	-0.37	1																	
[4] Resources (FTE)	51.23	31.59	13.1	121.3	0.52	0.80	-0.52	1																
[5] Combined Gates	0.73	0.46	0	1	-0.31	-0.48	-0.39	-0.14	1															
[6] Rel. and Perf. Waiver	1.00	1.13	0	4	-0.08	0.41	-0.65	0.49	0.20	1														
[7] Engg. Spend Waiver	0.53	0.74	0	2	0.54	-0.17	0.79	-0.24	-0.32	-0.53	1													
[8] Schedule Waiver	0.40	0.74	0	2	0.22	0.44	-0.36	0.49	-0.23	0.32	-0.15	1												
[9] Unit Manufacturing Cost Waiver	1.13	0.83	0	2	0.49	0.03	0.42	0.01	-0.24	-0.51	0.31	0.08	1											
[10] Testing	6.07	2.05	4	9	0.16	0.28	0.31	0.05	-0.90	-0.27	0.23	0.23	0.32	1										
[11] Development Time (weeks)	44.67	13.76	23.9	64.7	0.61	0.68	0.18	0.45	-0.72	0.20	0.38	0.22	0.06	0.50	1									
[12] Development Cost (\$m)	7.17	5.27	1.6	17	0.59	0.87	-0.42	0.91	-0.38	0.52	-0.06	0.49	-0.12	0.25	0.72	1								
[13] Schedule Overrun (%)	13.6%	28.5%	-1.0%	112.0%	0.07	0.39	-0.31	0.44	0.07	0.76	-0.20	-0.18	-0.42	-0.18	0.45	0.52	1							
[14] Schedule Overrun (weeks)	3.59	9.76	-0.1	32.1	0.23	0.48	-0.20	0.39	-0.11	0.75	-0.03	-0.07	-0.42	-0.11	0.62	0.57	0.91	1						
[15] Engineering Spend Overrun (%)	19.7%	44.4%	-23.5%	128.6%	0.07	-0.47	0.23	-0.29	0.13	-0.16	0.55	0.03	-0.20	-0.05	-0.13	-0.18	-0.21	-0.08	1					
[16] Engineering Spend Overrun (\$m)	0.77	1.45	-1.4	3.6	0.17	-0.29	0.30	-0.31	-0.28	-0.29	0.57	0.26	0.03	0.39	0.07	-0.10	-0.42	-0.21	0.85	1				
[17] Service Cost Overrun (%)	8.3%	53.4%	-49.1%	111.1%	-0.10	0.24	-0.29	0.29	0.41	0.39	-0.13	-0.16	-0.52	-0.61	0.02	0.21	0.53	0.46	0.00	-0.41	1			
[18] Service Cost Overrun (\$/machine-year)	33.42	118.24	-54	391	0.01	0.37	-0.43	0.48	0.31	0.66	-0.23	-0.20	-0.55	-0.45	0.25	0.47	0.89	0.76	-0.17	-0.52	0.82	1		
[19] Unit Manufacturing Cost Overrun (%)	1.7%	10.4%	-12.1%	29.3%	-0.09	0.08	-0.03	0.01	0.03	0.30	-0.01	-0.42	-0.36	-0.21	0.17	0.06	0.53	0.59	0.22	-0.05	0.59	0.52	1	
[20] UMC Overrun (\$)	11.80	112.84	-243	237	-0.25	-0.16	-0.25	-0.04	0.32	0.48	-0.22	-0.51	-0.53	-0.32	-0.11	-0.01	0.63	0.58	0.25	-0.06	0.40	0.57	0.79	1

Table 8 - Descriptive Statistics and Correlations for all Variables

4.7.3 Results - Performance Outcome – Development Time

We will now address the performance outcomes one by one and see what elements influence them. We begin with development time.

First, let me explain the structure of the tables in which the results are reported. Tables like this form the standard format in which results of regression analysis are reported in management journals. The rows include a list of the variables included in the model. The bottom row displays the Adjusted R^2 , a measure of how well the variables in model help to explain variation in the performance outcome. The columns represent different models. If a coefficient is reported within a column, it means that the variable was included in the model whose results are displayed in the column. We can see the trend of gradually adding variables as we move through models, starting with only newness and complexity and adding from there. The asterisks indicate statistical significance. If a coefficient is marked with a single asterisk (*) this indicates a p-value of less than 0.1, if a coefficient is marked with two asterisks (**) this indicates a p-value of less than 0.05, and if it is marked with three asterisks, this indicates a p-value of less than 0.01 (***).⁷ All models are tested using OLS regression (using the *regress* function in STATA).

Results of Regression Analysis for Development Time in Weeks

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Newness Low Dummy	-20.72***	-17.48**	-20.18***	-13.51	-16.30*	-18.44***
Newness High Dummy	-7.08	-7.91	-6.49	-5.67	-5.72	-6.37
Complexity Low Dummy	-2.75	-2.01	-3.93	-4.60	-0.75	1.64
Complexity High Dummy	8.88	15.07*	16.71**	17.65*	16.47*	9.10*
Ext. of dev. done by supplier Low Dummy		-6.43				
Ext. of dev. done by supplier High Dummy		3.48				
Resources (FTEs)			-0.15	-0.20	-0.15	
Project Manager 1 Dummy				-9.29	-4.65	
Project Manager 2 Dummy				-9.82	-3.41	
Project Manager 3 Dummy				-8.25	-4.23	
Combined Gates Dummy					-7.32	-10.47**
Intercept	51.91***	49.36***	57.77***	62.69***	62.58***	56.57***
Adjusted R^2	0.723	0.712	0.749	0.763	0.778	0.813

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

Table 9 - Results of Regression Analysis for Development Time in Weeks

⁷ A p-value indicates the probability that the data in the sample would take the form they do if there was no relationship between the dependent variable and the variable for which the coefficient is reported. So, a p-value of less than 0.01 for the relationship between Low Newness and Development time means that there is less than a 1% chance that data would appear as they do in our sample if there was no relationship between development time and low newness projects.

Let us examine how newness, complexity, and extent of supplier development are represented in these models. These constructs are each divided into three categories using dummy variables. Imposing a 1, 2, 3 ordinal scale on complexity would imply that the difference between a low complexity project and a medium complexity project is exactly the same as the difference between a medium complexity project and a high complexity project. However, this may not be true; complexity may not increase linearly between categories. To account for the categorical nature of our predictors, we utilize dummy variables. Using medium complexity as a baseline, we ask if any differences can be detected between low and medium complexity, or between medium and high complexity. The coefficient reported for low complexity represents the difference in development times between a medium complexity project and a low complexity project. The same argument holds for newness and extent of supplier development, therefore we apply the same method of creating categories using dummy variables and using the medium levels as a baseline for those constructs.

Model 1 includes only newness and complexity. We see that a substantial amount of the variation in development time can be explained by complexity and newness alone (Adjusted $R^2 = 0.72$). We also see that low newness is highly significant, but high newness is not. This means that low newness projects take substantially less development time than medium newness projects, but that the difference in development time between medium newness and high newness projects is not statistically distinguishable.

Model 2 adds extent of development at supplier. We see that this variable does not add any explanatory value as the Adjusted R^2 goes down slightly. An interesting point is that high complexity now becomes significant. The coefficient indicates that high complexity projects take more development time than medium complexity projects. The fact that this variable was not significant in Model 1 and then became significant means that complexity and extent of development at supplier are correlated. Adding extent of development at supplier to the model reduces some of the noise that was clouding the relationship between complexity and development time. We see that high complexity retains its significance across other model specifications, indicating that it is a robust result.

Adding Resources and Project Manager variables in Models 3 and 4 do not result in a substantial increase in Adjusted R^2 and do not yield any statistically significant relationships.

Model 5 includes the additional variable of combined gates. This variable also contributes only a small increase in Adjusted R^2 and does not give a statistically significant relationship. However, project managers and portfolio managers at Company E had consistently indicated to me that they combined gates to reduce development time. To test if combined gates showed any effect in a more sparse model, I test model 6, which only includes complexity, newness and combined gates. This is an example of an exploration driven by

previous knowledge. This exploration turns out to be very fruitful. In fact it yields a model with the highest Adjusted R² (0.81) of all the models tested (which indicates the best tradeoff of goodness of fit and parsimony) and gives a statistically significant coefficient for Gate Combination. The inclusion of four additional variables that are all weakly related to gate combination (inevitable in the small sample of 15 projects) was clouding the clear relationship between development time and gate combination. We see that Gate Combination reduces development time by 10.5 weeks, even controlling for the effect of newness and complexity. The estimate of 10.5 weeks changes a little depending on the model specification, but the number reported here serves to provide a sense of the magnitude of the effect.

In summary, from examining the results for development time, we learn that:

- Variation in development time is driven mostly by complexity and newness
- Low newness projects take less time and high complexity projects take more time
- Combining gates reduces development time, even holding complexity and newness constant.

The fact that combining gates can reduce schedule, even holding complexity and newness constant indicates that process choices are important.

4.7.4 Results - Performance Outcome – Development Cost

Now that we have been through one set of results, we should be able to move through the other performance outcomes at a faster pace.

Results of Regression Analysis for Engineering Spend in \$m

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Newness Low Dummy	-1.59	1.38	0.86	2.52	0.84
Newness High Dummy	-0.64	-1.66	-1.61	-1.34	-1.18
Complexity Low Dummy	-1.10	-1.19	-0.96	-1.54	-0.29
Complexity High Dummy	8.89***	11.22***	9.55***	10.22**	9.46***
Ext. of dev. done by supplier Low Dummy		3.63***	2.92*	3.18	4.98***
Ext. of dev. done by supplier High Dummy		5.76***	4.88**	4.60	4.34***
Resources (FTEs)			.027		
Project Manager 1 Dummy				-1.08	
Project Manager 2 Dummy				-2.76	
Project Manager 3 Dummy				-0.76	
Combined Gates Dummy					-2.60**
Intercept	5.97***	2.35**	1.85	3.60	4.50***
Adjusted R ²	0.714	0.940	0.937	0.930	0.967

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

Table 10 - Results of Regression Analysis for Engineering Spend in \$m

In the case of development cost, Model 1 shows that high complexity projects cost more to develop (this is perfectly expected, given their definition of complexity as size of development effort), and that complexity in itself explains a good amount of variation in development cost. Model 2 shows that including extent of supplier development greatly increases Adjusted R^2 (0.94), to the point where we are explaining almost all the variation in development cost. Given only newness, complexity, and extent of supplier development, we can predict development cost in our sample with 94% accuracy. The extent of development at supplier variables also have significant coefficients (the meaning of these coefficients is examined later). Models 3 and 4 show that adding resources and project manager variables to the model adds no explanatory value. Model 5 includes combined gates. This model shows that combining gates leads to a statistically significant reduction in development cost, even holding newness, complexity, and extent of supplier development constant.

Let us examine the relationship between development cost and extent of supplier development. As a reminder, the extent of development at supplier variable indicates if products were developed in-house, partnered, or sourced almost entirely from a supplier. The results show statistically significant positive coefficients for both low and high extent of supplier development. This means that projects that are developed entirely in-house, or projects that are developed almost entirely by suppliers, have a much higher engineering spend than products developed in partnered mode. A conclusion one might jump to would be that the company should develop all its products in partnered mode. However, let us pause to examine what is driving these results. It is useful to look at a plot of development cost against extent of development by supplier for all projects.

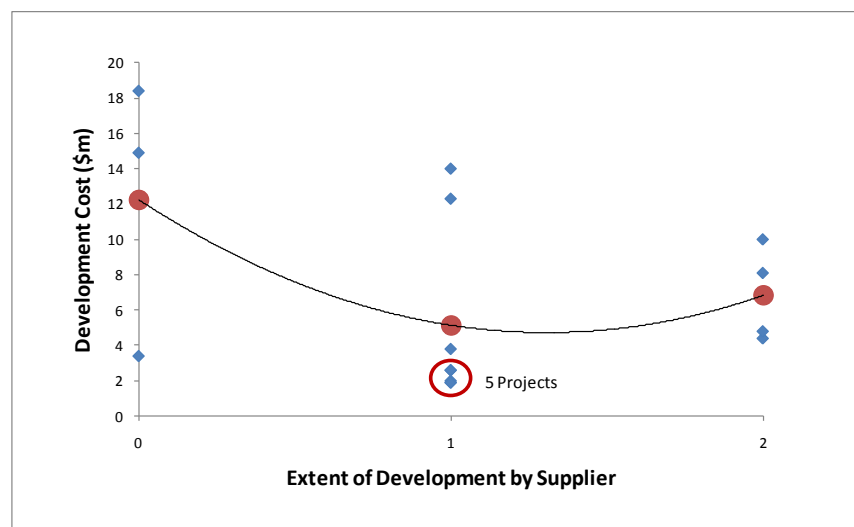


Figure 16 - Relationship between Development Cost and Extent of Development by Supplier

The blue diamonds are individual projects, the red dots are the averages of development cost for each category (0 = in-house, 1 = partnered, 2 = fully oem-in). A trendline through the averages shows the same u-shaped relationship as the regression results indicate. An examination of the individual projects will show why this is the case. By far the two biggest (and most expensive) projects in the sample are of a particular technology class for which the company only develops products in-house. These are on the left side of the plot. They are responsible for driving up the average cost in that category. Six of the smallest (and least expensive) projects in the sample are developed in partnered mode. These projects are incremental projects that build on an existing product already launched by a supplier and add some small number of features. The most expensive projects in the fully oem-in category are much smaller than the expensive projects in the in-house category. However, these projects are all represented as complexity and newness levels of high. It is the fact that complexity of 'high' includes projects ranging in development cost from ~ \$10m to \$18m, and that so many other projects are only \$2m development efforts that leads to the results we find. The coefficients found for 'extent of development by supplier' do not reflect an output of the mode of development, but are instead a result of Company E's sourcing strategy and the limits of complexity and newness measures. For this reason, I do not emphasize these results. It should be noted that having detailed project information available, along with qualitative information to establish the company's sourcing strategy was essential to discover the reasons behind these results and thus interpret them correctly.

In summary, from examining the results for development cost, we learn that:

- Variation in development cost is driven mostly by complexity
- High complexity projects cost more to develop
- Combining gates reduces development cost, even holding complexity, newness, and extent of supplier development constant.

4.7.5 Results – Performance Outcome – Schedule Overrun

Results of Regression Analysis for Schedule Overrun in Weeks

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Newness Low Dummy	-9.29	-9.27	-9.32	-12.65	-10.45	-9.96	-11.09**
Newness High Dummy	-9.64	-9.88	-9.67	-10.99	-10.00	-10.16	-2.45
Complexity Low Dummy	-0.02	-0.74	0.05	1.35	-2.25	-2.25	-0.27
Complexity High Dummy	8.45	5.35	8.03	7.77	8.34	11.62	-2.09
Ext. of dev. done by supplier Low Dummy		8.89					
Ext. of dev. done by supplier High Dummy		2.44					
Resources (FTEs)			-0.30				
Project Manager 1 Dummy				-5.52			
Project Manager 2 Dummy				3.35			
Project Manager 3 Dummy				-0.08			
Combined Gates Dummy					5.32	4.18	-1.01
Schedule Waiver						-4.10	
Reliability and Performance Waiver							6.49***
Intercept	6.37	5.14	10.69	7.75	4.00	5.47	2.45
Adjusted R ²	0.183	0.174	0.093	-0.025	0.155	0.153	0.617

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

Table 11 - Results of Regression Analysis for Schedule Overrun in Weeks

Let us now consider schedule overrun. Results from models 1, 2, 3 and 4 show that project characteristics do not help at all in explaining schedule overrun. Model 5 shows that including gate combination also does not help to explain this outcome. I move on to considering the addition of other process variables. I consider the set of deliverable waivers and add the one that make the most theoretical sense. As we are examining schedule overrun, it seems reasonable to include schedule waivers in the model. Model 6 shows that schedule waivers have no discernible effect and do not help to explain schedule overrun. I then add reliability and performance waivers to the model. This addition adds substantial explanatory value to the model. Reliability and Performance waivers are found to be a significant predictor of schedule overrun.

This result makes a great deal of sense in light of the organization's context. As explained previously, the organization holds technical performance constant. A project is not released until it hits established technical performance targets. A reliability and performance waiver occurs when a project has problems with technical performance during development, but is allowed to pass through a gate regardless. The fact that these projects have schedule overrun indicates that the performance projects do come back to bite project teams at the end. By taking a waiver, they are not addressing the problem, they are merely deferring it. As they have to hold product release until the problem is solved anyway, this leads to schedule slip at the end. We will examine alternative strategies to deal with reliability and performance problems later in this chapter.

I also conduct some further qualitative verification of the relationship. As I have schedules at each gate, I can track the onset of schedule slip. I find that on projects where reliability and performance waivers were taken, schedule slip occurred in gates after when reliability waivers were taken. This temporal sequence lends credence to the idea that reliability and performance waivers are leading indicators of schedule slip.

Results of Regression Analysis for Schedule Overrun as % of Projected Development Time

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Newness Low Dummy	-0.16	-0.16	-0.18	-0.11	-0.21	-0.19	-0.23
Newness High Dummy	-0.35	-0.36	-0.36	-0.33	-0.37	-0.37	-0.17
Complexity Low Dummy	0.08	0.06	0.10	0.08	-0.02	0.02	0.04
Complexity High Dummy	0.36	0.28	0.21	0.37	0.36	0.49	0.09
Ext. of dev. done by supplier Low Dummy		0.25					
Ext. of dev. done by supplier High Dummy		0.08					
Resources (FTEs)			0.003				
Project Manager 1 Dummy				-0.09			
Project Manager 2 Dummy				-0.06			
Project Manager 3 Dummy				-0.16			
Combined Gates Dummy					0.23	0.18	0.06
Schedule Waiver						-0.17	
Reliability and Performance Waiver							0.17**
Intercept	0.13	0.09	0.01*	0.15	0.03	0.17	-0.01
Adjusted R ²	0.102	0.070	0.054	-0.223	0.134	0.127	0.459

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

Table 12 - Results of Regression Analysis for Schedule Overrun as % of Projected Development Time

The models using percentage schedule overrun show the same effects and support the story described above. In summary, we find that schedule overrun is related to reliability and performance waivers.

4.7.6 Results – Performance Outcome – Development Cost Overrun

Let us now examine development cost overrun. Models 1, 2, 3 and 4 (Tables 13 and 14) show that project characteristics do not help to predict engineering spend overrun. Model 5 (Table 13) indicates that gate combination has a significant relationship with engineering spend overrun, but it is weakly significant and does not help in explaining much of the variation (Adjusted R²=0.13). In addition, the relationship does not hold when looking at percentage development cost overrun (Table 14). In model 6 (Tables 13 and 14) we add engineering spend waiver. Looking at percentage overrun (Table 14), we find that engineering spend waiver is highly significant and helps explain a substantial amount of variation in engineering spend overrun. However, looking at the absolute overrun (Table 13), we find that engineering spend waiver is not significant and the amount of variation explained is substantially lower. Model 7 (tables 13 and 14) removes gate combination. For percentage overrun (Table 14), the results stay relatively unchanged, with strong significance and high explanatory power. For absolute overrun (Table 13), engineering spend waivers become significant, but the

amount of variation explained is still low. This is a puzzling set of results and led me to dig deeper to understand engineering spend waivers.

Referring to the minutes from the review meetings, I find that engineering spend waivers are all of the same kind. They are taken for ‘Design and Development Agreements’ that have not yet been signed when they are supposed to be ready. Design and Development Agreements (DDAs) are agreements with suppliers about what suppliers are going to provide Company E and the cost at which they are going to provide it. Since the only engineering spend waivers were DDAs, it makes sense to examine the subset of projects that are eligible to sign DDAs. This subset of projects is the subset that works with suppliers in any form. The projects that do all in-house development ($n = 3$) are not eligible to sign DDAs and can therefore be removed from consideration. Of the remaining subsample ($n = 12$), 6 projects took engineering spend waivers because they had not signed DDAs at the required time. Two of these projects took engineering spend waivers on consecutive gates. This means they had not signed a DDA at the gate even after the one at which they were officially required to. I conduct an analysis only using this subsample of 12 projects. The results of this analysis are reported in Model 8. The subsample analysis is revelatory. Engineering spend waivers (in the form of unsigned DDAs) are found to be significant predictors of both absolute and percentage engineering spend overrun. They also explain a lot of variation in both absolute and percentage overrun (Adjusted $R^2 \sim 0.8$).

Results of Regression Analysis for Engineering Spend Overrun in \$m

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8 (subsample $n=12$)
Newness Low Dummy	-0.86	0.33	-0.86	0.53	-0.39	0.42	0.62	-0.28
Newness High Dummy	0.51	0.13	0.51	0.09	0.65	0.17	-0.15	-0.56
Complexity Low Dummy	0.97	1.03	0.97	0.76	1.86*	1.22	0.48	0.3
Complexity High Dummy	-0.24	1.12	-0.24	-1.05	-0.20	0.25	0.45	1.05
Ext. of dev. done by supplier Low Dummy		0.20						
Ext. of dev. done by supplier High Dummy		1.97						
Resources (FTEs)			0.00					
Project Manager 1 Dummy				-2.48				
Project Manager 2 Dummy				-2.90				
Project Manager 3 Dummy				0.06				
Combined Gates Dummy					-2.13*	-1.37		
Engineering Spend Waiver						0.96	1.44*	1.32***
Intercept	0.56	-0.72	0.57	1.56	1.51	0.45	-0.53	-0.24
Adjusted R^2	-0.187	-0.187	-0.318	-0.211	0.134	0.191	0.145	0.805

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

Table 13 - Results of Regression Analysis for Engineering Spend Overrun in \$m

Results of Regression Analysis for Engineering Spend Overrun as % of Projection

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8 (subsample n=12)
Newness Low Dummy	-0.35	0.02	0.29	0.32	0.23	0.05	0.03	-0.03
Newness High Dummy	-0.01	-0.13	-0.16	-0.32	-0.12	-0.28	-0.28	-0.34
Complexity Low Dummy	0.52	0.51*	0.39	0.38	0.47	0.09	0.09	0.27*
Complexity High Dummy	-0.01	0.32	1.18	0.94	1.00	-0.47	-0.57	0.08
Ext. of dev. done by supplier Low Dummy		0.34	0.71*	0.00	0.81*	0.92**	0.91***	
Ext. of dev. done by supplier High Dummy		0.69*	1.15**	0.74	1.01*	-0.59	-0.68	
Resources (FTEs)			-0.01	-0.01	-0.013	-0.001		
Project Manager 1 Dummy				-0.40				
Project Manager 2 Dummy				-0.59				
Project Manager 3 Dummy				-0.60				
Combined Gates Dummy					-0.21			
Engineering Spend Waiver						0.90**	0.93***	0.52***
Intercept	0.08	-0.36	-0.10	0.29	0.07	-0.13	-0.14	-0.26
Adjusted R ²	0.011	0.280	0.401	0.355	0.349	0.677	0.722	0.792

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

Table 14 - Results of Regression Analysis for Engineering Spend Overrun as % of Projection

Focusing within the subsample I looked for further qualitative verification of the trend. Tracking slips in engineering spend using information on planned engineering spend reported at each gate, I found that on projects that took engineering spend waivers, increases in engineering spend projections usually occurred after engineering spend waivers were taken. This temporal sequence lends credence to the idea that unsigned DDAs were leading to engineering spend overrun.

An alternative explanation is one of reverse causality. Perhaps it is projects that are having difficulty negotiating with suppliers (possibly because their engineering spend targets are too low) that have unsigned DDAs. Therefore it is not the unsigned DDAs that are leading to the overrun in development cost, but rather trouble negotiating with suppliers or unreasonable development cost targets that are leading to engineering spend. The temporal sequencing of effects would still be the same in this case. I am not able to conclusively eliminate this possibility, but I do find some reasons to question its validity. In the review meeting minutes, when waivers are listed, sometimes reasons are provided for taking the waivers. In the case of some unsigned DDAs leading to waivers, reasons are listed. The reasons presented for taking the waiver did not include payment negotiation with suppliers.

Once again, the availability of detailed qualitative information enabled me to dig in deeper to really understand the stories behind particular effects and to reframe the analysis appropriately. The results then point to clear relationships between process dimensions and outcomes.

4.7.7 Results - Performance Outcome – Quality - Service Cost Overrun

Let us now consider our measure of quality – service cost overrun. As mentioned earlier, only 12 projects in the sample had available reliability data. Therefore, for this analysis of service cost overrun, the n is 12. Table 15 shows results for service cost overrun reported in \$/machine/year and Table 16 shows results for service cost overrun reported as a percentage of projected service cost. Results from models 1, 2, 3 and 4 (Tables 15 and 16) show that project characteristics do not help at all in explaining service cost overrun. Model 5 adds gate combination. In both Tables 15 and 16 this has the same effects. First, the coefficient for combined gates is positive and highly significant. This means that combining gates is associated with increased service cost overruns. Second, the coefficient for the high newness variable becomes significant (with a negative coefficient). This indicates that high newness projects have lower service cost overruns as compared to medium newness projects. This is an interesting result, and seems counterintuitive; it bears further examination.

It is useful to consider how the measure of service cost overrun is defined. The company creates a projection of service cost per machine per year at PSR. Importantly, this projection is informed by testing data and *benchmarking against comparable company products already in the field*. Then service cost overrun is the difference between the actual cost of servicing the machine in the field and this projection. The coefficient from model 5 means that for high newness products, the cost of servicing in the field is less than the projection. If the projected service cost was set very conservatively for high newness products, then it is possible that it would actually end up costing less than projected to service the machines in the field. As the projections are based on similar products already released for which service cost data is available, and high newness products by definition do not have comparable products already released and so do not have data to make these projections, it is entirely reasonable to think that service cost projections for high newness might be set conservatively. I was not able to consult with company managers to verify if this was indeed the case, but I offer this as a possible explanation for the coefficient found in the model.

Results of Regression Analysis for Service Cost Overrun in \$ (per machine per year)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Newness Low Dummy	-41.9	-178.3	-28.8	-86.9	-122.6
Newness High Dummy	-142.0	-137.9	-139.1	-145.3	-168.9*
Complexity Low Dummy	53.6	39.1	65.5	77.1	-54.02
Complexity High Dummy	172.8	101.5	111.3	188.4	125.7
Ext. of dev. done by supplier Low Dummy		93.4			
Ext. of dev. done by supplier High Dummy		-117.8			
Resources (FTEs)			1.44		
Project Manager 1 Dummy				9.84	
Project Manager 2 Dummy				77.9	
Project Manager 3 Dummy				-12.2	
Combined Gates Dummy					201.7**
Testing (Prototypes and Software Builds)					
Intercept	2.97	127.0	-70.8	-7.98	-37.4
Adjusted R ²	0.076	0.065	-0.007	-0.516	0.601

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

Table 15 - Results of Regression Analysis for Service Cost Overrun in \$ (per machine per year)

Results of Regression Analysis for Service Cost Overrun as % of Projected Service Cost

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Newness Low Dummy	-0.13	-0.68	-0.11	-1.14	-0.54
Newness High Dummy	-0.64	-0.63	-0.64	-0.85	-0.78*
Complexity Low Dummy	0.21	0.18	0.24	0.51	-0.33
Complexity High Dummy	0.62	0.35	0.50	0.71	0.39
Ext. of dev. done by supplier Low Dummy		0.21			
Ext. of dev. done by supplier High Dummy		-0.51			
Resources (FTEs)			0.003		
Project Manager 1 Dummy				0.49	
Project Manager 2 Dummy				1.29	
Project Manager 3 Dummy				0.44	
Combined Gates Dummy					1.02**
Testing (Prototypes and Software Builds)					
Intercept	-0.01	0.51	-0.16	-0.10	-0.21
Adjusted R ²	-0.098	-0.236	-0.267	-0.344	0.566

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

Table 16 - Results of Regression Analysis for Service Cost Overrun as % of Projected Service Cost

The coefficient for gate combination also warrants further examination. What is the mechanism through which combining gates is associated with increased service cost overruns? To examine this in some more detail, I study what combining gates means in terms of other activities executed during development. I find that combining gates means doing less tests. Projects that combine gates, do significantly less tests (both hardware and software) than projects that do not combine gates. This seems reasonable, but it could simply be that complexity or newness are driving both gate combination and reduced testing. To parse out what is

driving the reduced testing, I run some regressions using Total Tests as the dependent variable. The results of these regressions are reported in Table 17.

Results of Regression Analysis for Total Tests		
Variable	Model 1	Model 2
Newness Low Dummy	-0.57	
Newness High Dummy	-0.33	
Complexity Low Dummy	0.44	
Complexity High Dummy	-0.48	
Combined Gates Dummy	-3.86***	-3.66***
Intercept	9.07***	8.75***
Adjusted R ²	0.533	0.641

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

Table 17 - Results of Regression Analysis for Total Tests

Model 1 shows that it is gate combination that drives reduced testing. Newness and complexity do not show any significant effect. Model 2 shows the relationship of Total Tests with combined gates, without including newness and complexity in the model. The results indicate that combined gates explain the variation in number of Total Tests. The Adjusted R² goes up from Model 1 to Model 2, which means that newness and complexity carry no explanatory value. The coefficient means that on average, projects that combine gates do 3.66 less tests than projects that do not combine gates. We use this number in future calculations because it is conservative (including newness and complexity in the model raises it to 3.86) and because newness and complexity carry no explanatory value, so including them in the model to estimate the coefficients is not necessary. Thus we see that combining gates means reduced testing.

Let us now examine the consequences of reduced testing. It is reasonable to expect that reduced testing might be responsible for increased service cost overrun. However, we know that reduced testing and combining gates are highly correlated. Is it possible to parse out whether reduced testing is responsible for increased service costs, or if some other aspect of combining gates is responsible? To check this, we perform more regressions with service cost overrun as the dependent variable. These are reported in Tables 18 and 19. I report the results as Model 6, 7, 8 and 9 to show that these are a continuation of the analysis process reflected in Tables 15 and 16.

Results of Regression Analysis for Service Cost Overrun in \$ (per machine per year)

Variable	Model 6	Model 7	Model 8	Model 9
Newness Low Dummy	-119.4	-75.8		
Newness High Dummy	-168.2*	-157.1*		
Complexity Low Dummy	-50.1	4.59		
Complexity High Dummy	127.5	152.1*		
Combined Gates Dummy	186.5		75.3	
Testing (Prototypes and Software Builds)	-2.9	-33.9**		-24
Intercept	-13.1	251.6*	-16.75	179.3*
Adjusted R ²	0.522	0.527	0.008	0.118

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

Table 18 - Results of Regression Analysis for Service Cost Overrun in \$ (per machine per year)**Results of Regression Analysis for Service Cost Overrun as % of Projected Service Cost**

Variable	Model 6	Model 7	Model 8	Model 9
Newness Low Dummy	-0.32	-0.33		
Newness High Dummy	-0.72**	-0.73**		
Complexity Low Dummy	-0.5	-0.07		
Complexity High Dummy	0.51	0.51*		
Combined Gates Dummy	-0.04		-0.44	
Testing (Prototypes and Software Builds)	-0.20	-0.20***		-0.15**
Intercept	1.49	1.42***	-0.21	0.99**
Adjusted R ²	0.643	0.702	0.085	0.315

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

Table 19 - Results of Regression Analysis for Service Cost Overrun as % of Projected Service Cost

In model 6, I include all variables from model 5 and simply add total tests. We see that Adjusted R² does not change very much and that combined gates and testing do not show significant coefficients (high newness retains its significant coefficient). We know that combined gates and total tests are highly correlated, therefore it is not unexpected that when they are both included in the model for a small sample of projects (n= 12) they become insignificant. I conduct more tests to parse out the effects. Model 7 drops combined gates and includes newness, complexity and testing. Here the coefficient for testing shows the expected negative sign (more testing means less service cost overrun) and is highly significant. The Adjusted R² also goes up in Table 19 indicating that including testing alone is a better model than including gate combination and testing or gate combination alone. Model 8 shows a test of service cost overrun only against combined gates, without even including newness and complexity. Results show that there is no relationship that can be discerned when only gate combination is used as a predictor. Model 9 shows the results for only Testing. In Table 19, testing still shows a significant negative relationship with service cost overrun and by itself helps explain a reasonable amount of variation. Taking the results of models 6-9 together, I conclude that reduced testing is the mechanism through which combined gates lead to service cost overrun.

4.7.8 Results – Summary across performance outcomes

Moving through individual performance outcomes one by one, we have seen how they are affected by a number of variables included in the study. The relationships between performance outcomes as dependent variables and process dimensions and project characteristics as predictors were discovered using a combination of quantitative and qualitative analysis. The overall case for the nature and significance of an effect was built in a multi-step process that asked the following questions:

- do the regressions show significant coefficients?
- does significance hold across model specifications?
- does variable explain a lot of variation in the performance outcome (adjusted R²)
- is the relationship consistent across outcomes represented in both absolute and percentage terms?
- is the available qualitative data consistent with the relationship?
- is it possible to discover mechanisms or to understand the story behind a relationship using available qualitative data?
- is the relationship consistent with existing established theory?

Using the above questions as guidelines, I uncovered relationships between the variables. A summary of these relationships is provided in Table 20.

	<i>Control Variables</i>					<i>Independent Variables of interest</i>				
	Newness	Complexity	Ext. of Supplier Dev.	Resources	Project Manager	Combined Gates	Rel. and Perf. Waiver	Engg. Spend Waiver	Testing	Proportion of Time in Phases
Development Time (weeks)	+	+				-				
Development Cost (\$m)		+	U			-				
Schedule Overrun (%)							+			
Schedule Overrun (weeks)							+			
Engineering Spend Overrun (%)								+		
Engineering Spend Overrun (\$m)								+		
Service Cost Overrun (\$/machine-year)	-					+			-	
Service Cost Overrun (%)	-					+			-	
Unit Manufacturing Cost (\$ and %)										

Table 20 - Summary of Results across Performance Outcomes

We see that newness and complexity drive development time and that complexity drives development cost. This indicates that the company's use of newness and complexity in its internal decision making and for project planning is well founded. The U-shaped relationship between development cost and extent of supplier development was examined in detail earlier and was found to be driven by the company's sourcing strategy.

No significant predictor was found for Unit Manufacturing Cost Overrun.⁸ The organizational project characteristics Resources and Project Manager were not found to be significant predictors of any of the outcomes. The process characteristic Proportion of Time in Phases was not found to be a significant predictor for any of the outcomes.⁹

Looking across performance outcomes, the importance of disaggregating into individual process dimensions is emphasized. Variations in the development process in the number of reviews (combined gates) were found to affect development time, development cost, and reliability (service cost overrun). Variations in other dimensions (deliverable waivers) were found to be associated with schedule overrun and engineering spend overrun. In fact, even within deliverable waivers, not all waivers were equal. Waivers associated with technical performance (Reliability and Performance Waivers) were found to be associated with schedule overrun, and waivers on supplier design and development agreements, were found to be associated with engineering spend overrun. Waivers on deliverables in other categories (Production – UMC waivers, Schedule) were found to have no effect on any of the performance outcomes considered. Also, the total number of waivers on a project, which is a measure the total extent of deviation on deliverables, was not found to be associated with any of the performance outcomes considered. All these results point to the importance of addressing individual process dimensions (and individual performance outcomes) when determining how standardization influences performance.

Looking down the column of ‘Combined Gates’ we see that combining gates is associated with reduced development time and development cost, but also with increased service cost overrun (through the mechanism of reduced testing). This points to a classic tradeoff – weighing the benefits of reductions in development time and cost against the costs of servicing products after release. To determine if variation from the standard process on the dimension ‘number of reviews’ was beneficial or not, how the benefits stacked up against the costs must be calculated. These calculations are presented in the next section. I also examine the financial consequences of ‘Reliability and Performance Waivers’ and ‘Engineering Spend Waivers’. Together, these will show if variations from the standard process (customization and deviation) resulted in net performance costs or benefits.

⁸ Because no significant relationship was found, UMC overrun was not discussed in a separate section.

⁹ Because Proportion of Time in Phases was not found to be a significant predictor for any outcome, it was not reported in the regression output tables. It was used in the analysis and tested against all outcomes, but no relationships were uncovered.

4.8 Examining the Consequences of Process Variations

4.8.1 Customization - Combining Gates

Is combining gates a good decision? Do the benefits outweigh the costs? We have seen that combining gates is associated with a 10.5 week reduction in development time (Table 9) and a \$2.6m reduction in development cost (Table 10). We have also seen that gate combination is associated with reduced testing. Projects that combine gates do 3.66 less tests than projects that execute all gates. (Table 17). Testing is strongly negatively related to service cost overrun. Each unit of testing is associated with a \$33.9 reduction in service cost overrun per machine per year (Table 18). Using these numbers, we can calculate the financial impact of increased service costs on a typical product and compare it to the reductions in development cost and time.

As the service cost numbers are reported on a per machine per year basis, we must perform some computations to calculate the total impact over all products in the field over their lifetime. For this, we need to know how many machines are introduced to the field. Thus we need sales numbers. At this company, the financial case for each product included information on total planned sales volumes. The planned sales for products ranged from about 20,000 units to about 100,000 units. For 10 products in the sample, there was also data on actual sales realized in the first year. Using the data for these 10 products, I determined that on average actual sales are about 80% of planned sales. For each product in the sample, I created a total sales number as 80% of planned sales from the financial cases. These total sales numbers reflect all planned sales for the product, which may be realized over the course of two or three years. However, each machine, no matter when it is sold, is still serviced for a planned period after sale. I then calculated the total service cost overrun/yr for each product by multiplying its service cost overrun/machine/year with its total sales.

Regressing total service cost overrun/yr on total tests (controlling for newness and complexity), I find that across products in the sample, each unit of testing reduces service cost overrun/yr by \$0.77m. Since combining gates means doing 3.66 less tests (Table 19), we can calculate that combining gates would lead to an increase in service cost overrun of \$2.81m /year ($0.77\text{m} \times 3.66$). This is a conservative method to estimate the financial impact of combining gates in terms of service cost. A direct regression of total service cost overrun on gate combination, gives a figure of \$4.34m /year. I use the more conservative estimate and say that combining gates (acting through reduced testing) is associated with an increase of \$2.81m / year in service cost overrun. Drawing information from the financial cases in product reviews, I see that at this company, products are serviced in the field for at least two, often three, years.

If we balance the reduction in development cost (\$2.6m) against the increase in service cost (\$2.8m/year), we see that the benefits obtained by reductions in development cost are compensated for in less than one year of

servicing the product in the field. As products are services for at least two, and often three years, it is evident that the negative effects of gate combination in terms of increased service cost easily outweigh the benefits. These results are consistent with the results from work done by Akamphon (2008). His work creates detailed models of the product launch process and shows that there is a tradeoff between development speed and warranty costs (equivalent to service costs in Company E). In many cases, the benefits of increased development speed are outweighed by increases in warranty cost. His work also considers reputation, which has a much larger negative effect (in terms of lost future sales).

My work does not include any reputation effects. My analysis also does not include consideration of the benefits of faster development other than development cost. It is possible that increased development speed to could lead to higher sales (although higher sales would mean more products in the field to service, and thus even more service costs, slightly ameliorating the potential benefit).

On net, we find that at this firm, customizing the standard process by combining gates, leads to net negative performance effects. Increased service costs outweigh the reduced development costs by more than a factor of two.

4.8.2 Deviation - Deliverable Waivers

Let us now examine the financial consequences of deviations in the form of deliverable waivers.

Reliability and Performance Waiver

Results from Table 11 show that a 'reliability and performance waiver' is associated with schedule overrun of 6.5 weeks. If we calculated the increase in engineering spend that this translates to, using the average project expenditure rate per week (average FTE x 'Person Cost'), a schedule overrun of 6.5 weeks would represent an increased engineering spend of \$0.96m. However, reliability and performance waivers show no direct relationship with engineering spend overrun or engineering spend, so this number of an increased spend is very suspect. However, a delay of 6.5 weeks counts as a significant cost in itself, even if it is not felt in terms of increased engineering spend.

A reasonable story to explain the effects seen in Table 11 is, if a project is having technical performance problems, maybe this just inevitably means that the project is going to be delayed. Taking a waiver has no real effect, it is simply a marker of the fact that the project ran into problems. If this is the case, it is underlying technical problems that cause the delay and not a deviation from the standard process.

To test this alternative explanation, we need counter cases. We need situations where a project ran into technical problems, but instead of taking a deliverable waiver, pushed the review date. This would be a strategy of acknowledge and fix your problems when the problem is identified. Do not pass to the next phase until the problem is solved. This would also represent following the standard process, because all deliverables would be submitted at gates as intended.

From meeting minutes and from the content of review presentation, we can identify three projects that did in fact follow this strategy. These represent the best available counter cases. The data available for these three projects indicates that they do not overrun service cost (which would be the case if they didn't fix the problem and just released the product) and they do better in terms of schedule overrun than the average project, and certainly better than projects that took waivers. Here is the data for three projects that elected to push gates because of reliability or technical performance problems.

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Project A – On time; 29.33% under Service Cost (\$30)

Project B – 9.79% over time (5.5 weeks); 20% under Service Cost (\$8)

Project C – 2.72% over time (1.7 weeks); 7.14% over Service Cost (\$13)

The average schedule overrun for these three projects is 2.4 weeks, and on average they come under their service cost projections by 14%. Because of the limited number of cases, the evidence is not very strong, but using the best available information, I conclude that not taking a deliverable waiver and instead pushing back reviews is a better strategy than taking a waiver. This indicates that deviating from the standard process by taking waivers leads to negative performance consequences.

Engineering Spend Waiver

Let us consider the financial consequences of engineering spend waivers (or unsigned DDAs). The results from Model 8 in Table 13 show that an unsigned DDA is associated with \$1.32m increase in engineering spend overrun. There are no clear counter cases, because we do not know what underlying problems lead to unsigned DDAs. However, available evidence indicates that for DDAs too, a deviation from the standard process by taking a deliverable waiver is associated with negative performance outcomes (increased engineering spend overrun).

4.9 Discussion of Phase III Results and Implications

We have seen that *customizations* of the standard process (gate combination), lead to net negative performance effects. Increased service costs outweigh the reduced development costs by more than a factor of two.

Deviations from the standard process (in the form of particular deliverable waivers) are also associated with

negative performance effects and analysis with available counter cases indicates that following the standard process would lead to better performance. Taken together, these results indicate that variations from the process standard (specific variations, not all) are associated with net negative project performance outcomes. On the whole, I find support for the argument that process standardization can be beneficial for project performance even across varied projects.

These results are consistent with the results from Tatikonda and Rosenthal (2000) and also Szulanski & Jensen (2006). This research has supported these results by conducting a study at a much greater level of detail, with a better understanding of the mechanisms through which process standardization can improve performance across varied projects.

The results from Company E also support insights developed in Phase I of the research. Variation on different process dimensions is associated with different performance effects. Combining different forms of variation together, results in conflation of performance effects and many insights are lost. The results support the importance of disaggregating to the level of individual process dimension to understand the effect of process standardization on performance.

4.9.1 Generalizability

This study was conducted in one company. How well do these findings apply to other organizations and settings? The results from this study indicate that variations from the process standard led to negative performance. Does this mean that variation from any standard process lead to negative performance?

First, I highlight the fact that this company was quite representative of the group of companies we studied. It had a reasonably well established process standard, it had some variation in its portfolio and it allowed process customization on a few dimensions. On no aspect was this company an extreme representative.

In thinking about generalizability, and important question to ask is – how good was this organization's standard process compared to standards used by other organizations? The standard process at this organization had been in place for some time and there was a reasonable amount of effort to maintain and update it. This implies that a fair amount of organizational learning and wisdom had accumulated in the process. If we want to understand how well findings at this organization generalize to others, we have to find a way to compare the 'goodness' of their process standards to the one in place at this company. Some questions that may provide clues as to the 'goodness' of an organization's standard process are:

How long has the process standard been in place? How often is it updated? How is it updated? What do the people in different roles in the organization think of the standard process? How is it regarded within the

organization? These are just some thoughts to keep in mind when thinking about the generalizability of these findings. I present some suggestions for future work to address this question in the next chapter.

5. Conclusions

5.1 Lessons Learned across all Phases

Provided here is a consolidated list of insights and lessons from all phases of this research.

Case Studies:

- To appropriately consider the impact of process standardization on performance it is essential to disaggregate the process into its *individual 'dimensions'*. This is important because standardization on different dimensions of the process impacts disparate performance outcomes quite differently.
- Process variation happens at different levels and at different times. *Customization* is centrally directed and planned and occurs at the start of a development effort. It is the embodiment of the organization's approach to managing the standardization-diversity tradeoff. *Deviation* is a result of local adaption and decisions by agents and occurs as projects unfold.
- Process variation is driven by variation in a wide range of project characteristics. Factors other than project characteristics can also be important drivers of variation - stakeholder interpretation, objectives, and cognition; history; organizational culture; and existing organizational technology and infrastructure can play a role.
- The *costs and benefits of standardization* on different process dimensions are felt differently by *different stakeholders*. Considering the distribution of costs and benefits across different stakeholders can be particularly useful when considering how to implement standardization. It can provide an indication as to where resistance to a standardization effort may emerge from and therefore what parties might need to be assuaged.
- The standard process does not stay stagnant over time. There is variation in its enactment each time it is executed. Lessons could be learned or improvements can emerge from each execution of the process, whether this knowledge is incorporated into the process can depend on the metaroutines used to update the process, power of stakeholders in the system, and existing organizational context

and technology. The *dynamics of knowledge embedded in standard processes* over time may display interesting behavior such as cycling.

- Companies differ in their process standardization approach because they differ in: the project characteristics across which there is variation in their portfolios; and their strategic priorities across performance outcomes. To determine the process standardization approach for a company, one should first consider these two factors.

Literature Study:

- To characterize the problem space of process standardization and its influence on performance it is useful to consider Project Characteristics, Process Design and Project Performance at the individual project level and also Portfolio Characteristics, Process Standardization, and Organizational Performance at the level of the portfolio or organization. Lists of elements in each of these categories were identified.
- Most links between standardization at level of individual process dimensions and performance outcomes are *unexplored*. In terms of the effects of process standardization broadly construed, it is reasonably well *established* that standardization of processes supports efficiency, knowledge transfer, and decision making and resource allocation. The effects of process standardization on project performance for varied projects, learning over time, adaptation to changing environments, innovation, creativity, and employee satisfaction are *contested*.

Detailed Empirical Study:

- At firm under study, Newness and Complexity drive development time and Complexity drives development cost. This indicates that the company's use of newness and complexity in its internal decision making for project planning is well founded.
- At firm under study, *Customization* of the standard process by combining gates, leads to net negative performance effects. Increased service costs outweigh the reduced development costs by more than a factor of two. *Deviations* from the standard process (in the form of particular deliverable waivers) are also associated with negative performance effects and analysis with available counter cases indicates that following the standard process would lead to better performance.

- Taken together, results indicate that variations from the process standard (specific variations, not all) are associated with net negative project performance outcomes. On the whole, results support that process standardization can be beneficial for project performance even across varied projects.
- Results also support insights developed in Phase I of the research. Variation on different process dimensions is associated with different performance effects. Combining different forms of variation together, results in conflation of performance effects and lost insights. Results support the importance of disaggregating to the level of individual process dimension to understand the effect of process standardization on performance.

5.2 Contributions

The academic and practice-oriented contributions of this research project are presented below.

5.2.1 Academic

- Improvement to construct of process standardization through disaggregation into individual process dimensions
- Integration and summary of the current state of knowledge about process standardization in existing literature. Creation of lists of elements, and description of the established links, contested links, unexplored links between them.
- Detailed empirical evidence for one set of contested links – the influence of process standardization on project performance across a set of varied projects.

5.2.2 Practice

- Creation of a decision framework and laying of groundwork for creation of a tool to support organizational decision-making about process standardization approach
- Evidence from one company to support conclusion that process standardization can be beneficial for project performance even across varied projects.

5.3 Suggestions for Future Work

5.3.1 Links between Portfolio Characteristics and Process Standardization Approach

An insight from the case studies was that the process standardization approach adopted by a company depends on its portfolio characteristics. A more rigorous empirical examination of this link would be a fruitful avenue for future work. Benner and Veloso (2008) are among the first to acknowledge that the influence of process standardization on performance is contingent on portfolio characteristics. Extensions to their work

that characterize variation in portfolios on several project characteristics (perhaps using data from company reports or analyst reports, or perhaps data obtained directly from managers in the company) and link that variation to process standardization approach (using individual process dimensions and project characteristics) would provide much greater insight to the relationship between portfolio characteristics and process standardization. The empirical relationships could then be compared to existing guidance in the literature at the individual project level on how process design should be contingent on project characteristics to see if the approaches used by the companies are aligned with the recommended profiles from literature.

5.3.2 Different levels of Standard Process ‘Goodness’

An important aspect to keep in mind when extending the work to other companies and thinking about generalization is the ‘goodness’ of a company’s standard process. This is described in Section 4.9.1. Benner and Veloso (2008) and Benner and Tushman (2002) use information on the number of ISO9000 certifications and the amount of time that a company has been ISO9000 certified to measure the extent of process management within a company. This is an approach that utilizes publicly available data. However, as described in section 4.9.1 this only addresses one of the many questions that need to be answered to establish the goodness of a standard process. Methods that seek to measure goodness of standard process should consider all questions outlined in section 4.9.1.

5.3.3 Creation of a Decision Framework and Tool

The literature study reveals many contested links and also many unexplored links, especially at the level of individual elements. Taking this knowledge and converting it into a useable tool to support organizational decision making about process standardization could be a practically valuable focus for future work.

5.3.4 Applying Methods and Models from Product Commonality Literature

As explained in section 2.10.1, decisions about process standardization have a useful analog in decisions about product commonality. This is a useful connection because tools for decision making about product commonality are well developed. If these tools can be adapted to address the question of process commonality, faster progress in understanding and improved decisions may be possible. Surveys of literature

on product commonality including good overviews of the problems considered and state of knowledge are provided by Ramdas (2003) and Simpson (2004).¹⁰

5.3.5 Evolution and Dynamics of Standard Process

As described in section 2.10.6 the standard processes in an organization can exhibit very interesting dynamics and evolution. The extent of knowledge embedded in standard process, how knowledge gained on projects is passed on to other projects over time (Marsh and Stock, 2003), how standard processes are updated (Salvato 2009, Howard-Grenville 2005) and how improvisations become part of organizational memory (Miner et al. 2001) are all very interesting aspects of study. One could adopt the approach that March et al. (2000) use to study the dynamics of rules to study the dynamics of standard processes. Some organizations have archives that store historical versions of their standard process, these could prove to be a valuable data source to study these dynamics.

5.3.6 Increasing Breadth and Depth of Study

Another useful direction of extension is to simply expand the study by increasing depth or rigor of analysis or breadth in terms of number of elements considered.

More reasons and more variations

Collecting large-n data on process variations, reasons for process variations, and project performance would allow the movement of this research from the intermediate stage to the mature stage. Some large companies do have data on many process variations. In the course of my research, I found that defense contractors generally had good archives of process data.

More sophisticated measures of process variation

This research measures process variation using very simple measures (a binary measure for gate combination, and a count measure for deliverables waived). Future work could adopt more sophisticated quantitative measures for process variation. Some of these measures are described in Pentland (2003) and Poole et al. (2000).

More performance measures

Another useful direction would be to extend the research to more performance outcomes for which the influence of process standardization is contested. These performance outcomes are often at the organizational level – learning over time, adaptation to changing environments, innovation, creativity, and

¹⁰ In fact, the analogy with product commonality holds even beyond the scope of planned variation. Boas (2008) studies divergence in product commonality over time, which is comparable to what is described as *deviation* in this document.

employee satisfaction. Using individual process dimensions as the level of analysis might help to shed light on these links in much the same manner as this project has done for project performance.

5.3.7 Simulation Model

The large number of elements in the system under study and the complicated relationships between them make an algebraic approach impractical to create a model of the system. Additionally, the long term performance and the dynamics of the system are of great interest. Characterizing dynamics is straightforward with simulations and extremely difficult with analytical models, which tend to focus on equilibrium outcomes. Therefore, to create a model of the system, a simulation approach might be a useful step forward.

A possibility for a simulation is to build on work by Gavetti (2005) and Rivkin and Siggelkow (2003). These two papers in turn build on a long stream of papers using the NK framework to model problems of search and decision making in organizations (Kauffman 1995, Levinthal 1997, Levinthal and Warglien 1999, McKelvey 1999, Gavetti and Levinthal 2000, Ghemawat and Levinthal 2000, Rivkin 2000, 2001, Kauffman et al. 2000, Fleming and Sorenson 2001). A number of elements of the models in these papers address the numerous modeling requirements to appropriately represent the phenomenon of process standardization. Certainly, extensions and modifications will be necessary to make these models applicable to this setting and question, but they provide a useful starting point. These models are useful because the NK framework is well suited to representing the dimensions of the product development process distinctly, yet acknowledging the interdependencies between them. In fact, by considering a string of N bits as a project-process combination, one can even get to the issue of ‘fit’ between a project’s characteristics and a process design. The issue of multiple projects can also be addressed by adapting work on multiple divisions (Gavetti 2005). One of the big lines of research that has been extended by these papers is the explicit inclusion of cognition in the search behavior of firms, so the inclusion of cognition of stakeholders executing the process might also be possible. The area that will possibly require the biggest extension from the NK-models papers is the issue of multiple performance outcomes. With adaptation and extension, these models could be well suited to tackling the problem. Other possible models from which to seek inspiration include the model presented in Davis et al. (2009) and also system dynamics models as presented in Repenning and Sterman (2002) and Repenning (2001).

5.3.8 Tradeoffs in Performance Outcomes

This suggestion for future work is not directly related to the issue of process standardization; it is a little broader and addresses the management of product development generally. The manner in which companies manage the product development operations – what performance outcomes they hold fixed and what they

outcomes they are willing to trade against each other – is an interesting aspect of product development project management. It is possible that companies have unique ‘fingerprints’ in terms of how they manage against performance outcomes. This is an interesting avenue for further exploration. In the survey upon which results reported in Gordon et al. (2009) are based, data were collected on what outcomes companies are willing to trade off. In the survey, these data were collected under the heading ‘Align on Strategic Priorities’. How companies differ in their willingness to make tradeoffs, and the degree of agreement within a company (across different stakeholders) on the nature of tradeoffs they would make in a product development effort could be interesting features with which to gain insight into management of product development.

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