A CONTINGENCY THEORY APPROACH TO THE DEPLOYMENT OF LEAN PRINCIPLES: THE CASE OF ADVANCED RESEARCH AND COMPLEX PRODUCT DEVELOPMENT ENVIRONMENTS

by

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DEDICATION

To my family, without whose support this would not have been possible.

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ABSTRACT

The introduction of lean principles is a common approach for organizations seeking to improve quality, lower cost, and shorten time to market. Many companies have applied lean to manufacturing, but a smaller number have brought it upstream to product development. This research focuses on how organizations can begin the transformation to lean product development through three essays.

The first study is a comparative case analysis comparing approaches based on "rational planning" and "disciplined problem solving" to identify their relative advantages and disadvantages and organizational characteristics that enable successful deployment. The comparison shows that in the case of non-routine processes like product development the disciplined problem solving approach is more effective, while the rational planning approach can be effective for highly routine aspects of the job.

The second study is an in-depth case study of how value stream mapping and *obeya,* two common lean product development tools, if used properly, can help cross-functional development teams achieve coordination and integration as well as team member engagement. This facilitates the learning of lean as a socio-technical system with a culture of problem solving and people development through the effective development of a product.

The third study looks at how standardization can be used to establish an enabling bureaucracy with structures and standards effectively supporting people's work. A common misunderstanding is that standardization kills creativity. It can be used to create predictability while maintaining flexibility and enabling innovation. Coercive bureaucracies result when formalization is used to control employees or when there is a misalignment between task requirements and the standards and/or organizational design. Having the people doing the work develop, maintain, continuously improve, and adapt the standards is an effective way to create an enabling bureaucracy.

The insights from this study help to understand the challenges of lean deployment and characteristics that enable success in lean transformations. This can serve as an example to aid in the transformation to lean systems in other complex environments.

Chapter 1

A Contingency Theory Approach to the Deployment of Lean Principles: The Case of Advanced Research and Complex Product Development Environments

Introduction

The development of new products is critical to the success of many companies. Increases in global competition, demanding customers seeking niche products, and rapid technology developments has changed the competitive landscape in several industries (Wheelwright and Clark 1992). In some industries, improving quality, lowering cost, and shortening lead time from concept to market while developing innovative products to meet customer needs is necessary to remain competitive; in other industries these qualities can provide the company a competitive advantage. One approach to achieving these goals is through the introduction of lean principles in product development (Wheelwright and Clark 1992; Morgan and Liker 2006; Barrett, Musso et al. 2009; Morgan and Liker 2011).

Introducing lean principles into product development is a common approach for companies that have had success with lean manufacturing. This is a logical step as the magnitude of the costs and cycle time of development projects provides a rich target for improvement opportunities. Additionally, it can enable a higher level of performance in manufacturing by ensuring that products are designed for optimal manufacturing. And lastly, it is a step towards achieving a holistic lean enterprise. Expanding lean thinking to product development is recommended in *The Machine that Changed the World,* the original work which coined the term "lean." This work emphasized the need to take a holistic view and focus on the lean enterprise. *The Machine that Changed the World* describes a system utilizing half the human effort in the factory, half the manufacturing space, half the tooling investment, and half the engineering hours to develop products in half the time of mass production. However, little attention has been given to the chapter on product development (Womack, Jones et al. 1990).

Prior to deploying lean product development, organizations should first define what lean product development is and ensure that the perceived benefits match the objectives of the effort. How the organization defines and understands lean product development will impact the approach taken towards deployment. There are many existing interpretations of lean product development, which can generally be categorized into two philosophies:

1. Lean product development is a development system where lean manufacturing tools are adapted to the product development environment. (Reinertsen 1997; Smith and Reinertsen 1998; Reinertsen 1999; Reinertsen 2005; Smith 2007; Reinertsen 2009)
2. Lean product development is a development system modeled after principles of Toyota's product development system. (Ward, Liker et al. 1995; Sobek 1997; Sobek, Liker et al. 1998; Sobek, Ward et al. 1999; Morgan 2002; Morgan and Liker 2006; Ward 2007)

Additionally, based on the viewpoint that lean is a socio-technical system that enables people to solve problems and continuously improve (Liker 2004; Rother 2010; Liker and Rother 2011; Liker and Franz 2011), a third philosophy is presented:

3. Lean product development is a development system designed to enable people development, problem solving, and organizational learning.

These categorizations of lean product development are not mutually exclusive and rather reflect different understandings of lean and the resulting applications within product development. A development system that enables people development, problem solving, and organizational learning is very likely to include characteristics similar to those seen at Toyota and/or lean manufacturing tools adapted to the product development environment. Similarly, lean manufacturing tools adapted to product development environments may enable people development, problem solving, and organizational learning. These three philosophies are unique perceptions of the nature of lean product development and the perception will impact the approach taken towards deployment and the results achieved. Furthermore, the goal of product development is to create usable knowledge for the creation of profitable value streams (Ward 2007), which can be achieved through the development of products that customers value and are willing to pay for.

As practitioners have seen improvements through the use of the technical lean manufacturing tools derived from the Toyota Production System, it is natural to postulate that the use of the same tools could lead to improvements in product development. An example would be the use of value stream mapping to define the value added activities and waste within the product development value stream. Standardization can then be used to improve the value added tasks while eliminating wasteful activities. Another example would be the use of visual management to highlight deviations from plans, which allows problems to be easily identified.

Given that Toyota invented TPS, the model for lean, and is exceptional in the auto industry at product development, another approach to defining lean product development is to study how Toyota approaches product development. With this approach, the Toyota Product Development System is to lean product development what the Toyota Production System is to lean manufacturing. Several academic studies have been conducted to define the Toyota Product Development System, resulting in a model of an integrated development system with key principles in process, people, and tools subsystems (Ward, Liker et al. 1995; Sobek 1997; Sobek, Liker et al. 1998; Sobek, Ward et al. 1999; Morgan 2002; Morgan and Liker 2006). The use of value stream mapping and standardization are both key principles within the process subsystem defined by Morgan. In relation to standardization he emphasized standardizing lower-level tasks to create higher-level system flexibility. Visual management is part of the tools subsystem and is used to achieve alignment throughout the organization (Morgan 2002).

The Toyota Production System and the Toyota Product Development System are organizational systems reflecting a deeper philosophy known as the Toyota Way. The Toyota Way is characterized by Liker (2004) as a set of 14 principles categorized into the 4P model of philosophy, process, people, and problem solving. The foundational “philosophy” focuses on long term thinking; “process” is the way the work gets done and ideally should be free of waste; “people” emphasizes that developing people and partners adds value to the organization; and “problem solving” focuses on a systematic method for continuous improvement. Most organizations’ understanding of lean is primarily at the process level focusing on the technical system (Liker 2004). This consists of the lean tools that are countermeasures developed by Toyota to solve their unique problems as they have made their lean journey (Spear and Bowen 1999; Liker 2004). Using the 4P model framework what you see in the Toyota Production System and Toyota Product Development System are the developed organizational structure and culture that enable people development and problem solving within the environmental contexts that Toyota operates. Under this view, tools are used to make problems visible, enable people to solve them, and capture what is learned throughout the organization. Value stream mapping and visual management are used to recognize problems, so that they can be solved. Standardization is used as the foundation of continuous improvement and to support organizational learning.

Complexity of the Product Development Environment

Prior to implementing lean, it is important for organizations to understand the environmental context in which they are operating. Contingency theory is based on the assumption that there is no one right way for an organization to be organized and that not every method of organizing will be equally effective (Galbraith 1973). For organizations to be most effective, they should be designed with social and technical subsystems fitting the needs of one another, the organization’s purpose, and the external environment (Pasmore, Francis et al. 1982). To achieve the goals of a lean organization to solve problems and develop people, the “right” tools and organizational design for enabling people development and problem solving that “fit” with the environment need to exist or be created.

Complex product development is described in comparison to manufacturing because manufacturing is the best known environmental context for lean deployment. Understanding the differences between these environments will help to understand what aspects of lean manufacturing may be applicable to lean product development and what aspects need to differ to ensure a fit with the environment. It should be noted that manufacturing and product development environments are not in reality two discrete entities but rather vary on a continuum from routine widget production to fundamental research. The two environments discussed here are discrete points used only for comparative purposes. Within industry, there are some manufacturing environments that have characteristics closer to what is depicted here as complex product development and some product development environments that would be more closely reflected by the manufacturing description.

Table 1.1: Comparison of Environments: Manufacturing and Complex Product Development

Manufacturing	Complex Product Development
Repetitive production.	Every project is unique.
Cycle time measured in seconds, minutes.	Cycle time measured in weeks, months, years.
Lower levels of differentiation with most workers from the same region and similar technical depth levels (within a plant).	High levels of differentiation leading to communication breakdowns across a diverse group with regional and technical depth differences.
Sequential interdependence within a function.	Reciprocal interdependence across functions.
Line workers usually working together on the same unit.	Technical specialists working semi-autonomously for a group goal.
Tasks and expected durations are clearly defined (cycle time 45 seconds).	High degree of ambiguity for the task at hand. What is / are the task(s) to be done?
Finite value added tasks. Focus on eliminating waste to increase the ratio of value added time / total time.	Objective is value creation. Focus on enabling value creation in addition to eliminating waste to increase the ratio of value added time / total time.
Knowledge created not usually incorporated into the work for that unit.	Knowledge generated might change the next step.
Opportunities are usually related to eliminating waste in processes (barriers to effective problem solving).	Opportunities are usually related to achieving integration / alignment (barriers to effective problem solving).

Research Objectives

As organizations seek to implement lean product development, the approach taken will vary since every organization is unique and will begin their lean journey at different points based on their history, culture, internal and external environments, perception of lean, and objective for the effort (Liker and Meier 2006; Liker and Franz 2011). This provides motivation for the following research objectives:

1. Better understand the opportunities, challenges, and methodologies by which lean principles and philosophies can be applied in complex product development environments.
2. Determine advantages and disadvantages of approaches to lean methodology deployments in complex product development environments.
3. Identify organizational characteristics that enable successful deployment of lean methodology in complex product development environments.

Chapter 2 addresses these objectives through a comparative case study of two organizations in the early stages of lean product development deployment. One organization began their deployment efforts by focusing on technical changes to the process that could be leveraged across the organization; whereas the other organization's initial efforts focused on supporting people to work effectively and to develop a lean culture within individual projects. The cases are compared across the identified characteristics for successful lean implementations of achieving stability, length of problem solving cycles, and achieving coordination and integration as well as breadth and depth of deployment.

In complex environments, such as product development, one of the biggest inhibitors to quick and effective problem solving is ineffective coordination and integration across functions. Using mechanisms that achieve effective coordination and integration while supporting people to solve problems can facilitate the transformation to a lean culture (Shook 2010). How complex organizations that develop complex products integrate across functions to efficiently and effectively complete product development programs using some of the most commonly used lean product development tools leads to the following research questions:

1. How can lean tools, specifically value stream mapping and *obeya,* act as enablers to transform R&D organizations so they can more efficiently and effectively introduce new products?
2. What are organizational characteristics that enable successful use of these tools to begin the process of a cultural transformation to a lean enterprise?

Chapter 3 addresses these research questions through an in depth case study of how one organization used value stream mapping and *obeya* to effectively achieve coordination and integration within one product development project while introducing lean principles. The use of lean tools in a manner that resulted in team member engagement while supporting the work effectively and efficiently enabled problem solving and started the process of embedding a lean culture.

Prior to using lean tools, the intent behind the tools should be understood and align with the purpose of the effort. The use of lean tools that don't fit with the environment or support the intended purpose can result in the creation of a coercive bureaucracy, which uses rules, procedures, and structures to control employees (Adler and Borys 1996). Whereas the use of tools in a manner that supports people to identify and solve problems can result in an enabling bureaucracy, which uses rules, procedures, and structures to support the work of employees (Adler and Borys 1996). One of the most commonly used lean tools is standardization, which has many purposes including enabling problem solving, establishing stability for a foundation for continuous improvement, and enabling integration. The approach towards standardization and the contextual fit to support the purpose of standardization can result in the establishment of coercive or enabling bureaucracies. The following research questions seek to address how standardization can be used to support lean principles in complex product development and advanced research environments:

1. How can standardization simultaneously be used to create predictability while enabling innovation?
2. How can standardization be used as a mechanism to achieve integration and coordination?
3. How can standardization support problem solving?
4. How can standardization enable organizational learning?

Chapter 4 addresses these research questions by analyzing how standardization was used within two organizations in the early stages of lean product development deployment. These examples of standardization are analyzed for effectiveness with regards to the purpose for which the standardization was used. Whether the standardization was used in coercive or enabling ways was also determined along with the resulting effectiveness. This leads to an understanding of ways in which standardization can be used to support lean principles through supporting problem solving and people development.

Taken together these papers provide deeper insight into how to deploy lean in complex research and development, as well as the role of lean methodologies in the transformation.

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Chapter 2

Lean Product Development: A Comparative Case Analysis of Rational Planning and Disciplined Problem Solving Approaches

Introduction

Companies frequently develop new products to create a competitive advantage. This has become more critical as global competition increases, demanding customers seek niche products, and technology developments occur rapidly (Wheelwright and Clark 1992). Lean principles can be introduced to shorten the lead time from concept to market while developing innovative products to meet customer needs with improved quality and lowered cost (Wheelwright and Clark 1992; Morgan and Liker 2006; Barrett, Musso et al. 2009; Morgan and Liker 2011). The approach taken towards introducing lean principles serves as a model for how product development and problem solving should be conducted within an organization.

Prior to attempting the transformation to lean product development, organizations should first have an understanding of what lean product development is to ensure that the benefits will align with their objective. Without committed leadership who understands what it is and believes it will deliver benefits, lean programs will likely fail (Liker and Franz 2011). Additionally, the approach to lean PD needs to be tailored as every organization is unique and will begin their lean journeys at different points based on their history, culture, and internal and external environments resulting in different approaches to deployment (Liker and Meier 2006; Liker and Franz 2011).

This study seeks to gain insight into advantages and disadvantages of different deployment approaches. This is examined through a comparative case study of two organizations beginning the process of lean transformation within product development (Eisenhardt 1989; Yin 2003). One organization began their deployment efforts by focusing on technical changes to the process that could be leveraged across the organization, whereas the other organization's initial efforts focused on supporting people to work effectively and develop a lean culture within individual "model" projects.

Research Objectives

Though there has been extensive research into understanding and defining lean product development systems (Ward, Liker et al. 1995; Sobek 1997; Sobek, Liker et al. 1998; Sobek, Ward et al. 1999; Morgan 2002; Morgan and Liker 2006; Ward 2007) there has been limited investigation into how organizations can transform to lean product development systems (Baker 2011; Morgan and Liker 2011). Experts in this field emphasize that lean is a way of thinking and a cultural transformation, not a toolkit (Womack and Jones 2003; Liker 2004; Morgan and Liker 2006; Ward 2007; Liker and Hoseus 2008; Liker and Franz 2011; Morgan and Liker 2011). This study analyzes two approaches to lean product development deployment comparing and contrasting the methods used (Eisenhardt 1989; Yin 2003). This research aims to:

1. Better understand the opportunities, challenges, and methodologies by which lean principles and philosophies can be applied in complex product development environments.
2. Determine advantages and disadvantages of approaches to lean methodology deployments in complex product development environments.
3. Identify organizational characteristics that enable successful deployment of lean methodology in complex product development environments.

Theoretical Discussion

Lean Product Development

Lean product development is a development system designed to enable people development, problem solving, and organizational learning enabling the organization to achieve its purpose. Lean systems seek to have problems identified as soon as possible (Liker 2004) and solved by the people closest to the problem since they have the most thorough understanding of the issues (Spear and Bowen 1999). This includes making everyone responsible and accountable for solving problems, while ensuring that they are given the resources and support needed to do their jobs successfully (Shook 2008; Shook 2010). The role of lean tools is to make problems visible, enable people to solve them, and capture what is learned throughout the organization (Liker 2004). Lean product development can be modeled as a socio-technical system, which recognizes the interdependencies and influences between the social and technical systems of the organization (Pasmore, Francis et al. 1982; Morgan 1997). For organizations to be most effective, they should be designed with social and technical subsystems fitting the needs of one another and the organization's purpose (Pasmore, Francis et al. 1982).

An example of an integrated socio-technical product development system that enables people development, problem solving, and organizational learning is Toyota's product development system. This is described by Morgan and Liker as thirteen principles within three integrated subsystems that are: process, people, and tools (Morgan and Liker 2006). Though Toyota's product development system has evolved since the development of this model the lean product development principles are broad enough to still be valid and to be applied in other development environments (Morgan and Liker 2011).

The process subsystem refers to all of the tasks needed to bring a product from concept to the start of production (Morgan and Liker 2006). Tasks can be categorized as value added or non-value added, from the customer perspective with non-value added tasks (waste) to be eliminated as much as possible (Womack and Jones 2003; Morgan and Liker 2006).

Value within product development is achieved through the creation of usable knowledge leading to profitable value streams (Ward 2007). Standardization of tasks is used to reduce variation resulting in predictable outcomes as well as the flexibility to be creative within clear boundaries (Sobek, Liker et al. 1998; Morgan and Liker 2006). The sequencing of tasks is also used to front-load the process for greater exploration of solutions in the design space (Ward, Liker et al. 1995; Sobek, Ward et al. 1999; Morgan and Liker 2006) and to level the flow of work within and across projects (Cusumano and Nobeoka 1998; Morgan and Liker 2006).

The people subsystem refers to the organizational culture including the organizational structure, leadership styles, learning patterns, and the development of employees (Morgan and Liker 2006). The organizational structure and culture should enable problem solving, people development and continuous improvement (Liker 2004; Liker and Hoseus 2008; Spear 2009; Rother 2010; Liker and Franz 2011). One organizational design that can encourage this is a matrix organization with strong functional specialists on one axis and a powerful and exceptional chief engineer to ensure that development is integrated across functions throughout the process (Sobek, Liker et al. 1998; Morgan and Liker 2006).

The tools subsystem consists of the tools and technologies used to support the development process (Morgan and Liker 2006). This includes the use of simple, visual communication to achieve alignment throughout the organization (Morgan and Liker 2006). An example of a tool to support the development process is *obeya* (literally “big room”), which was first used in the development of the Prius at Toyota (Itazaki 1999). It is a process of having a cross-functional team of experts coordinating development work in a room with relevant information posted on the walls. The *obeya* is effective at integrating product development while enabling fast and accurate decision making, improving communication, and maintaining alignment across functions. The *obeya* allows for quicker decision making and conflict resolution as all of the key people are gathered together and working from the same information to solve cross-functional issues (Liker 2004).

Lean Deployment

Lean is a highly integrated complex system that cannot be deployed all at once, with some pieces easier to implement than others. There are many existing strategies for where to begin deployment with advantages and disadvantages to different approaches (Liker and Meier 2006; Liker and Franz 2011). For successful deployment, it needs to be broken up into smaller steps to be practical, but with the beginning phases supporting the integrated system. Though some gains can be achieved through the use of isolated technical tools as solutions to particular issues, it will not lead to a transformation into a sustainable learning organization without integration with the whole system (Karlsson and Ahlstrom 1996).

Lean Deployment: Key Characteristics

A key lean tenet is that there is no one right way to do something and that the approach taken should be dependent on the particular context. Engaging in a continuous learning process is more important to lean deployment than implementing the right tool. Since every organization is different there can be no one universal road map for becoming lean (Liker and Meier 2006). Nonetheless there are key attributes that should be achieved and some logical sequencing of steps. In order to create a culture of continuous improvement basic process stability should first be achieved making achieving stability an important first step in lean deployment efforts. Focusing on stability ensures a consistent level of capability to produce consistent results to create a foundation for improvement (Liker and Meier 2006). Once foundational stability has been achieved efforts can focus on establishing a culture of problem solving and continuous improvement by providing people with the tools and resources needed to identify and solve problems. Defining appropriate behavior, providing training to support the behavior, and creating a support system to reinforce the behavior can be an effective method to change the culture of an organization (Shook 2010). Creating a system that highlights problems, makes solving problems without placing blame an essential part of the job, and creates a support structure that enables people to do their jobs successfully can facilitate the adoption of a lean system and culture (Shook 2010).

Deploying Lean in Product Development

Though there are few documented examples of successful transformations to lean product development those that do exist maintain the same focus on establishing stability and enabling problem solving and continuous improvement as seen in successful lean manufacturing transformations. For example Charles Baker of “North American Auto Supplier” (former Honda executive) views a lean transformation as a process of transforming people and developing a problem solving culture. This was achieved using the plan, do, check, adjust (PDCA) problem solving methodology, formalized through A3 reporting, to bring stability to the product development process and to enable other lean tools to be used at “North American Auto Supplier” (Baker 2011).

The *obeya* has been used effectively in successful lean product development deployments. It has been used to allow cross-functional teams to work together effectively in the same room with key data displayed visually on the walls and through weekly meetings creating a cadence to the product development process and enabling real time problem solving to occur (Baker 2011; Morgan and Liker 2011). The cross-functional development of schedules and plans through the *obeya* drives cross-functional teamwork, empowers teams, and enables the plan to be executed through PDCA loops. PDCA loops facilitate real time problem solving to address gaps between actual and target conditions. Participants in the *obeya* have instant visibility to details, commitments made, and task dependency as all key information is posted (Baker 2011). Additionally, putting the responsible party’s name next to completion dates drives accountability as it is evident if the work was not completed in the following meeting (Morgan and Liker 2011).

At Ford Motor Company the development of the global product development system (GPDS) was used to represent and communicate the desired lean processes and behavior.

The process began with a clear vision, followed by a conceptual design, and then detailed designs within work streams. Pilot programs were used to refine the approach and methods. This process was led through the use of an *obeya* with each work stream having a leader that owned a section of the wall to display their activities visually. Current state maps as well as future state maps, based on Mazda, were developed. Each work stream team also developed detailed development timelines and identified gaps in productivity, lead time, and quality along with detailed plans to identify enablers to close the gaps using A3 reporting. The visual nature of the *obeya* allowed people to walk the walls of the room and understand the status of the process. This aided in gathering support for the initiatives and the spreading of *obeya* since people saw value in its use (Morgan and Liker 2011).

Mechanistic versus Organic Strategies for Lean Deployment

There are several strategies that can be used to transform to lean and the appropriate strategy is highly dependent upon the environmental context and culture of the organization (Liker and Meier 2006; Liker and Franz 2011). Two commonly used and contrasting approaches to the beginning stages of deployment are mechanistic and organic (Kucner 2008; Liker and Franz 2011). Mechanistic deployments achieve a broad and shallow implementation utilizing an infrastructure to deploy across the organization. Organic deployments facilitate a narrow and deep level of understanding with the ability to learn and adapt in an uncertain environment (Kucner 2008). While these two approaches are starting points, successful transformations typically achieve a balance between mechanistic and organic approaches in later stages of deployment (Liker and Franz 2011).

Similarly, with the end goal of an integrated socio-technical system of process, people, and tools changes may begin in any of the subsystems, but for successful transformations changes will need to eventually occur in every subsystem. A common theme across lean deployments is starting with technical changes, primarily at the process level (Liker 2004). If the technical changes are designed with working level people and managers taking responsibility for the changes so they learn as the project is carried out it can lead to a lean transformation (Nadler and Tushman 1980; Morgan and Liker 2006; Shook 2010; Liker and Franz 2011).

Perspectives on Deployment Strategies

Organizational change can be viewed from a rational planning perspective or from a disciplined problem solving perspective. This parallels models for product development (Brown and Eisenhardt 1995). March and Simon note that organizations should use problem solving methodologies when introducing organizational changes (March and Simon 1958) and product development can be viewed as a problem solving process (Clark and Fujimoto 1991). The rational planning perspective of organizational change assumes that management and experts should develop a detailed plan, manage deployment, and reward compliance while punishing resistance. The disciplined problem solving perspective of organizational change assumes that a strong vision for the change, supported by management, with disciplined local leaders who take responsibility, and distribute problem solving will result in a fast and high quality organizational change. The process used for organizational change is often reflective of how the organization will operate and solve problems.

This study compares an enterprise-wide tool based approach and a model line value stream map based approach. These two approaches parallel commonly used methods for lean manufacturing deployment, with one approach focusing on breadth of deployment and the other on depth of deployment (Liker and Meier 2006; Liker and Franz 2011). The enterprise-wide tool based approach follows a rational planning model of organizational change with efforts focused on the breadth of deployment based on top-down control. The model line value stream map approach follows a disciplined problem solving approach to organizational change focusing on the depth of deployment with local ownership.

The cases are compared along the previously identified characteristics of successful lean deployments of achieving stability and supporting a lean culture. In terms of supporting a lean culture the cases will be compared on characteristics of problem solving and learning cycles and on how integration and coordination are achieved. Additionally, the cases will be compared in terms of how breadth and depth of deployment across the organization is achieved.

Research Setting & Methodology

The research purpose is to develop an empirically grounded, theoretical model for an approach to the introduction of lean product development principles based on literature and case studies (Eisenhardt 1989). This is an iterative process of theory development followed by field research, refinement of the theory and additional field research with multiple cycles (Eisenhardt 1989). A comparative case study of two deployments of lean product development is conducted.

Case Selection and Overview

The cases are selected based on their contrasting approaches to lean product development deployment, as well as on the accessibility of data (Eisenhardt 1989; Yin 2003). The cases compared in this study are two organizations that had success with lean in manufacturing and saw value in the use of lean principles within product development. One organization is a Fortune 500 company in the consumer goods industry, further referred to as Consumer Goods, with product development dispersed globally. The other organization is a wholly owned subsidiary of a Fortune 500 company that produces gas turbine generators, further referred to as Turbine Gen, with product development activities centralized in one location. Both organizations have historically been very successful, have had success with lean manufacturing, and viewed the deployment of lean methodology in product development as an opportunity to improve operational performance. Though each of these organizations operates in a unique environmental context it is hypothesized that the learning from the unique challenges and experiences each organization faced can lead to a general understanding of the advantages and disadvantages of different approaches to lean deployment along with the enablers for success. Both of the case study organizations used the Morgan & Liker model of lean product development (Morgan and Liker 2006) as their basis of understanding lean product development.

Both organizations had similar motivations for deploying lean product development. Consumer Goods was looking to overcome unpredictable financial results, products not aligning with market needs, and lengthy development cycles in product development. Turbine Gen was not meeting commitments for time to market, product cost, sales volume, quality, or budget. Though they had similar motivations the deployment approaches taken by the organizations differed. Consumer Goods benchmarked best in class companies including Toyota, Honda, and Motorola, and focused efforts on cadence planning, being accurate to market, and predictable to drive quality improvements, cost leadership, margin improvement and innovation. Turbine Gen focused on front-loading projects in the concept phase, managing the pipeline with an engineering resource capacity planning tool, and adopting lean principles in product development to enable people to work more effectively, which was expected to lead to quality improvements, cost reductions, and shortened lead time. Consumer Goods utilized internal resources for the planning and deployment of lean product development. Turbine Gen used an external lean consultant to mentor the deployment efforts.

Differences in the deployment approaches are reflective of the different perspectives of what lean product development is and the organization's culture and environment. This study focuses on the organizations' efforts that affect individual projects. Consumer Goods focused on achieving predictability across the enterprise through compliance with development processes, including the definition of new processes, having a detailed up-front understanding of requirements and targets, inventing on a separate track with narrow scope, and exploring multiple options. Turbine Gen initially focused on introducing lean principles within two pilot areas with the intent of lean spreading organically throughout the organization in later phases.

Data Collection

Data was collected through participant observation, direct observation, review of documentation and interviews (Yin 2003). The researcher was an employee of Consumer Goods involved with some of the efforts described in the case study. Observations within Consumer Goods were documented as field notes. Internal documentation related to the efforts was reviewed and unstructured interviews were conducted with participants throughout Consumer Goods. Direct observations documented in field notes and unstructured interviews were conducted at Turbine Gen over the course of a five day on-site visit. The researcher was also able to review the responses of an internal Turbine Gen questionnaire that 70 participants responded to.

Case Description

Case Study 1: Consumer Goods Deploys Lean Enterprise Wide

In 2006 Consumer Goods began the development of a global product quality management system. Efforts focused on identifying and documenting processes while identifying and eliminating or controlling all sources of variation. The importance of the integration of people and process for an integrated system was emphasized with the need for people to understand their role in the process and to have the capability to execute their role. The processes being standardized included support processes, e.g. failure mode and effect analysis, and core processes, e.g. developing and testing concepts to determine feasibility, necessary to develop a product. The vision of the effort was to be able to click through a navigation system for the development process with an understanding of all the tasks necessary to develop a product with variation removed or controlled and people knowing what they are accountable for.

Within the advanced research & development (R&D) function of the product development organization there was a subgroup of the global product quality management system working on processes for the advanced R&D organization, which was a separate group from the product development organization bringing specific designs to market. This subgroup formed, in 2006, after R&D resources, that were originally assigned to support the broader product development organization's quality management system, sought support to focus efforts on the unique environment within R&D. This group actively embraced lean concepts and began working on pilot efforts such as reducing waste and thus lead time in the testing area supporting the labs and had considerable success in the pilot. The researcher was a member of this group conducting research through participant observation. By 2007 this group was focused on standardizing common aspects across projects such as how knowledge is captured and the development and use of common project charters.

For the most part the product development organization, which was focused on detailed design and launch of new products, took a rational planning approach. In 2007 Consumer Goods launched a strategy to be accurate to market, develop a launch cadence, and to be predictable upon delivery. The previous efforts towards developing a global product quality management system were incorporated into this effort. This effort also included multi-year product planning with common platforms, up-front understanding of consumer needs, and exploring multiple options early in the design phase.

In 2008 Consumer Goods reorganized integrating the advanced R&D function into the more routine product development organization. This ended the separate lean effort that had been unique to advanced R&D.

Consumer Goods followed a rational planning approach to deployment with the assumption that the expected benefits would be realized when the plan was executed. Thus a detailed standardized process was defined by the corporate quality function that expected the development programs to comply. Consumer Goods perceived the lean product development principles, described by Morgan and Liker, to be countermeasures that could be selected and used individually to overcome problems. The lean product development principles deployed at Consumer Goods were:

1. Establish customer-defined value to separate value-added activity from waste. (process)

To overcome the problems of products not aligning with the market and large numbers of changes in direction throughout the development process Consumer Goods focused on obtaining a detailed understanding of market requirements prior to beginning work on projects. If the requirements are understood before the project starts they can be planned for and the projects can be executed to deliver value to the customers.

2. Front-load the product development process while there is maximum design space to explore alternative solutions thoroughly. (process)

To decrease the risk associated with invention on the critical path of product development the exploration of alternative solutions was instituted to minimize the risks associated with changing customer requirements, technology cost uncertainty, and technology uncertainty.

3. Create a leveled product development process flow. (process)

To level the flow of market launches, product development multi-year (5-7 years) product launch planning was done to ensure platform consistency and to manage the number of large projects at a time.

4. Utilize rigorous standardization to reduce variation, and create flexibility and predictable outcomes. (process)

To become more predictable Consumer Goods developed a global product quality system focusing on standardizing processes to reduce variation. This also included ensuring compliance to standardized processes and informing people of their roles and responsibilities.

13. Use powerful tools for standardization and organizational learning. (tools and technology)

To address an identified shortcoming in knowledge management, Consumer Goods developed a design guide system to allow knowledge to be captured and shared in a standardized way allowing it to be easily found across projects, functions, and time.

Design Guides: A Successful Case that Enabled Global Standardization

The global product quality management system efforts created an infrastructure across Consumer Goods for the development of standardized processes. Many of these standardized processes saw limited implementation and thus effectiveness. The high level of detail and navigating through connected processes created confusion as engineers got lost in the details. These processes were pushed onto engineers and not adaptable to address the challenges of different development projects. Engineers did what was necessary to effectively complete their projects, which didn't always include following the processes they didn't find of value. One exception was a standardized process that was developed when there was a pull from engineers—a design guide system for knowledge management.

The objective of most R&D organizations is the creation of usable knowledge for the development of products (Ward 2007). Within the advanced R&D organization this led to a focus on how to capture knowledge in a useable way, so that it could be leveraged across different product groups as well as time to minimize the recreation of previously obtained knowledge. The infrastructure created by the global quality management system was viewed as an enabler to the creation of a knowledge management system. There were several self-initiated, disconnected design guide and other knowledge management efforts across different engineering groups within Consumer Goods. In 2007 a group of engineers saw value in aligning these efforts, initiated through the focus on knowledge management within advanced R&D, so that the acquired knowledge could be shared across the organization. They volunteered and recruited other engineers across functions, who saw value in the development of a system, to develop a knowledge management system. This group was able to gain sponsorship for the efforts through the global product quality management system.

Sections of the design guides were standardized to allow the information to be found and pulled as needed, whereas other sections were open to encourage engineers to capture all information that they believed to be relevant. The standardized sections included purpose, scope, keywords, references, definitions and abbreviations, and contributors. Some of these sections were standardized to ensure that the information could be found when searched for through IT systems and others so that the information could be traced to the original sources if needed, while giving credit to those that contributed to the design guide. The standard design guide templates also included sections that were specific to each document. This was to be flexible to the specific needs of each module or technology for which a design guide was developed. Within the flexible sections of the design guides it was required to include why information was relevant. It was expected that many engineers would contribute to design guides, but each had a single owner who was responsible for maintaining and updating the design guides. This ownership structure was aligned with module owners and technical leads both within product groups and in cross-product groups. An example of a product specific system that would have a design guide was tumble patterns within dryers. Cross-product examples would include materials and controls and electronics. Controls and electronic design guides would be for hardware and software designs.

An example of a design guide within materials for steel was on the topic of heat treatment. This included descriptions of the different heat treatments processes for hardness. The process descriptions included performance characteristics noting when the method could be used effectively and when a method shouldn't be used. The design guide also included information on geometry considerations and stress and environmental considerations amongst other things. Because Consumer Goods has corrosion concerns the design guide included information about needing a narrower tempering (processing method for heat treatment) range than industry standards along with information on what to consider when selecting a tempering temperature.

This approach allowed knowledge to be captured and pulled as needed across projects and time throughout Consumer Goods. This was achieved by standardizing sections that allowed the information to be found through the infrastructure, while being flexible and adaptable to the unique needs of different technologies and products. This was also an effort initiated and developed by engineers who saw value in it.

Similarly, routine aspects of the development process were able to be standardized for greater coordination across the organization. Examples of routine support processes that were standardized and used by engineers to effectively support their work include FMEAs and A3s. Failure mode and effects analysis (FMEA) is used to identify all possible failures, so that actions can be taken to eliminate or reduce failures (Tague 2004). A3 is a problem solving methodology based on the scientific method with direct observations of the problem, presentation of data, proposed countermeasures, and follow up with checking and adjusting based on the results (Shook 2008). The processes and forms for these processes were standardized, including examples of 'best practice' examples to use as a template. Coaching for how to use these processes was available from six sigma black-belts within Consumer Goods when requested by engineers. These processes were used as appropriate and when engineers needed them to support their work to effectively complete product development projects.

Case Study 2: Turbine Gen's Model Line Deployment

Turbine Gen Phase 1: Model Line Deployment

In 2008 Turbine Gen initially deployed lean principles in two pilot areas by doing value stream mapping workshops and setting up *obeya* (literally "big room") for each pilot. One of the pilot projects was an uprate of an existing gas turbine generator to give it greater and more efficient power generation capacity and the other was the redesign of a specific component, a fuel injector, that also led to establishing a prototype test cell. The two projects were selected as the pilot programs because they were relatively short duration so the results could be seen in a reasonable amount of time and they represented both a turbine uprate program and a component redesign program.

The fuel injector is a major and complex component that affects combustion. It is very difficult to accurately model so they have to go through several iterations of design and test. The test stage became a bottleneck as they were sharing the same test process that was used for production versions and frequently getting bumped so shortening the lead time of the test process became a major focus.

Within the fuel injector project the *obeya* was less effective than for the turbine uprate project, but with strong and very technically knowledgeable leadership the team worked together effectively to achieve their reduced lead-time target. They benefited from an early, extensive concept stage that was based on set-based design so when they selected the final version they had great confidence in it. One key to their success was developing the dedicated test cell which became the focal point of much of the later stage of product development—a stage that in the past could easily get out of control and add another year of development. After the program ended the team continued to refine the test cell eventually developing an innovative visual *kanban* system to schedule all of the work going through the cell. On-time completion of tests increased significantly.

Turbine Gen followed a disciplined problem solving approach to deployment with the assumption being that with proper management support the expected benefits would be achieved as the organization moved through quick problem solving cycles. Turbine Gen perceived lean product development as a learning system following PDCA that enables people to do their jobs effectively and efficiently. The model, described by Morgan and Liker, provided an example to be learned from and adapted to fit their unique organization. Lean product development principles were initially used at the project level as appropriate to support the execution of two product development projects. The lean product development principles were most evident in the turbine uprate project which was a more traditional development program of an entire product:

1. Establish customer-defined value to separate value-added activity from waste. (process)

An initial activity of the product development team was the creation of a current state value stream map for the project, which included the identification of value-added activities and waste, and a future state map that would reduce the lead time to reach the target set by sales. The future state map became an overall project plan that was adjusted as the program progressed.

2. Front-load the product development process while there is maximum design space to explore alternatives thoroughly. (process)

Through the value stream mapping process, which created the initial project plan, the project plan was front-loaded. In particular, the planning for many downstream activities like tooling development, prototype casting, and manufacturing preparation were pulled up to the concept stage and through simultaneous engineering many past downstream bottlenecks were avoided.

3. Create a leveled product development process flow. (process)

Through simultaneous engineering, early supplier involvement, and an extended concept stage the downstream process became one of execution and was much more stable and level than in past programs.

5. Develop a chief engineer system to integrate development from start to finish. (people)

A project leader without the traditional background, but with the appropriate skill-set was selected and given support as needed to lead the development program through the *obeya* process. The project leader had previous experience working directly with customers and with downstream partners of the product development organization both within Turbine Gen and in other organizations. He became an avid student of lean product development and very consciously worked to develop himself into a role resembling Toyota's chief engineer.

6. Organize to balance functional expertise and cross-functional integration. (people)

The *obeya* process was used to bring the team members together to work on cross-functional issues in the *obeya*, while maintaining their roles within their functional organizations. Meetings dealt with critical cross-functional issues on a weekly cadence which in the past may have slipped through the cracks surfacing much later as major crises. Even a major crisis was dealt with very effectively as the team came together and dedicated themselves to solving the problem thus allowing them to still meet their shortened delivery date.

8. Fully integrate suppliers into the product development system. (people)

Key suppliers were involved early in the program and one of the most critical suppliers (of castings) actually sent a full-time on-site representative who became a member of the project team, had wall space in the *obeya*, and participated throughout the development process.

10. Build a culture to support excellence and relentless improvement. (people)

Through quick learning cycles, project leader coaching, and management support team members were given the support and means necessary to do their jobs and make improvements. The team truly began acting as an aligned team and through short problem solving cycles were developing their capabilities to work together effectively.

12. Align your organization through simple, visual communication. (tools and technology)

The *obeya* process allowed the functions to display key data visually and for alignment to be achieved across functions. Clever ways of calculating key metrics and presenting them visually were developed, such as in the cost of the product, which allowed visibility to actual versus targets on a weekly basis—visibility they never before had. Also A3 reports became a standard means of documenting problems and reporting on key information which greatly streamlined report writing and made key information very easy to grasp. The *obeya* became so informative that the group decided not to hold the usual gateway reviews through extensive PowerPoint presentations (itself all non-value added). Rather senior leaders came to the *obeya* to observe the status of the process at the gate ways.

GTG Phase 2: Lean Spreads Organically

In 2009 the use of lean tools started to spread organically in the organization as people saw value in the tools to effectively support work within the pilots. The *kanban* system for fuel injector prototyping spread from the test cell upstream into drawing and modeling using the same *kanban* card for a fuel injector throughout the process. Value stream mapping workshops were used for the initial creation of project plans across the organization. A team member on the initial project to use an *obeya* room started an *obeya* room for a project that they were the project leader on. The project leader of the original *obeya* pilot used an *obeya* to problem solve customer issues in the field for existing turbines in operation. Tools that were best practices and became standards in one *obeya* were borrowed, adapted, and improved to effectively support the work in other *obeya*. The spread of lean was limited to those who had experienced the value within the original lean pilots with varying levels of success throughout the organization.

Case Analysis

The approaches taken towards deploying lean within both organizations matched how the leader perceived the use and benefits of lean and the organizational culture.

Case Study 1: A Rational Planning Approach

Consumer Goods followed a rational planning approach assuming that good planning and execution of the plan would result in good results. The viewing of lean as a toolkit with principles to be used selectively to overcome particular issues based on a linear cause and effect relationship represents the good planning leads to good results viewpoint. For example, they invested heavily in understanding market requirements in detail prior to work beginning. This is certainly worthwhile but product development teams need to make changes if the customer requirements change or the understanding of customer requirements change. The lack of flexibility to be responsive to changes in customer demand is counter to lean principles (Womack, Jones et al. 1990).

Achievement of Stability

Following the rational planning approach Consumer Goods used standardization of processes to achieve stability. The standards were set and controlled by a central staff function. Many people within management and the staff function believed that when objectives were not met it was a result of a lack of process compliance. The solution to overcome the lack of process compliance was to further detail the standardized processes with clear accountability of roles and responsibilities. The result was similar to the common use of stage-gate systems that assume variation can be reduced by planning the development in stages with review checkpoints (Cooper 1990). Consumer Goods assumed that, through compliance, deviations from the standard would be corrected and no problems would occur. The lean literature emphasizes the importance of having standards and responding to deviations from the standard with good problem solving (Liker and Hoseus 2008; Rother 2010; Liker and Franz 2011). However, the standards should be adapted to each product development program and monitored and controlled by the product development team, with continuous improvement of the standards. Consumer Goods attempted to achieve stability through a central staff creating a general standard process to control the complexity of the environment and force process compliance.

Additionally Consumer Goods's focus on the establishment of standardized processes throughout the product development process was an attempt to ensure that processes were predictable. Unfortunately, many of the standards became cumbersome and resulted in more non-value added activities then they eliminated. However, there were a few examples of effective process standardization efforts. Examples of this were the failure mode effects analysis (FMEA) process, A3s for problem solving, and the design guide system for knowledge management.

The design guide was initiated by practicing engineers in R&D who saw a need. They took the initiative to get approval, create, and sustain the guides. Individuals took responsibility for each design guide. As they created it they were thinking not about control, but about creating an aid to enable better engineering. They recognized that too much standardization would be counterproductive and possibly hamper creativity. Thus, the design guide system had sections standardized to allow information to be easily found, while maintaining flexibility to capture knowledge. The standardization efforts that were effective were support processes that were used as appropriate and when needed to support the work while allowing non-value added variation to be removed. Removing variation from these common engineering tools leads to greater predictability within the product development process (Adler, Mandelbaum et al. 1996), which resulted in greater stability in the product development process (Liker and Meier 2006).

In retrospect the design guides were not following the rational planning approach, but rather were following a problem solving approach with rapid learning cycles as the engineers learned what information to include, how prescriptive to be, and where there were needs for flexibility.

Problem Solving / Learning Cycles

Following the rational planning deployment approach Consumer Goods spent time developing standards, documenting, and deploying standards globally. Consumer Goods planned to begin auditing and enforcing the standards in 2010, which was outside of the observation period of this study. Efforts focused on collecting best practices and leveraging them across the organization. Consumer Goods did not develop feedback mechanisms to enable the checking and adjusting of the standards once deployed until four years after the initial deployment. They implicitly assumed that the plan was correct and there was no need to have a problem solving cycle to make adjustments to the deployment plan. With a lengthy planning phase if the plans were checked and adjusted it would be a slow learning process given the length of the planning and executing phases with auditing beginning four years after the planning began.

Coordination and Integration

Consumer Goods sought to obtain coordination and integration through the use of standardized tasks and milestone integration events. Standardized processes can be an effective means of obtaining coordination and integration when they facilitate the understanding of task characteristics and interdependencies (March and Simon 1958; Sobek, Liker et al. 1998; Morgan 2002). Though, if the complexity is great enough that standardization is not sufficient to coordinate the interdependent relationships, as was the case within Consumer Goods, it will not be an effective means of achieving coordination or integration (March and Simon 1958; Thompson 1967) and can lead to a coercive bureaucracy (Adler and Borys 1996). Consumer Goods also used standardization to capture knowledge in a way that facilitated the ability to share it across projects and time, which is noted as crucial by Clark and Fujimoto for effective product development (Clark and Fujimoto 1991). The knowledge was stored in a way that allowed developers to pull the knowledge as needed, similar to the approach used at Toyota (Sobek 1997).

Breadth and Depth of Deployment

Consumer Goods achieved breadth of deployment by focusing on global processes. This approach allowed for economies of scale and for the gains to be leveraged across the entire enterprise. However, the centralized control approach did not allow for feedback and learning to improve the standards and did not provide local ownership of the standards by the development teams. Thus, the breadth was at the expense of depth of actual use of the standards to improve product development and create a learning culture that continuously improves the standards.

Case Study 2: A Disciplined Problem Solving Approach

Turbine Gen followed a problem solving approach to lean deployment assuming that with vision, support, and problem solving the plan could be adapted as needed to ensure good results in the uncertain environment. By viewing lean as a socio-technical system that supports the effective and efficient completion of work lean principles were introduced as appropriate and as an integrated system at the project level. Executing projects with weekly cross-functional *obeya* meetings enabled cross-functional problem solving to adjust both the project and tools as needed. This allowed for necessary adaptation in the complex environments of product development and lean deployment, which supports the lean approach of learning and adapting through PDCA since uncertainty exists (Rother 2010; Liker and Franz 2011).

Achievement of Stability

Turbine Gen achieved process stability by establishing accountability through value stream mapping and weekly *obeya* meetings. The cross-functional value stream mapping process enabled team members to create the project plan with an understanding of the interdependencies of the work. Weekly cross-functional *obeya* meetings allowed for adjustments to the plan as needed with an understanding of the impact on other parts of the project, which drove accountability as it was evident on a weekly basis how team member's actions impacted the rest of the project. Stability was achieved by team members taking accountability for the commitments they made to the project and team. Clear visibility to the interdependencies and consequences for the project of not meeting commitments drove people to be accountable (Baker 2011; Morgan and Liker 2011). Having work completed as planned leads to stability in the development process. Instead of attempting to control the work from the top down, stability was achieved by meeting commitments on a weekly basis.

Problem Solving / Learning Cycles

Through the model-line deployment approach Turbine Gen was able to have very frequent learning cycles. The use of PDCA with checking and adjusting on a weekly basis through project execution in the *obeya* led to quick learning cycles on projects and also on how the lean tools were supporting the work. An example of this was the introduction of "*Andon*" (signals of serious problems) in the *obeya* to highlight cross-functional issues that were not being properly addressed. Another example was in the fuel injector prototype *obeya*. Through the quick learning cycles it became evident that addressing the bottleneck for testing with a dedicated test cell would support the reduction of lead time. Refinements continued on the dedicated prototype test cell resulting in the establishment of a *kanban* board to schedule the work, which was effective for supporting the testing process for all fuel injector development projects.

The nature of the work was better supported through adjustments to tools with the team continuously modifying the tools to best support their work. Adjusting the tools to best support the work not only led to the work being done more effectively, but also supported the culture change to focusing on problem solving (Shook 2010). The ability to check and adjust is important in a lean context since every environment is different and the appropriate approach to deployment will vary and may need to be adjusted (Liker and Meier 2006). Executing the project via the *obeya* with cross-functional weekly meetings resulted in a weekly learning cycle for projects and the lean tools supporting projects (Rother 2010; Liker and Franz 2011).

Coordination and Integration

Turbine Gen achieved coordination and integration at the project level through the use of value stream mapping and *obeya*. Both the value stream mapping process and *obeya* allowed an understanding of the tasks and interdependencies of the work (Rother, Shook et al. 2003; Liker 2004; Morgan and Liker 2006; Baker 2011; Morgan and Liker 2011). The use of the *obeya* process allowed for real time mutual adjustment as plans deviated allowing integration and coordination to be achieved (Lawrence and Lorsch 1969; Baker 2011).

Breadth and Depth of Deployment

Achieving breadth of deployment was more difficult for Turbine Gen than Consumer Goods as initial efforts were focused on a few projects and the spread of lean organically relied on observations of the value of the tools and practices resulting in their use elsewhere in the organization. Through participants seeing the value of the tools within the pilot projects and being engaged in the process they pulled the tools and used them as appropriate in other contexts. In addition to the spread of value stream mapping and *obeya* to other projects the tools within *obeyas* that became standards were borrowed and improved upon within and across projects. Turbine Gen made adjustments to the lean tools when applying them in different contexts, which follows the *yokoten* (across everywhere) process of sharing practices in organizations considering the environmental context (Liker and Hoseus 2008; Liker and Franz 2011).

Table 2.2: Comparison of Enterprise Wide Tool Based & Model Line Value Stream Map Deployment Approaches

	Enterprise Wide: Lean Engineering – Tool Based Approach (Rational Planning)	**Model Line: Product Development Project – Value Stream Mapping (Disciplined Problem-Solving)**
How stability is achieved.	Standardize tasks to be more predictable with centralized control for compliance. Standardize routine support functions.	Accountability to complete tasks when commitments are made.
Problem solving / learning cycle characteristics	Long learning cycles	Short learning cycles: adapt & improve quicker; target setting & problem solving is more focused.
How integration & coordination is achieved.	Following the standard process is intended to force cross-functional coordination across projects & time.	Cross-functional integration and coordination within projects.
How breadth of implementation is achieved	The same process controlled by a staff function is deployed to multiple projects.	Organic spread: As value is seen it is implemented & adapted to fit throughout the organization.

Discussion

Consumer Goods followed a common approach of lean deployment by focusing on the technical process (Liker 2004), attempting to drive culture change through standardization and enforcement of standard use of lean tools. Whereas, Turbine Gen used and adapted the technical tools in a way that focused on enabling people to work effectively assuming that people would see value in the lean system through the resulting technical gains. Those involved in the early pilot programs would become evangelists helping to spread a culture change.

Within product development the cause and effect relationship between the use of lean tools and the results are difficult to see. This is because in a complex environment there are several interacting factors and there is long task duration in product development. These factors make it more difficult in complex environments, such as product development, to get culture change by demonstrating the value through technical changes in pilot projects or enterprise wide efforts. In complex environments through the development of the technical system to support the work with employee engagement enabling bureaucracies, which use standardization and structure to support work (Adler and Borys 1996), can be created.

Both case studies were in the early stages of lean deployment in product development at the time of observation. Each organization initially focused on achieving stability, which is a key first step in lean deployments (Liker and Meier 2006). However, the philosophy and approach to achieving stability varied greatly. It appears at this early stage of deployment that the focus on achieving stability through people may be more effective in a product development environment as it enabled work to be integrated and standards started to emerge within Turbine Gen. By contrast, the standardized processes within Consumer Goods were not necessarily followed and the discipline to follow the processes didn’t exist.

Each approach to lean deployment had benefits and advantages over the other approach. The enterprise wide rational planning approach created an infrastructure across the organization. This enabled common routine tasks to be standardized facilitating predictability, coordination, and integration across the organization. It also enabled the development of a knowledge system that facilitated knowledge to be captured and found across projects and time. The model line disciplined problem solving approach allowed adaptability to make adjustments in the uncertain environment of product development. This allowed greater opportunity for learning lean as a socio-technical transformation with the capability to adapt the process based on learning. The lean tools were adjusted to best support problem solving, people development, and organizational learning.

The advantages of each approach were the disadvantages of the other approach. Whereas the rational planning approach created an infrastructure that allowed efforts to be leveraged across the organization the spread of lean through the disciplined problem solving approach was limited as it only spread as quickly as value was seen and lean was pulled. And while the disciplined problem solving approach allowed adjusting for the uncertain product development environment the rational planning approach assumed adjusting wasn't necessary.

Ultimately the efforts that were successful in both organizations had characteristics of an enabling bureaucracy of supporting people to do their work (Adler and Borys 1996). People used and created the tools that best supported them to do their work effectively. Within Consumer Goods these were the routine support processes including the design guide system for knowledge management. This was created when there was a pull from engineers because there was a need to support them to work effectively and because there was a global infrastructure that supported its use across projects. Within Turbine Gen the lean tools were continuously adapted and used in ways that best supported the effective execution of projects.

Different environments have different deployment challenges, which are also impacted by the deployment objectives. Depending on the different environmental contexts and objectives of deployment there should be different approaches to deployment to meet those goals. The tools and approach need to fit with the objective and the environment rather than there being one best way to approach deployment. With the objective of leveraging gains and sharing knowledge across the global enterprise the rational planning approach was effective for the routine aspects of product development within Consumer Goods. And with the objective to learn lean as a socio-technical system the disciplined problem solving approach was more effective for Turbine Gen in the uncertain environment of product development.

Within advanced R&D there are inherently higher levels of variation than within product development groups bringing specific designs to market. This along with a greater emphasis on how lean could be used in that environment within Consumer Goods led to the focus on standardizing common aspects while maintaining flexibility to be adaptable to the needs of different groups in the development of the design guide system. The complexity and variation of the knowledge created make it impossible to standardize all aspects as doing so would require complete knowledge of all potential knowledge to be created across the organization. In this way the more complex nature of advanced R&D work may have made it easier to see and understand the need to be adaptable to the unique needs of each development project.

Eventually to achieve an enabling bureaucracy a balance between the rational planning and disciplined problem solving approaches needs to be achieved. The infrastructure created through a rational planning approach allows the routine aspects of the product development process to be standardized facilitating coordination and integration, whereas the disciplined problem solving approach allows adjusting as needed for each development project.

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Chapter 3

Facilitating Cross-Functional Teamwork in Lean Product Development: The Role of *Obeya* and Value Stream Mapping

Introduction

The development of new products is critical to the success of many organizations. Increases in global competition, demanding customers seeking niche products, and rapid technology developments has increased the competitiveness in several industries (Wheelwright and Clark 1992). Organizations frequently need to specialize to develop the capabilities to meet the demands of the market. At the same time, improving quality, lowering cost, and shortening lead time from concept to market while developing innovative products to meet customer needs is necessary to remain competitive or to develop a competitive advantage. Lean principles can be used to achieve these goals (Wheelwright and Clark 1992; Morgan and Liker 2006; Barrett, Musso et al. 2009; Morgan and Liker 2011), while enabling effective teamwork across functions.

Lean is a socio-technical system that enables people to solve problems and continuously improve (Liker 2004; Rother 2010; Liker and Rother 2011; Liker and Franz 2011). Product development is a problem solving process (Clark and Fujimoto 1991; Brown and Eisenhardt 1995). There are some similarities in lean product development to lean manufacturing: focus on shorting the lead time by eliminating waste, striving to make the work flow in a smooth and leveled way, improvement through rapid cycles of PDCA, teamwork focused on shared, measureable objectives, building quality into the work instead of fixing problems after the fact, and more. On the other hand, product development is a complex cross-functional effort and a lack of effective coordination and integration are the biggest impediments to best quality, lowest cost, and on-time delivery.

As a creative design process, creatively defining options and thinking deeply through issues of systems integration are critical in the front-end of the process, an area of weakness in many development organizations that find themselves fire fighting to get products fixed after launch.

Research Objectives

Though there has been extensive research into understanding and defining lean product development systems (Ward, Liker et al. 1995; Sobek 1997; Sobek, Liker et al. 1998; Sobek, Ward et al. 1999; Morgan 2002; Morgan and Liker 2006; Ward 2007) there has been limited investigation into how organizations can transform to lean product development systems (Baker 2011; Morgan and Liker 2011). Experts in this field emphasize that lean is a way of thinking and a cultural transformation, not a toolkit (Womack and Jones 2003; Liker 2004; Morgan and Liker 2006; Ward 2007; Liker and Hoseus 2008; Liker and Franz 2011; Morgan and Liker 2011). This study addresses this gap by conducting an in-depth case study within one project of how value stream mapping and *obeya* played a key role in the introduction of lean principles. In this case lean product development was viewed as an organic process of getting the right people to work together as a team and focus on shared objectives. The tools were viewed as levers to help start the process of cultural transformation in this organization. This research also addresses the broader issue of how complex organizations that develop complex products integrate across functions to efficiently and effectively complete product development programs focusing on customers using some of the most commonly used lean product development tools. This is addressed through the following research questions:

1. How can lean tools, specifically value stream mapping and *obeya*, act as enablers in the transformation of R&D organizations so they can more efficiently and effectively introduce new products?
2. What are organizational characteristics that enable successful use of these tools to begin the process of a cultural transformation to a lean enterprise?

Research Methodology

This research develops a theoretical model for an approach to the introduction of lean product development principles based on literature and a case study (Eisenhardt 1989). This study seeks to show replication of success factors for lean implementation as found in other environmental contexts to increase the validity of those findings (Yin 2003). The unit of analysis for the study is at the project level, an in-depth case study showing how value stream mapping and the *obeya* process were used within one product development project. This study addresses the call for in-depth case study research, by Morgan and Liker, within lean product development, particularly for the role of *obeya* (Morgan and Liker 2011). The case was selected based on the approach taken to introduce lean product development principles, as well as for the accessibility to data (Eisenhardt 1989; Yin 2003). Direct observation, review of documentation, and unstructured interviews were the data sources collected allowing for data triangulation to increase the validity of the research (Yin 2003).

Theoretical Discussion

Complexity of the Product Development Context

Growing Product and Organizational Complexity

The complexity of product development environments continues to increase (Lawrence and Lorsch 1967; Wheelwright and Clark 1992; Koufteros, Vonderembse et al. 2001; Lovelace, Shapiro et al. 2001; Koufteros, Vonderembse et al. 2002; Holman, Kaas et al. 2003; Smith 2007). The primary forces driving the increases in complexity are intense international competition, fragmented and demanding markets, and diverse and rapidly changing technologies (Wheelwright and Clark 1992; Lovelace, Shapiro et al. 2001). For firms to be successful as these forces increase they need to develop the capability to quickly and efficiently develop new quality products to meet customer demands (Wheelwright and Clark 1992; Zirger and Hartley 1996). As organizational mechanisms are put in place to manage the complexity in the external environment it can create complexity in the internal environment.

Increasing complexity leads to higher levels of uncertainty within organizations. Uncertainty is “the difference between the amount of information required to perform the task and the amount of information already possessed by the organization.” (Galbraith 1974). Uncertainty is the fundamental problem that complex organizations face (Thompson 1967; Galbraith 1973; Galbraith 1974; Tushman and Nadler 1978; Galbraith 1982; Daft and Lengel 1986). One of the reasons organizations exist is to solve problems and to process information in order to do so (March and Simon 1958; Galbraith 1973; Galbraith 1974; Tushman and Nadler 1978; Daft and Lengel 1986). When tasks have higher levels of uncertainty associated with them it increases the amount of information organizations must process to execute tasks and solve problems. In addition to uncertainty organizations must also deal with equivocality, multiple and conflicting interpretations of an organizational situation (Weick 1979), when processing information (Daft and Lengel 1986).

As levels of interdependence between tasks increase from pooled, to sequential, to reciprocal the complexity within the organization increases (Thompson 1967). Pooled interdependence exists when the task can be accomplished by parts of the organization working independently, relying on a common pool of resources, though if any part doesn’t perform adequately it has an impact on the entire organization’s ability to perform adequately. Sequential interdependence occurs when the output for one part of the organization is the input for another part of the organization. And reciprocal interdependence occurs when the outputs of one part are the inputs to another and the outputs of that become the inputs for the first and so on in an iterative manner.

The quality of the reciprocal interaction ultimately determines the quality of the output (Thompson 1967). An example of pooled interdependence would be the case where a design is modular and each company, given performance specifications, can develop its module independently of other modules. This often is the case in computers, for example the hard disk may be developed very independently of the mother board. In automotive there is much more customization of designs and reciprocal interdependence. For example, there are many steel body parts that interact and will affect structural characteristics like crash worthiness, thus there must be close coordination between engineers for doors and hoods and structural members. Similarly, the design of the vehicle has a huge influence on the ease of manufacturing and assembling the vehicle. The traditional "throw it over the wall" design process where product engineers complete the design and pass it to manufacturing assumes sequential interdependence, but to optimize product and process design requires reciprocal interdependence. Concurrent engineering is an example of an attempt to address this reciprocal interdependence across functions. The difficulty in coordinating tasks increases as the levels of interdependence increase from pooled to reciprocal, with the increased reliance on other parts of the organization (Thompson 1967).

To develop the capabilities needed to maintain effectiveness with increased complexity greater specialization is needed, which leads to greater levels of interdependence between the specialized functions and thus requires greater needs for coordination (Lawrence and Lorsch 1967). In addition to increasing interdependence, specialization leads people to develop unique orientations related to the tasks of their functions. The resulting differentiation is defined as the "difference in cognitive and emotional orientation among managers in different functional departments" (Lawrence and Lorsch 1969). The dimensions upon which differentiation occurs are orientations towards goals, time orientation (short term versus long term), interpersonal orientations, and formality of structure (Lawrence and Lorsch 1969). The negative effects of differentiation can be overcome with effective integration across functions by resolving interdepartmental conflicts and achieving unity of effort among functional specialists (Lawrence and Lorsch 1969).

Organizational Design Countermeasures to Achieve Coordination and Integration Required by Increasing Complexity.

Contingency theory is based on the assumption that there is no one best way for an organization to be organized, but on the other hand not every method of organizing will be equally effective (Galbraith 1973). Organizations need to have a “goodness of fit” between their structure, the technology, and their external environment in order to be effective (Pasmore, Francis et al. 1982; Daft 2004). In order to process information effectively and efficiently organization structures need to provide the appropriate level of support to achieve coordination and integration. Organizations are most effective when their strategy is consistent with their external environment and when organizational components are congruent with the tasks necessary to implement that strategy (Nadler and Tushman 1980).

As uncertainty increases organizations deploy strategies to either reduce the need to process information or to increase their capacity to process information. Different organizational designs exist as a result of the different strategies used to increase the ability to preplan, increase flexibility to adapt to the inability to preplan, or to decrease the level of performance required for continued viability (Galbraith 1973). The organizational designs chosen will impact the complexity of tasks and the levels of interdependence between tasks. Similarly, the technology itself can be designed to reduce interdependence, for example, designing the product so it is modular can reduce some of the need for reciprocal interdependence. Common organizational and technology design countermeasures utilized for increasing uncertainty include: The creation of slack resources or self-contained tasks to decrease the need for information processing and investment in vertical information systems or the creation of lateral relations to increase the organization’s ability to process information (Galbraith 1973; Galbraith 1974). The development of lateral relations seeks to ensure that decision making occurs at the location where the information exists, which is usually at lower levels of the organization (Galbraith 1973).

In addition to resolving uncertainty, information processing at the organization level must address disagreement and diversity of opinion (Daft and Lengel 1986). Equivocality exists when information can have multiple interpretations and the acquisition of new data can lead to increases in the level of uncertainty (Weick 1979). Equivocality can be resolved with the exchange of existing views among managers to define problems and resolve conflicts with a shared interpretation to guide future activities. Structural mechanisms that enable debate and clarification of information will reduce equivocality. Rapid feedback cycles with rich information sharing will speed the process for managers to reach a common interpretation of information (Daft and Lengel 1986).

Different coordination mechanisms are appropriate for varying levels of interdependence. Standardization, which involves the establishment of routines or rules which constrain the action of each part into paths consistent with those taken by others in the interdependent relationship, is appropriate for pooled interdependence (March and Simon 1958; Thompson 1967). To be effective for achieving coordination, standardization should only be applied in stable and repetitive situations (Thompson 1967). Coordination by plan, which involves the establishment of schedules for the interdependent unit to guide actions, is appropriate for sequential interdependence (March and Simon 1958; Thompson 1967). Coordination by mutual adjustment, which involves the transmission of new information during the process of action, is appropriate for reciprocal interdependence (March and Simon 1958; Thompson 1967).

Past Attempts to Integrate Product and Process Development

To maintain effectiveness with the increasing demands for coordination and integration many organizational innovations have emerged. Methods commonly used in product development include stage-gate systems, product lifecycle management software, concurrent engineering with collocated dedicated teams, and integrated product development.

Stage gate systems are designed to reduce cycle time, improve product “hit rates”, and be an effective tool to manage, direct, and control product-innovation efforts. Stage gate systems apply process-management methodologies to the innovation process with attempts to reduce variation and use gates as quality checkpoints between stages of the development process (Cooper 1990). The development process is divided into predetermined stages with the activities within each stage also predetermined. Different activities within different parts of the organization occur during the stages, but they converge at the gates where the project is evaluated to determine if it can proceed to the next stage of development. These systems provide an overview of the entire new product development process for senior managers giving structure and a vocabulary for better management and control. Benefits of the stage-gate system include: the establishment of discipline in the process, a simple and visible system where the requirements for each stage and gate are understood by all, a road map to facilitate the project, defined objectives and tasks for the project leader, and built in evaluation stages to rank projects and align resources (Cooper 1990).

Stage-gate systems achieve coordination and integration within product development through the gate review process between stages where all of the functions come together and make decisions to determine if the project should continue. The stage-gate system generally assumes sequential interdependence which would be an appropriate fit in an environment where all activities can be preplanned and the uncertainty levels are low enough so that all necessary coordination and integration can effectively occur at the review gates. This is a technical solution to the coordination and integration problem by providing a high level of definition to the development process with reviews of substantial parts of the development work at specified points with a focus on providing management control of the process.

Product lifecycle management (PLM) allows companies to manage and control products across their entire lifecycle, with the key innovation being the use of computer software. PLM is portrayed as a holistic business activity that provides a logical way to manage the many tasks in each phase of the product lifecycle (Stark 2005). PLM software is used to create and store information related to products and activities to ensure that the data can be found and utilized as needed throughout the product's lifecycle (Saaksvuori and Immonen 2008). To achieve the objective of developing, producing, and supporting products companies need accurate definitions of products, details of processes, organizational structures, working methods, processes, and people (Stark 2005). Similar to stage-gate systems, PLM assumes sequential interdependence and requires a detailed understanding of the product and the processes necessary to bring the product to fruition to achieve the full benefits. It is a technical system that can be used to ensure that the right coordination can occur as needed with the proper planning.

Concurrent engineering is an approach to address the uncertainty and ambiguity that exists in product development through the establishment of concurrent work-flow and early involvement of cross-functional product development teams (Koufteros, Vonderembse et al. 2001). One means of conducting concurrent engineering is through the use of collocated dedicated teams. An example of this was the platform teams utilized by Chrysler in the 1990s. The product development teams had dedicated team members from various functional disciplines including product engineering, manufacturing engineering, finance, and marketing who were all physically collocated (Sobek 1997). This allowed integration to occur by gathering all functions together to allow for mutual understanding to occur. Problem solving was conducted by giving every team member as much information as possible through cross-functional meetings allowing for understanding of the concerns and issues of others to be considered as problems were addressed cross-functionally (Sobek 1997). This approach displays an organizational design approach to foster greater integration within projects by facilitating communication with direct contact as a collocated team. The creation of teams is the next countermeasure, beyond standardization, by plan, and mutual adjustment, for increasing interdependence (Ven, Delbecq et al. 1976). The use of teams facilitates and enables mutual adjustment to occur more frequently.

The use of concurrent engineering assumes reciprocal interdependence is required because components of the product are interdependent and decisions made across functions are interdependent (e.g., product design, product engineering, purchasing, tooling design, manufacturing). Dedicated collocated teams with many meetings is one organizational design to deal with the high levels of reciprocal interdependence. Integrated product development expands on concurrent engineering by utilizing heavyweight product development managers and methods to increase information sharing and availability in addition to concurrent engineering methods (Koufteros, Vonderembse et al. 2002). The problem-solving cycles, used to execute product development, need to be integrated both in terms of the timing of actions and through communication between upstream and downstream groups (Clark and Fujimoto 1991). Effective integration requires attitudes, systems, and structures that support problem solving across traditional organizational boundaries. Capabilities that enable integrated problem solving include understanding of the conditions required by other functions within functions, quick engineering cycles, and quick adjustments to unexpected changes (Clark and Fujimoto 1991).

Lean Product Development as an Approach to Social and Technical Integration

What is Lean Product Development?

Lean product development is a development system designed to enable people development, problem solving, and organizational learning allowing the organization to achieve its purpose. Lean systems seek to have problems identified as soon as possible (Liker 2004) and solved by the people closest to the problem since they have the most thorough understanding of the issues (Spear and Bowen 1999). This includes making people responsible and accountable for solving problems, while ensuring that they are given the resources and support needed to do their jobs successfully (Shook 2008; Shook 2010). The role of lean tools is to make problems visible, enable people to solve them, and capture what is learned throughout the organization (Liker 2004).

Lean development can be viewed as a socio-technical system approach, which recognizes the interdependencies and influences between the social and technical systems of the organization (Pasmore, Francis et al. 1982; Morgan 1997). For organizations to be most effective, they should be designed with social and technical subsystems fitting the needs of one another and the organization's purpose (Pasmore, Francis et al. 1982).

An example of an integrated socio-technical product development system is Toyota's product development system. This is described by Morgan and Liker as consisting of three integrated subsystems that are: process, people, and tools (Morgan and Liker 2006). This model helps to understand how Toyota addresses the challenges, including achieving coordination and integration, of designing complex products in a complex environment. Toyota's development system is continuously evolving as new challenges are encountered and must be overcome (Morgan and Liker 2006). Though Toyota's product development system has evolved since the development of this model the lean product development principles still hold and are broad enough to be applied in other development environments (Morgan and Liker 2011). Toyota has been able to achieve integration within projects as well as across projects leading to a competitive advantage. This is achieved through the use of several mechanisms that allow for cross-functional integration while developing functional expertise. These mechanisms include mutual adjustment, close supervision, integrative leadership, standardized skills, standard work processes, and design standards (Sobek, Liker et al. 1998).

Lean Product Development and Integration

The process subsystem refers to all of the tasks needed to bring a product from concept to the start of production (Morgan and Liker 2006). Process standards are utilized to ensure effective cross-functional coordination throughout the development process. Having an understanding of how and when the work gets done, everyone's specific role and responsibility, interdependencies, inputs, and outputs for each task allows coordination and integration to occur across functions (Sobek, Liker et al. 1998; Morgan and Liker 2006). The consistency that comes with standardized processes leads to better integration across functions as understanding of what is expected and what will be delivered is clear (Morgan and Liker 2006). On the other hand the standardized processes need to be flexible, unlike some versions of stage-gate models, to adapt to all the uncertainties in the development process.

The people subsystem refers to the organizational culture including the organizational structure, leadership styles, learning patterns, and the development of employees (Morgan and Liker 2006). Product development, from concept to production, is led by a systems-integrating chief engineer (Clark and Fujimoto 1991; Morgan and Liker 2006; Ward 2007). The chief engineer coordinates and integrates the work across the diverse technical specialists in the process of vehicle development (Sobek, Liker et al. 1998). The organization is organized around functions to facilitate the training and development of experts with "towering technical competence" (Morgan and Liker 2006). The resulting differentiation contributes to the challenge of achieving effective integration. The people are the source of innovation, coordination and adaptation. It is the people who are constantly monitoring and adjusting the process as conditions change and they must be responsible and accountable for the targets and tasks they sign up for.

The tools subsystem consists of the tools and technologies used to support the development process. A standardized approach to problem solving using the plan, do, check, adjust process through A3s facilitates the mutual adjustment necessary to achieve integration when solving cross-functional problems (Shook 2008; Sobek and Smalley 2008). Standardized designs enable a common understanding and support coordination and integration across projects (Sobek, Liker et al. 1998). Visual management makes the current state and all deviations from the plans visible so there can be immediate action to put in place countermeasures.

The Role of Value Stream Mapping in Organizational and Technical Integration

Lean Thinking identifies five lean principles to aid in the transition of traditional organizations to lean organizations. These principles are specifying customer value, identifying the value stream, making value flow without interruptions, letting the customer pull value, and pursuing perfection (Womack and Jones 2003). Mapping the entire value stream allows for the identification of opportunities for improvement that can enable value to flow and be pulled by the customer (Rother, Shook et al. 2003; Womack and Jones 2003). Value stream mapping is an essential tool that:

- Helps you visualize more than just the single-process level and see the flow.
- Helps you see more than waste. Mapping helps you see the sources of waste in your value stream.
- Provides a common language for talking about processes.
- Makes decisions about flow apparent, including those across functions, so you can discuss them, thus preventing decisions being made by default.
- Ties together lean concepts and techniques, which helps avoid “cherry picking”
- Provides a shared vision of a desired future state to align actions around a common vision.
- Forms the basis of an implementation plan by helping you see and design how the entire value stream should flow.
- Is a qualitative tool used to describe in detail how you should operate to create flow. (Rother, Shook et al. 2003)

Value stream mapping can be a valuable tool for aiding in the transition to a lean enterprise. Mapping of the current state identifies the current processes, highlights waste and opportunities for improvement, gets the whole group engaged in seeing the waste, and provides a foundation for improvements. The future state map provides a vision for how the process will operate with reduced lead time in the future. The future state map then becomes the current state map, as improvement opportunities are realized, and a new future state vision for the next round of improvements is created (Rother, Shook et al. 2003).

Although originally developed for manufacturing, value stream mapping can be used very effectively in complex environments such as product development (Morgan 2002; Morgan and Liker 2006). Many of the benefits of value stream mapping previously noted are even more valuable in complex environments than in manufacturing. Value stream mapping fosters integration through the common understanding of processes, causes of waste, and how the work of functions fits together. The cross-functional nature of product development with parallel and highly interdependent tasks makes the ability to see the whole process and where waste exists highly valuable for identifying improvement opportunities (Morgan and Liker 2006).

Value stream mapping can help ensure a thorough understanding of:

- The details of how the work actually gets done.
- Each participant's specific roles and responsibilities.
- Key inputs, outputs, and interdependencies for each activity.
- Sequence of activities in all functions.

These all need to be understood for effective coordination in cross-functional work (Morgan and Liker 2006).

A highly effective means for creating value stream maps in product development is through the use of value stream mapping workshops. These workshops are done with cross-functional teams with current state and future state maps being created. The creation of the maps with cross-functional teams allows for dialogue on the process and the development of common objectives (Morgan and Liker 2006). These events can be very valuable for achieving integration.

The Role of Obeya in Organizational and Technical Integration

The *obeya* (literally "big room") was first used in the development of the Prius at Toyota to facilitate cross-functional integration (Itazaki 1999; Liker 2004; Morgan and Liker 2006). The unique nature of the project and the selection of a chief engineer, Takeshi Uchiyamada, without a typical chief engineer background required an organizational innovation to effectively develop the vehicle (Itazaki 1999; Liker 2004; Morgan and Liker 2006). The *obeya* utilized a cross-functional team of experts coordinating development work in a room with relevant information posted on the walls. In some ways it is like collocated teams, though team members are not necessarily dedicated to that one project and they generally have offices outside of the room. The *obeya* is effective at integrating product development while enabling fast and accurate decision making, improving communication, and maintaining alignment between functions. The *obeya* allows for quicker decision making and conflict resolution as all of the key people are gathered together and working from the same information to solve cross-functional issues (Liker 2004).

Obeya has also been an effective tool to introduce disciplined problem solving leading to stability, which is necessary for effective coordination (Thompson 1967). At North American Auto Supplier this was done through cross-functional development of schedules and plans. The *obeya* was used to drive cross-functional teamwork, empower teams, and enable plans to be executed through rapid plan-do-check-adjust (PDCA) loops (Baker 2011). The *obeya* provides an environment for PDCA loops to occur more frequently as it enables the process to occur as often as cross-functional integrating meetings are scheduled. Plans are posted on the walls creating an environment for visual management. Visual management makes it immediately obvious when work is deviating from the standard (Hirano 1995; Liker 2004). In this way PDCA and visual management allow for real time problem solving to occur as gaps between actual and target conditions are addressed (Baker 2011).

The ability to check, adjust, and plan is especially important in uncertain environments. Rother describes this process of continuous improvement, observed at Toyota, as a set of practiced routines (*kata*) driving toward explicit “target conditions” (Rother 2010). Target conditions are simple and measureable desired future states on the path towards your vision. Since the environment is always changing the path between the current state and the final results is unclear. This level of uncertainty leads to an approach of engaging in several small plan-do-check-adjust (PDCA) cycles focused on achieving shorter-term target conditions. This allows learning and adjustment, based on that learning, to find the path to the target condition. Toyota places emphasis on conducting quick PDCA loops allowing for greater learning to occur and for what is being learned to be included in the plan stage of the next PDCA cycle (Rother 2010).

In addition to providing a forum for quick learning cycles the *obeya* facilitates coordination and integration of the development process through visual management and accelerates the frequency of coordinating and integrating activities. Participants in the *obeya* process have instant visibility to details, commitments made, and task dependency as all key information is posted. Putting the responsible party's name next to completion dates drives accountability as it is evident if the work was not completed in the following meeting (Morgan and Liker 2011), which results in stability as commitments made are met. The visibility also makes interdependencies obvious creating awareness of how the work needs to integrate together. The use of the *obeya* process allows for real time mutual adjustment as plans deviate, allowing integration and coordination to be achieved (Lawrence and Lorsch 1969; Baker 2011).

Table 3.3: Approaches to Achieve Integration

Approach to Integration	Methodology	Interdependence Assumptions	Key Tools
Stage Gate System	– Reduce variation by defining the innovation process in stages with predetermined activities – Use quality checkpoints to determine if the project proceeds to the next stage	– Sequential within defined stages – Reciprocal at gate reviews	– High level definition of development process to provide a common understanding of requirements – Gate reviews to establish discipline, evaluate projects, and align resources
Product Lifecycle Management Software	– Manage product lifecycle by defining and making available all information related to the product and related activities	– Sequential with all aspects defined	– High level definition of development process to provide a common understanding of requirements – Software allowing access to all project information
Concurrent Engineering: Dedicated Collocated Teams	– Cross functional teams are dedicated to the development team sharing all information to ensure mutual understanding	– Reciprocal with mutual adjustment in meetings	– Dedicated collocated teams
Lean Product Development	– Cross-functional teams meet to resolve cross-functional issues and achieve mutual understanding while remaining in functional areas to maintain technical competence	– Reciprocal with mutual adjustment	– Standardized processes to achieve an understanding of expectations – Chief engineer to coordinate and integrate work across functions – *Obeya* to highlight and enable the solving of cross-functional issues

Lean Deployment Perspectives

To successfully deploy lean product development it needs to be looked at as a whole system. Implementing a few of the techniques, without integration of the entire system, will not lead to substantial benefits (Karlsson and Ahlstrom 1996). Though some gains can be achieved through the use of technical tools as solutions to particular issues, it will not lead to a transformation into a sustainable learning organization.

A key tenet in lean is that there is no one right way to do something and that the approach taken is dependent on the particular situational context. This is reflected in the view that engaging in a continuous learning process is more important to lean deployment than implementing the right tool. And thus it follows that since every organization is different there can be no one universal road map for becoming lean (Liker and Meier 2006; Morgan and Liker 2006).

There are key attributes that must be achieved in a lean transformation. In order to create a culture of continuous improvement basic process stability must first be achieved. A focus on stability ensures a consistent level of capability to produce consistent results to create a foundation for improvement (Liker and Meier 2006). Once foundational stability has been achieved efforts can focus on establishing a culture of problem solving and continuous improvement by providing people with the tools and resources needed to identify and solve problems. Defining appropriate behavior, providing training to support the behavior, and creating a support system to reinforce the behavior can be an effective method to change the culture of an organization (Shook 2010). Creating a system of highlighting problems, making solving problems without placing blame an essential part of the job, and creating a support structure that enables people to do their jobs successfully can facilitate the adoption of a lean system and culture (Shook 2010).

Though there are few documented examples of successful transformations of lean product development those that do exist maintain the same focus on establishing stability, enabling problem solving, and continuous improvement as seen in successful lean manufacturing transformations. For example Charles Baker of North American Auto Supplier treated lean transformation as a process of transforming people and developing a problem solving culture. This was achieved using the plan, do, check, adjust problem solving methodology, formalized through A3 reporting, to bring stability to the product development process and to enable other lean tools to be used at North American Auto Supplier (Baker 2011). Similarly, Ford Motor Company focused on transformation following lean product development principles to support a lean culture and create stability through standardization and the use of the *obeya* to manage the transformation (Morgan and Liker 2011).

A common theme across lean deployments is starting with technical changes, primarily at the process level (Liker 2004), with working level people and managers taking responsibility for the changes so they develop as the project is carried out. Focusing on the technical changes that support the desired culture can be an effective means for the transformation to a lean product development system (Nadler and Tushman 1980; Morgan and Liker 2006; Shook 2010).

Case Background

The in-depth case study focused on one company's early stages of lean transformation which began with two pilot product development programs. The focus here is on one of those projects. The organization is a wholly owned subsidiary of a Fortune 500 company that produces gas turbine generators, and will further be referred to as Turbine Gen. Turbine Gen had historically been very successful, had success with lean manufacturing, and viewed the deployment of lean methodology in product development as an opportunity to improve operational performance. Though Turbine Gen operates in a unique environmental context it is hypothesized that the learning and experiences from the unique challenges and experiences Turbine Gen faced can lead to a general understanding of the enablers for successful lean deployments. The case focuses on how value stream mapping and *obeya* can be used to enable a cultural transformation to a lean organization.

This case study represents one pilot project within a larger effort towards lean transformation. The overall effort is discussed briefly here and in greater detail in Chapter 2: Lean Product Development: A Comparative Case Analysis of Rational Planning and Disciplined Problem Solving Approaches. Though Turbine Gen had been successful, the organization was not meeting commitments in terms of time-to-market, product cost, sales volume, quality, and budget and saw the use of lean principles as an opportunity to enable the organization to meet commitments. The initiatives taken to address the gap between the current conditions and the target condition of meeting commitments included:

- Frontload the project in the concept phase.
- Manage the development pipeline – leveling of product launches and engineering resources.
- Adopting lean principles in product development (initially in two pilot projects).

The case study is of one of the pilot projects focusing on how the lean tools of value stream mapping and *obeya* were utilized to effectively and efficiently manage the development while introducing lean principles.

Similar to Toyota's selection of a chief engineer without a traditional chief engineer background when a new way of developing vehicles through the Prius project was developed (Itazaki 1999; Liker 2004; Morgan and Liker 2006), Turbine Gen selected a project manager without the strong technical background of a traditional project manager, but with the appropriate skill-set to lead a project using the *obeya* process. Team members initially had a lack of respect based on the level of technical depth, which the project manager had to overcome with his approach to managing the project. The project manager, who had an engineering background, had previous experience working directly with customers and with downstream partners of the product development organization both within the case study organization and in other organizations. The project was an upgrade of power of an existing turbine power generator selected because it was a significant project, but would be completed in less than 1.5 years, so they could learn from it relatively quickly.

Case Description

Value Stream Mapping: Initial Team Creation of the Project Plan

The project was kicked off with a cross-functional team participating in a three day value stream mapping workshop. The workshop consisted of the creation of a current state map, identification of wastes and opportunities for improvement, and the creation of a future state map, which became the basis of the design program plan. This process brought the whole team together in a forum that enabled the understanding of others' work and the interdependencies between the different functions. It also gave visibility and showed how everyone's work connected to the overall project.

The current state map was created based on similar recent projects that had taken between 24-27 months to complete. The map was like a matrix with time across the top and swim-lane columns each focused on the work done within a function. Thus the functional tasks were clear and the interdependencies between functions were visible.

Value stream mapping identified waste-drivers that included batching, lack of scope clarity, scope creep, work within functional chimneys, and communication breakdowns. The batching of work resulted in large amounts of work moving through the system, without visibility to the amount of work that was coming. Scope clarity was related to a lack of specifying what was out of scope. And scope creep was a result of market changes leading to changes in the scope of the project. These changes were often made without an understanding of the interdependencies and potential amplifying effects throughout the project. Making the work visual makes it easier to see the effects and consider those effects when making decisions on changing the scope of the project. Work within functions was of a "waterfall" fashion in which early stages were handled by product engineering and then "thrown over the wall to downstream functions" who had to fix the work so they could source tools and parts, create and test tooling, and prepare the factory. Communication problems occur when people make assumptions on others' work that may not always be accurate. When the assumptions are wrong about how work interrelates it can cause large amounts of waste.

Countermeasures to overcome the issues identified through the mapping of the current state were developed. This included the creation of a scope document to address the scope creep and scope clarity issues that defined what was in and out of scope. Visibility of the wastes related to batching and communication issues allowed the work to be planned differently to minimize those wastes. This included minimizing rework loops through better communication and leveling deliverables to not overwhelm suppliers. This resulted in the resources from all functions for the project being front-loaded in the early stages of the project which also led to simultaneous engineering.

The countermeasures were incorporated into the future state map that was developed for the project that had a reduced timeframe of 18 months. The creation of the future state map included starting at the beginning and planning how long the work should take. The creation of the future state map by those working on the project established a shared vision of how the project should be executed. It also allowed participants to take ownership and accountability for the work plans they created. The future state map became the plan for the project setting the standard. Through the value stream mapping process each discipline established their commitments to each other.

Obeya: Effective Project Execution

Once the future state standard for the project plan had been created the *obeya* was used to effectively execute the project. The use of the *obeya* allowed for frequent checking and adjusting on the project as performance was compared to the standard.

What should be included on the walls of the *obeya* was driven by what was of value in executing the work. The only standard imposed at the beginning of the project was allocating wall space throughout the room by function. The participants discussed the key program objectives and were encouraged to post what they felt would be of value to help them effectively complete the project and achieve those objectives. These included cost, quality, and timing metrics. As participants saw the value of the tools used by others they adopted them and began using them. Additionally, participants treated the tools created by others as the standard and built off of them with incremental improvements to make the tools more valuable and created a new standard. During the weekly *obeya* meetings the project manager frequently noted the tools being used that were effective, which may have contributed to the adoption of the tools by others. The project manager gave recognition for tools that were working effectively to give credit to those who created them and to encourage other team members that were struggling to consider adopting them.

One example of a tool that was developed by one member and became adopted as a team standard became known as a “Nick Chart”. The tool was called “Nick Chart” because Nick created it and others started to use it as it was perceived as being a valuable tool. “Nick Charts” provided a visual display of deliverables, status, and who is accountable for the work. A color coded scheme was used for deliverables with the following scale:

- Cool mint green – On schedule, no work in process
- Dark green – In process
- Dark green w/ checkmark – Complete
- Yellow – Risk identified, working on a resolution
- Red – Team deliverables impacted

A key part of the use of this tool was that it was created by a team responsible for the work and thus was owned by the people accountable for the work rather than imposed by the consultants or a staff organization. This tool is also an example of project members building off of tools to increase the effectiveness of the tool. “Jill’s cool mint green”, was used to represent things that are on schedule, but for which there is no work in process. This serves to distinguish from the dark green used to represent that work is on schedule and in process. This makes it visually evident what is being worked on and what is planned to be worked on. By referring to it as “Jill’s cool mint green” credit for the improvement of the tool is given. Through the use of “Nick Charts” the schedules made through the value stream mapping process were translated to individual work plans and established a standard that could be easily checked and adjusted on a weekly basis.

Within the *obeya* all of the project information that team members think is relevant is displayed, which creates transparency. Having the information displayed "lowers the walls" between the functions of the organization, which fosters collaboration and enables alignment between functions through visual communication. The meetings that happen through the *obeya* process facilitate the identification of cross-functional issues and problems, which can then be addressed and solved between meetings. Through this process a resolution or plan or progress towards a resolution is expected by the next meeting.

A key part of the *obeya* process was how the cross-functional meetings were run. This entailed each function "walking the walls" and reporting out to the team from their section of the wall. This included managing by exception and only spending the cross-functional time if something was off target (schedule, cost, and quality) and needed to be addressed rather than spending meeting time discussing tasks that were on target. This directed attention to the issues that need to be resolved and allowed efforts to be focused on those issues. Following meetings it was common to have smaller groups of two to three people, on average, discuss the issues that they need to resolve together.

The visual clarity of the interdependencies also enabled the responsibility for capital expenditures to be allocated to the functions using the capital. Historically all capital responsibility and accountability were located in design engineering and manufacturing. Under that structure a system that enabled decisions to be made with incomplete or inaccurate information existed. The visibility across the functions through the *obeya* enabled accountability to be placed at the location where the information existed and decisions were made.

The *obeya* also offered an effective means of giving project updates as all relevant project information was posted on the walls of the room. When PowerPoint presentations are created to give updates it can appear that the data is being presented from a particular perspective and data might not be included that other perspectives would find relevant (Tufte 2003). When updates were given in the *obeya* the walls were walked discussing the status of the work with focus on the issues highlighted by "*Andon* lights". *Andon* (literally "lantern") lights are used to signal abnormal conditions to highlight deviations from the target through a visual indicator (Suzaki 1987). And when questions were asked they could be addressed by looking for the data in the relevant part of the room. This style of presenting made it very evident that the presentation wasn't being manipulated to show it from a particular angle. And when it was necessary to create a PowerPoint presentation it could be done much more efficiently and effectively by doing it within the *obeya*, where all relevant information was located on the walls.

The *obeya* is a dynamic tool that supported modifying of the project as needed along with the modification of the tool itself to support the work as needed. As the group matured and tool improved the length of the weekly meetings decreased from one-and-a-half hours to forty-five minutes as the tool allowed increased efficiency while maintaining effectiveness. The room progressed and was adapted continuously, but can be viewed as moving through three generations of improvements.

Obeya: Phase 1

The room was initially only labeled by the sections of the wall owned by each function with freedom for team members to include anything that they felt would enable them to do their work. This resulted in a lot of information being displayed on the walls. Though it wasn't clear how all of the information on the walls fit together. At this stage the *obeya* was effective for supporting the work of the team, but it was difficult for people outside of the team to understand.

In response to the room not working effectively for other people to come in and understand, category signs were brought in such as financial and quality. Team members were encouraged to put up these categories if they applied to their part of the project.

Additionally, if it applied to you, but you hadn't addressed it yet you were encouraged to put up a construction sign. The construction sign was meant to give visibility that it would be addressed.

The team struggled through what the appropriate tools should be for quality. Though it was important for the team to take ownership and create or borrow tools that they found of use to effectively complete the project, when the team struggled to create those tools a quality expert within the organization developed a tool for quality. This is an example of the team needing to be given the proper support and resources needed to do their job effectively. The team members were still responsible for taking ownership for quality for their portion of the project. Support was provided to develop a quality tool, though it was not an external entity being responsible for the quality or policing the quality aspects.

At this stage of the project, participants were borrowing best practices from each other. When tools that were developed were valuable they were discussed and frequently adopted by others. There was also clear visibility to interdependent relationships that allowed savings opportunities to be seen and realized. For example when engineering was considering making a change manufacturing was able to highlight how it would impact the cost and engineering decided to not make the change based on the visibility for how it would impact other aspects of the project. The visibility to data and impact on other areas allowed the right business decisions to be made since the big picture and aspects of the business model were understood.

Overall in the first phase of the *obeya* the team was taking responsibility by taking accountability, being committed to the team and company, and feeling empowered to take ownership of their part of the project. The team's performance was exceeding the average in the company with good visibility to what was happening within the project. It was increasingly clear that the minimum requirements for the project would be met.

Obeya: Phase 2

The transition between the first phase and the second phase of the *obeya* progression represents the point when it was clear that the project had obtained engagement from participants and was exceeding the performance of an average project. This level of performance alleviated concerns for success with a new way of managing development and provided a baseline for the process to continue to progress. This phase continued with compliments and discussions when tools were good. Team members started using the best tools created by others at a frequency that led to some standardization of the tools used.

At this stage each function had their individual plans that they created and were taking accountability for, which fit together and rolled-up into the overall project plan. This ensured that decision making and accountability were in the proper place based on where information within the organization existed.

Though the room was functioning well there were still recognizable opportunities to continue to improve upon. The status of the project wasn't as visibly evident as it could have been. This included lots of information on the walls that wasn't technical and didn't contribute to the message. This created noise and added confusion. There were also tools that weren't being utilized that added to the clutter. For example, cross-functional whiteboards, that were intended to be used for making note of issues, when they needed to be resolved by, and the status on the issue, were not being used effectively. And thus it wasn't clear what cross-functional issues existed and if they were being worked on. Struggles at this point also included it not being visually clear what the deliverables were from a project management standpoint and the tools and charts being used were not intuitive to understand and not necessarily clear on how they connected to the program.

The visual management within the *obeya* wasn't working effectively for those outside of the project, including managers, to see what was happening with the project. To overcome this, the high level status was included on the door of the *obeya*, so that the overall high level status could be quickly seen. And for greater detail people could walk into the room and see the details to understand what was happening. Through this phase the team was performing well and tools were being developed, praised, adopted, and improved across the project team.

Obeya: Phase 3

In the next phase of the *obeya* room, to overcome weaknesses with issues not being highlighted, "*Andon* lights" were added. These were signs that were red, yellow, or green to show the status of the project. Green represented that things were on track, yellow that there was an issue that needed to be addressed, and red that there was a problem that was detrimental to the program. This allowed managing by exception as things that were green didn't require discussion and efforts could then be focused on the yellow and red issues. The use of "*Andon* lights" at this stage of the project had a dramatic effect on the functioning of the weekly meetings within the *obeya*. Prior to the use of "*Andon* lights" there would be a lot of off-topic conversations occurring during the meetings. After the "*Andon* lights" had been introduced, conversations were focused on the problems. Discussing problems as soon as they were evident gave opportunities for cross-functional issues to be discussed cross-functionally.

There was also continuation of the progress of team members adopting the tools others developed as they saw the value and effectiveness of the tools used by others. This was the case for one section of the room that was highly innovative. Discussions of the value of the tools led to other participants pulling them for their own use leading to standardization of the lower level tools being used, when they were of value. At this phase of the project all team participants had adopted "Nick Charts". This resulted in an environment where it was visually clear what each and every member of the project needed to accomplish and deliver to be able to walk away from the project. It also made the interdependencies between functions and tasks visibly obvious. Puzzle pieces were also introduced and put on the walls to represent that we all have a part in it and none of us are the whole part.

Case Analysis

Achievement of Integration

By creating the value stream map through a cross-functional workshop integration began with a common future state vision and engagement of team members in the planning process. Involvement through the value stream mapping process created an empowering environment by letting team members plan their own work. This was feasible because the value stream map gave visibility to the tasks, waste, and interdependencies of the work giving the team members the knowledge needed to plan their own work, while ensuring the overall project could be completed effectively. This continued through the use of the *obeya* as the interdependencies were evident and drove people to be accountable for their commitments since the impact on the rest of the project was clear if commitments were missed. The visibility to the interdependencies enabled team members to find opportunities to better coordinate and integrate the work.

Traditionally in many organizations, including the case study organization, the project manager is responsible for creating the project plan from the start to the finish of the project. To be effective project managers need to understand the tasks, people involved, and interdependencies across the project, which can be very difficult to do in complex environments with traditional tools like Gantt charts. The value stream map overcomes this short coming through the creation of the project plan by the cross-functional team. This includes discussions of the interdependencies and how to remove waste, that becomes visible, when a shared understanding of the situation exists. The visual nature of the *obeya* removes the burden from the project manager to keep track of all of the interdependencies independently. The *obeya* enables it to be visually clear what the deliverables are and who is accountable thus enabling individuals to coordinate their work.

The visual nature of the *obeya* facilitated integration through the understanding of the interdependencies between functions. Puzzle pieces were used to emphasize that everyone has a piece of the project that fits together to form the overall project. This understanding drove accountability as the effects of not making commitments were evident. Posting all of the relevant information in the *obeya* ensured transparency and clear communication within the project. It also made it clear when key information for the project was not posted allowing the absence of data to be addressed before it led to problems in project execution. Overcoming this is why construction signs were included to acknowledge awareness of things that had not yet been addressed.

Lean Deployment: Enabling Problem Solving

The value stream mapping process created the initial plan for the project, which was continuously checked and adjusted through the weekly meetings in the *obeya*. This ensured that plans were developed and evolved with awareness of consideration of the interdependencies between function. The *obeya* ensured that the PDCA cycle was occurring on a weekly basis with the team working together to effectively achieve smaller targets.

The weekly meetings in the *obeya* resulted in quick PDCA cycles not just for the project plan, but also for the tools to support effective project execution. The same approach for making adjustments to the project was used for the tools to support the process. Each was a problem solving process executed through PDCA cycles. The addition of the high level status on the door to the *obeya* and the modification of “Nick Charts” are examples of the adjusting done through this process resulting in the room being more effective.

The *obeya* was a key enabler to allow managing by exception to occur. Managing by exception entails only focusing on an issue when it deviates from the schedule, target, or standard. The gap between the actual condition and the target condition signals that there is a problem that needs to be addressed (Liker and Hoseus 2008; Rother 2010; Liker and Franz 2011). The identified problem may indicate that something needs to be adjusted so that the target is met or that the plan may need to be adjusted (Liker and Hoseus 2008). Several of the lean tools that became standards in the project were to facilitate managing by exception to occur including “Nick Charts” and “*Andon* lights”. These tools made it visibly evident when plans were deviating allowing energy and effort to focus on the resolution of those problems. These tools effectively highlighted problems and signaled a call for help to address the cross-functional issues with the people impacted involved rather than the entire team needing to be involved.

Discussion

Value stream mapping and *obeya* were effective enablers of project execution through the plan, do, check, adjust method of problem solving. The project was completed ahead of schedule in 17 months, instead of 18 months as scheduled, and quicker than the typical 24 months of similar projects. All other objectives were either met or exceeded.

Using the *obeya* was a new approach to managing a project within Turbine Gen, which presented challenges. These challenges included getting team members engaged in the new process including earlier involvement and transfers of accountability and decision making between functions. The integration achieved through the value stream mapping workshop and *obeya* process helped to overcome these challenges. The effectiveness of the approach with the understanding of the interdependencies facilitated the ability to get buy in from team members as the value of the tool was evident.

There were several key enablers that led to the success of the *obeya* process for project management. There was executive support for the project, which conveyed to the team members that this approach should be taken seriously and helped to overcome barriers to success.

Additionally, there was a large focus on getting engagement of the team members to see the value of the tools to support them to effectively do their work. This was achieved through the approach taken in introducing the tools and the managing style of the project manager. By only standardizing at a high level the sections of the room it enabled the team members to develop and modify the tools so that they enabled them to do their work effectively. This was facilitated by having a project manager who was an effective coach in getting people to see the value of the tools by encouraging and giving credit to the team members who developed effective tools, such as “Nick Charts”. The standardization that emerged through the *obeya* process was a result of team members seeing the value of tools and using the tools that supported their work and made their jobs easier. This approach of coaching to get employee engagement while providing support to work effectively, with an understanding of customers and downstream partners, enabled the project manager to earn the respect of team members.

The visual nature of the *obeya* makes it clear what everyone needs to do for the project to be successful, which led to greater collaboration ensuring the project goals were realized. This contrasts with traditional project management where the leader has to serve as the coordinator between functions and focuses efforts on trying to determine why commitments aren’t being met. Managing by exception is effective at focusing on the issues that need resolution rather than focusing time and effort on the tasks that are on schedule. This visibility ensured that if alignment wasn’t achieved it could be recognized and actions could be taken to resolve the issue much quicker than when traditional means of coordination were utilized.

By the team members posting information and developing the tools to help them effectively execute the project the visual management wasn’t always effective to communicate to people outside of the project. Though it is helpful if management can understand the visual management, it is more important that the system supports the team to be effective. That is why it is important to let the standards used evolve out of what is effective for the team rather than imposed from top-down to standardize for communication to management. Lean aims to support the people closest to the work (Spear and Bowen 1999; Liker 2004). This includes signally to management when help is needed, but that should not replace effective team functioning. Supporting the team’s ability to function is the primary goal of the *obeya* and communication to others outside of the project is a secondary goal.

Value stream mapping and *obeya* are effective enablers of achieving objectives in product development projects while supporting the use of lean principles. These tools facilitate the coordination and integration of the product development process, which are some of the greatest impediments to the problem solving process. These tools support and enable people to do their work effectively and efficiently.

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Chapter 4

The Technical System of Lean: How Standardization can Support Problem Solving and People Development in Complex Product Development

Introduction

As global competition increases, customers become more demanding seeking niche products, and technology developments occur rapidly (Wheelwright and Clark 1992), firms can develop a competitive advantage by shortening lead time from concept to market while developing innovative products with improved quality and lowered costs. One approach to achieving these goals is through the introduction of lean principles in product development (Wheelwright and Clark 1992; Morgan and Liker 2006; Barrett, Musso et al. 2009; Morgan and Liker 2011). Introducing lean principles into product development is a common approach for companies that have had success with lean manufacturing. This is a logical step as the magnitude of the costs and cycle time of development projects provides a rich target of improvement opportunities. Lean implementations often begin with the technical process (Liker 2004), including the use of standardization.

Lean Thinking identifies five lean principles, focusing on value, to aid in the transition of traditional organizations to lean organizations. These principles are specifying customer value, identifying the value stream, making value flow without interruptions, letting the customer pull value, and pursuing perfection (Womack and Jones 2003). Specifying value from the customer’s perspective ensures that a common definition of value is utilized throughout the process and that the customer is willing to pay for it. The value stream includes all of the tasks necessary to produce the product for the customer, including both value added activities and non-value added activities, which can be eliminated or reduced. Aligning tasks in the value added sequence reduces opportunities for problems to occur, allows problems to be found and solved sooner, and shortens the overall time for a product to be produced. This shortened lead time allows customers to pull the product as wanted and allows the organization to respond to changes in customer demand. As wasteful activities are removed from the value stream more opportunities for improvement become visible and can continue to be taken allowing for continuous improvement of the process.

The focus on value and removal of waste is the result of a technical framing of lean looking at the process with the purpose of solving problems to eliminate waste. Liker defines the philosophy behind lean as the Toyota Way consisting of 14 principles categorized into the 4P model of philosophy, process, people, and problem solving (Liker 2004). The foundational "philosophy" focuses on long term thinking; "process" is reflective of that the right process will produce the right results; "people" emphasizes that value is added to the organization by developing people and partners; and "problem solving" focuses on continuous improvement. Most organizations understanding of lean is at the process level with a technical viewpoint (Liker 2004). The technical lean tools are the countermeasures developed by Toyota to solve their unique problems in their environmental context (Spear and Bowen 1999; Liker 2004). From this view of lean it is easy to conclude that it doesn't matter whether "lean experts" or engineers doing the product development are solving the problems, as long as the problems are being solved. This has often resulted in implementation of technical lean tools achieving initial gains that were not continuously improved upon or sustained (Liker and Rother 2011; Liker and Franz 2011). This lack of sustainability led to a change in the reward criteria for the Shingo Prize for Operational Excellence to add the criteria of creating a culture of continuous improvement as past winners, who had not embedded lean into their culture, had failed to maintain their gains[1]. In order to transform to a lean culture there needs to be a deeper understanding of lean principles beyond eliminating waste.

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[1]Robert Miller, Executive Director of the Shingo Prize, interviewed on radiolean.com, July, 2010. *"About 3 years ago we felt we needed deep reflection. After 19 or 20 years we went back and did a significant study of the organizations that had received the Shingo Prize to determine which ones had sustained the level of excellence that they demonstrated at the time they were*

The culture of continuous improvement, *kaizen*, is achieved through teaching, coaching, and enabling people to solve problems. Problems are identified as the gap between actual conditions and the standard (Liker and Hoseus 2008; Shook 2008; Liker and Franz 2011). The first phase of *kaizen* is establishing standards, systems, and procedures to maintain the standards through problem solving any deviation. When the standard is achieved on a consistent basis a new standard is established to increase capability beyond the previous standard with the problem solving efforts focused on improving capabilities. When this standard is achieved on a consistent basis the next more challenging standard is established resulting in continuous improvement of the organization's capabilities (Liker and Hoseus 2008).

A common misconception is that standardization kills creativity by defining all of the tasks in detail (Adler, Mandelbaum et al. 1996; Sobek, Liker et al. 1998; Morgan and Liker 2006). Concerns about standardization killing innovation result from the creation of coercive bureaucracies, which use rules, procedures, and structures to control employees to ensure that they do the right thing (Adler 1999). However, standardization can also be used to create an enabling bureaucracy, which use rules, procedures, and structure to support the work of employees (Adler 1999). Standardizing common aspects across projects allows product teams to focus creative efforts on the unique aspects of projects (Adler, Mandelbaum et al. 1996; Morgan and Liker 2006).

Standardization is what enables Toyota's product development process to be flexible, fast, and predictable with high quality and low cost (Morgan and Liker 2006). Design standardization allows parts to be shared across platforms with modularity and engineering checklists for design for manufacturing standards (Sobek, Liker et al. 1998; Morgan and Liker 2006). Essentially design standards place constraints on the solution space and force creative thinking to achieve the product objectives within these constraints. Process and engineering skill set standardization facilitate coordination,

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evaluated and which ones had not...We were quite surprised, even disappointed that a large percentage of those organizations that had been recognized had not been able to keep up and not been able to move forward and in fact lost ground ... We studied those companies and found that a very large percentage of those we had evaluated were experts at implementing tools of lean but had not deeply embedded them into their culture."

integration, flexibility, and effective performance (Sobek, Liker et al. 1998; Morgan and Liker 2006). The standard skill set is a baseline of skills and knowledge, as you would want in any world class athlete or artist. Standardization can enable flexibility allowing the organization to adjust and innovate as new information is obtained (Adler, Mandelbaum et al. 1996; Reinertsen 1997; Sobek, Liker et al. 1998; Morgan and Liker 2006; May 2007; Smith 2007; Reinertsen 2009).

Research Objectives

Though there has been extensive research into understanding and defining lean product development systems (Ward, Liker et al. 1995; Sobek 1997; Sobek, Liker et al. 1998; Sobek, Ward et al. 1999; Morgan 2002; Morgan and Liker 2006; Ward 2007) there has been limited investigation into how organizations can transform to lean product development systems (Baker 2011; Morgan and Liker 2011). Experts in this field emphasize that lean is a way of thinking and a cultural transformation, not a toolkit (Womack and Jones 2003; Liker 2004; Morgan and Liker 2006; Ward 2007; Liker and Hoseus 2008; Liker and Franz 2011; Morgan and Liker 2011). This study addresses the call for in-depth case study research, by Morgan and Liker, within lean product development, particularly for the relationship between standardization and innovation (Morgan and Liker 2011). This study also addresses the call to continue the study of how technology can be developed and designed to support the joint optimization of socio-technical systems, by Pasmore, Francis, et al. (Pasmore, Francis et al. 1982). This study analyzes how the technical system design can enable lean thinking. This research aims to better understand how standardization can support lean principles in complex product development and advanced research environments. This will be addressed through the following research questions:

1. How can standardization simultaneously be used to create predictability while enabling innovation?
2. How can standardization be used as a mechanism to achieve integration and coordination?

3. How can standardization support problem solving?
4. How can standardization enable organizational learning?

Theoretical Discussion

Lean

Lean Product Development

Lean product development is a development system designed to enable people development, problem solving, and organizational learning allowing the organization to achieve its purpose. Lean systems seek to have problems identified as soon as possible (Liker 2004) and solved by the people closest to the problem since they have the most thorough understanding of the issues (Spear and Bowen 1999; Liker and Hoseus 2008). This includes making people who are managing or doing the value added work of the organization responsible and accountable for solving problems, while ensuring that they are given the resources and support needed to do their jobs successfully (Shook 2008; Shook 2010). The role of lean tools is to make problems visible, enable people to solve them, and capture what is learned throughout the organization (Liker 2004). This design can be modeled as a socio-technical system, which recognizes the interdependencies and influences between the social and technical systems of the organization (Pasmore, Francis et al. 1982; Morgan 1997; Daft 2004). For organizations to be most effective, they should be designed with social and technical subsystems fitting the needs of one another and the organization's purpose (Pasmore, Francis et al. 1982). An example of an integrated socio-technical product development system is Toyota's product development system as described by Morgan and Liker as consisting of three integrated subsystems that are: process, people, and tools (Morgan and Liker 2006).

Role of Standardization in Lean

Standardization has multiple uses including enabling problem solving, establishing stability allowing for continuous improvement, and enabling integration. As with any lean tool an understanding of the intent and context of the use of the tool is important to achieve the expected benefits.

Standardization facilitates problem solving by providing a standard against which to compare the actual situation thereby highlighting problems. In fact, in the Toyota system a gap between the standard and actual is the definition of a problem (Liker and Hoseus 2008). Visual management shows the standard versus actual to make it immediately obvious when work is deviating from the standard (Hirano 1995; Liker 2004; Liker and Meier 2006; Liker and Hoseus 2008; Rother 2010; Liker and Franz 2011). Without a standard condition to compare actual performance to there is not a problem to resolve (Liker and Hoseus 2008; Shook 2008; Rother 2010; Liker and Franz 2011).

Problem solving is executed through plan, do, check, adjust (PDCA) cycles (Shook 2008; Rother 2010; Liker and Franz 2011). The ability to plan, try something, check, and adjust is especially important in uncertain environments. Rother describes this process of continuous improvement, observed at Toyota, as a set of practiced routines (*kata*) driving toward explicit "target conditions" (Rother 2010). He defines as target conditions simple and measureable desired future states on the path towards your vision. Since the environment is always changing the path between the current state and the final results is unclear. This level of uncertainty leads to an approach of engaging in several small plan-do-check-adjust (PDCA) cycles focused on achieving shorter-term target conditions. This allows learning and adjustment, based on that learning, to find the path to the target condition. Toyota places emphasis on conducting quick PDCA loops allowing for greater learning to occur and for what is being learned to be included in the plan stage of the next PDCA cycle (Rother 2010). The checking and adjusting phases of the cycle allow for correction if the plan needs adjusting. The shorter the PDCA loops the quicker the learning can be incorporated into the next phase of problem solving.

In order to create a culture of continuous improvement, basic process stability must first be achieved. A focus on stability ensures a consistent level of capability to produce consistent results to create a foundation for improvement (Liker and Meier 2006). Standardization to drive predictable outcomes is one means of achieving stability (Morgan 2002). If the process has high levels of variation using standardization as a means to achieve stability will not be effective (Liker and Meier 2006). When this is the case problems may need to be solved to achieve stability and allow standardization or the variation may need to be isolated with pieces of the process standardized (Adler, Mandelbaum et al. 1996; Reinertsen 1997; Liker and Meier 2006; Smith 2007). Isolating the non-value added variation from the value added variation, within product development can allow the non-value added variation to be addressed resulting in stability and predictable outcomes (Adler, Mandelbaum et al. 1996). When initial stability is achieved flow between process steps can be created, which will expose problems and when they are solved will lead to greater levels of stability (Womack and Jones 2003; Liker and Meier 2006). This allows greater flow between processes and leads to the next level of problems being exposed allowing them to be solved.

Standardization is also an effective means of achieving integration in complex environments such as product development. Integration is the unity of effort and resolution of conflict to overcome the differentiation of orientations towards goals, time (short term versus long term), etc. that result from high levels of specialization in different functional departments (Lawrence and Lorsch 1969). Toyota has been able to achieve integration within projects as well as across projects leading to a competitive advantage. This is achieved through the use of several mechanisms that allow for cross-functional integration while developing functional expertise. These mechanisms include mutual adjustment, close supervision, integrative leadership, standardized skills, standard work processes, and design standards (Sobek, Liker et al. 1998).

Process standards are utilized as part of a collection of methods to ensure effective cross-functional coordination throughout the development process. Having an understanding of how and when the work gets done, everyone's specific role and responsibility, interdependencies, inputs, and outputs for each task allows coordination and integration to occur across functions (Sobek, Liker et al. 1998; Morgan and Liker 2006). The consistency that comes with standardized processes leads to better integration across functions as an understanding of what is expected and what will be delivered is clear (Morgan and Liker 2006).

Standardized work plans should be simple, relevant, and up to date making them more likely to be followed. Having simple plans allows for flexibility, common understanding, and continuous improvement, while the deadlines of regular milestones keep the project on track. The use of standards saves the engineers from reinventing the process for each distinct project. The standardized processes are developed and maintained by the people who use them. Since the reason for the standards is understood, engineers can deviate from them as long as consistency and predictability for the other functions is maintained. The use of design standards increases predictability throughout the organization, including across vehicle subsystems and between product and manufacturing engineers (Sobek, Liker et al. 1998).

Coercive versus Enabling Bureaucracy

The bureaucratic form of an organization is designed from the technical standpoint to obtain efficiency through the rational organization of work (Weber, Henderson et al. 1947). Coercive bureaucracies use rules, procedures and structure to control employees to ensure that they do the right thing. Enabling bureaucracies use rules, procedures and structure to support the work of employees (Adler 1999). The approach towards the formalization of the written rules, procedures, and instructions can lead to coercive or enabling bureaucracies (Adler and Borys 1996). Formalization designed to highlight deviations to superiors that employees' actions are out of compliance will lead to a coercive bureaucracy. Whereas formalization designed to help employees determine if the process is operating to standard, help them solve problems that inevitably occur, and help them identify improvement opportunities will lead to an enabling bureaucracy (Adler and Borys 1996).

Misalignment of task requirements and organizational design can lead to coercive bureaucracies (Adler and Borys 1996). As levels of interdependence between tasks increase from pooled, to sequential, to reciprocal the complexity within the organization increases (Thompson 1967). Pooled interdependence exists when the parts of the organization work independently, though if any part doesn't perform adequately it has an impact on the entire organization's ability to perform adequately. Sequential interdependence occurs when the output for one part of the organization is the input for another part of the organization. And reciprocal interdependence occurs when the outputs of one part are the inputs to another and the outputs of that become the inputs for the first and so on. The quality of the reciprocal interaction ultimately determines the quality of the output (Thompson 1967).

Different coordination mechanisms are appropriate for varying levels of interdependence. Standardization, which involves the establishment of routines or rules which constrain the action of each part into paths consistent with those taken by others in the interdependent relationship, is appropriate for pooled interdependence (March and Simon 1958; Thompson 1967). To be effective for achieving coordination, standardization should only be applied in stable and repetitive situations (Thompson 1967). Coordination by plan, which involves the establishment of schedules for the interdependent unit to guide actions, is appropriate for sequential interdependence (March and Simon 1958; Thompson 1967). Coordination by mutual adjustment, which involves the transmission of new information during the process of action, is appropriate for reciprocal interdependence (March and Simon 1958; Thompson 1967). The use of coordination mechanisms appropriate for lower levels of interdependence for higher levels of interdependence will not be effective and will likely result in a coercive bureaucracy.

Table 4.4: Interdependence Matched with the Appropriate Lean Coordination Mechanism

Interdependence Level	Coordination Mechanism	Lean Example
Pooled	Standardization	Standardization
Sequential	By Plan	Milestones for alignment & coordination
Reciprocal	Mutual Adjustment	*Obeya* - mutual adjustment when creating the plan, weekly as the project is being managed.

The work done within organizations varies from routine to non-routine based on the number of exceptions to the work and the analyzability of the exceptions that do occur (Perrow 1967). Work with few exceptions that are analyzable is routine, whereas work with many exceptions that are hard to analyze is non-routine (Perrow 1967). Organizations often seek to make non-routine work more routine by decreasing the number of exceptions and/or by increasing the knowledge of exceptions that occur making the exceptions more analyzable (Perrow 1967). If tasks are made more routine and as a result do not fit with the internal or external environments or with the organization's strategy the organization will not be as effective (Galbraith 1973; Pasmore, Francis et al. 1982) and may become a coercive bureaucracy. If the task requirements are such that aspects of the non-routine work can be made routine and fit with the environment and strategy the work can become more predictable and facilitate the creation of an enabling bureaucracy.

Research Setting & Methodology

This research develops a theoretical model for the design of technical systems to support lean principles within product development based on literature and case studies (Eisenhardt 1989). This is an iterative process of theory development followed by field research, refinement of the theory and additional field research with multiple cycles (Eisenhardt 1989). The case studies consist of examples from two organizations and comparisons both across organizations and within one organization that had some very different examples with different levels of success.

Case Selection and Overview

The cases were selected based on their approaches to lean product development deployment, as well as to the accessibility of data (Eisenhardt 1989; Yin 2003). The cases discussed in this study are two organizations that had success with lean in manufacturing and saw value in the use of lean principles within product development both using standardization as part of their implementation efforts. One organization is a Fortune 500 company in the consumer goods industry, further referred to as Consumer Goods, with product development dispersed globally. The other organization is a wholly owned subsidiary of a Fortune 500 company that produces gas turbine generators, further referred to as Turbine Gen, with product development activities centralized in one location. Both organizations have historically been very successful, have had success with lean manufacturing, and viewed the implementation of lean methodology in product development as an opportunity to improve operational performance.

Data Collection

Data was collected through participant observation, direct observation, review of documentation and interviews (Yin 2003). The researcher was an employee of Consumer Goods involved with some of the efforts described in the case studies. Observations within Consumer Goods were documented as field notes. Internal documentation related to the efforts was reviewed and unstructured interviews were conducted with participants throughout Consumer Goods. Direct observations documented in field notes and unstructured interviews were conducted at Turbine Gen over the course of a five day on-site visit. The researcher was also able to review the responses of an internal Turbine Gen questionnaire that 70 participants responded to.

Case Studies

Case Study 1: Consumer Goods Standardization Efforts

Case Description

Coercive Standardization: Attempting to Standardize the Entire Product Development Process

Consumer Goods developed a global product quality management system defining, documenting, and standardizing the processes for developing products. This included the identification of all sources of variation so that the variation could be eliminated or controlled. The standardization also included informing people of what they are accountable for so that predictability could be achieved through process compliance which would be audited on an annual basis. The audits were planned to begin in 2010, which was outside of the scope of this study. The detailed standardized processes were documented in workflow process maps that could be navigated on-line to link connected processes. Some engineers felt that the level of detail was being used so that anyone could develop products rather than valuing the acquired experience of engineers. Additionally, with high levels of detail it wasn't clear what was important. Navigating through connected processes with high levels of detail also led to confusion as engineers got lost while navigating through the cumbersome processes. Engineers did what they needed to do to complete their projects, which didn't necessarily include following the processes that they didn't find of value.

Standardizing the Routine Aspects of Product Development

The global product quality management system at Consumer Goods established an infrastructure that allowed developed processes to be leveraged across the organization. Whereas this was a poor environmental fit for tasks with high levels of interdependence, it allowed non-value added variation to be removed from routine aspects of the development process to achieve coordination while maintaining flexibility to adjust in the uncertain product development environment. Examples of routine support processes that were standardized and used by engineers to effectively support their work include FMEAs and A3s. Failure mode and effects analysis (FMEA) is used to identify all possible failures, so that actions can be taken to eliminate or reduce failures (Tague 2004). A3 is a problem solving methodology based on the scientific method with direct observations of the problem, presentation of data, proposed countermeasures, and follow up with checking and adjusting based on the results (Shook 2008). The processes and forms for these processes were standardized, including examples of 'best practice' examples to use as a template. Coaching for how to use these processes was available from six sigma black-belts within Consumer Goods when requested by engineers. These processes were used as appropriate and when engineers needed them to support their work to effectively complete product development projects.

Within the advanced research & development (R&D) function of the product development organization of Consumer Goods there was a subgroup of the global product quality management system working on processes for the advanced R&D organization. The researcher was a member of this group conducting research through participant observation. This group focused on standardizing common aspects across projects rather than focusing on standardizing and controlling the variation in all processes. The advanced R&D group became convinced that standardizing lower-level tasks would lead to greater predictability and flexibility (Morgan and Liker 2006). The inherently higher levels of uncertainty within advanced R&D compared to the product development organization bringing specific designs to market along with a greater emphasis on lean led to the focus on standardizing the common routine aspects of the research process. The common aspects to standardize were identified by the engineers, researchers, and lab technicians doing the work. These included lab testing processes, prototype development, common project charters, and literature searches.

Enabling Processes: The Case of Design Guides

Within product development and advanced R&D environments one of the greatest wastes is recreating knowledge that was previously created and discarded (Ward 2007). The ability to share knowledge across projects and time is critically important for effective product development (Wheelwright and Clark 1992). The advanced R&D engineers, who aligned efforts with other product development engineers, within Consumer Goods saw the infrastructure created by the global standardization efforts as an opportunity to develop a design guide system for knowledge management that could be leveraged across projects and time.

There were several self-initiated, disconnected design guide and other knowledge management efforts across different engineering groups within Consumer Goods. In 2007 a group of engineers saw value in aligning these efforts, so that the acquired knowledge could be shared across the organization. They volunteered and recruited other engineers across functions, who saw value in the development of a system, to develop a knowledge management system. This group was able to gain sponsorship for the efforts through the global product quality management system.

Sections of the design guides were standardized to allow the information to be found and pulled as needed, whereas other sections were open to encourage engineers to capture all information that they believed to be relevant. The standardized sections included purpose, scope, keywords, references, definitions and abbreviations, and contributors. Some of these sections were standardized to ensure that the information could be found when searched for through IT systems and others so that the information could be traced to the original sources if needed. Including all of the contributors also ensures that credit is given to those who generated the knowledge. The standard design guide templates also included sections that were specific to each document. This was to be flexible to the specific needs of each module or technology for which a design guide was developed. Within the flexible sections of the design guide why information was relevant was also included.

It was expected that many engineers would contribute to design guides, but each had a single owner who was responsible for maintaining and updating the design guides. This ownership structure was aligned with module owners and technical leads both within product groups and in cross-product groups. An example of a product specific system that would have a design guide was tumble patterns within dryers. Cross-product examples would include materials and controls and electronics. Controls and electronic design guides would be for hardware and software designs.

An example of a design guide within materials for steel was on the topic of heat treatment. This included descriptions of the different heat treatments processes for hardness. The process descriptions included performance characteristics noting when the method could be used effectively and when a method shouldn't be used. The design guide also included information on geometry considerations and stress and environmental considerations amongst other things. Because Consumer Goods has corrosion concerns the design guide included information about needing a narrower tempering temperature (processing method for heat treatment) range than industry standards along with information on what to consider when selecting a tempering temperature.

The design guide process was designed to be used when engineers or researchers needed knowledge to answer a question or solve a problem. It was used to minimize the recreation of knowledge from knowledge not being captured in a form that made it easy to find and understood in context, so that it could be reused in different contexts. This was used by engineers when they needed knowledge and gave them a format to capture their knowledge that made it accessible across the organization, which the lack of prior was a common frustration of many engineers. This allowed knowledge to be captured and pulled as needed across projects and time throughout Consumer Goods with credit and traceability to the sources of knowledge creation.

Enabling Support Processes: Speeding up the Experimental Learning Cycle via Testing

The objective of most R&D environments is to create usable knowledge for the development of products. Improvement opportunities to reduce the lead time of knowledge creation are frequently support processes that can speed up the rates of learning cycles.

Consumer Goods focused on bringing stability to the research process by standardizing common routine aspects. One of the areas that this was done was lab-testing processes. The preparation activities, testing processes, and analysis processes were standardized to have greater understanding for scheduling within the laboratory and for planning the projects that the lab was supporting. This didn't entail that every research project had the same testing plan, but that the tasks to conduct testing were understood allowing for more predictable testing plans to be created. Visual management was used for scheduling testing, which included tracking actual testing durations compared to planned testing durations along with upcoming testing. Red dots were used to indicate jobs that had problems that needed to be resolved. Visibility into the testing processes enabled scheduling to best support the research projects.

Case Analysis

The complexity and levels of routineness vary amongst different environments and is dependent not only on the external environment, but on how the organization is structured and the resulting internal environment. The central quality organization, working from a paradigm of control, went too far in attempting to create a coercive bureaucracy that detailed all the processes and sub-processes of R&D and engineering. This was mostly rejected by the organization. However, even in highly complex non-routine environments there are routine aspects of work and Consumer Goods did have success in these areas. By standardizing the common routine aspects the benefits of standardization can be realized while maintaining the flexibility to adjust and be adaptable in complex environments. The standardizing of common routine tasks also creates predictability and enables coordination as there is better understanding of the task characteristics.

In the non-routine environment of advanced research Consumer Goods focused on standardizing the common and routine aspects of the work to make it more predictable by removing the non-value-added variation (Perrow 1967; Adler, Mandelbaum et al. 1996). Similarly, the successful standardization efforts in product development were the routine aspects that were used in an enabling way. This enabled better coordination and integration as what to expect was understood for those aspects of projects creating a more stable process (Liker and Meier 2006). Standardizing the common tasks allowed engineers to focus on the unique aspects of each project potentially leading to the development of more innovative products (Adler, Mandelbaum et al. 1996).

The design guide system used standardization for the routine sections of documents as was necessary to create a structure for coordination that allowed knowledge to be found when searched for. At the same time the documents were flexible to enable engineers to capture the relevant knowledge for different technologies and modules. This flexibility allowed the guides to be adaptable to capture knowledge effectively across different technologies and products. Capturing knowledge in a way that it is usable and can be found enables innovation as efforts can build off of the existing knowledge base. Furthermore, the engineers are building off of the knowledge created by others and are able to capture it in a way that allows it to be transferred to others.

The development of the design guide system is an example of the creation of a standard by people doing the work to enable them to do their work more effectively. Engineers are able to pull knowledge as needed to effectively support their work. In this way the infrastructure within Consumer Goods was used in an enabling way (Adler and Borys 1996).

Standardization that facilitates quicker experimental testing and thus learning can enable innovation. Quicker learning cycles enable more knowledge to be created in a shorter time period. The frame of analysis should be at the research or development project level and not at optimizing testing processes. As the costs of the delay in lead time for the research and development projects are usually far greater than underutilizing the testing resources (Hayes, Wheelwright et al. 1988). This is similar to how exploring multiple alternatives in set-based concurrent engineering is more efficient than the traditional point-based design, though at the surface it may initially appear wasteful (Sobek, Ward et al. 1999).

Understanding of the lab processes by engineers and visibility to testing schedules enable coordination and integration between laboratory testing and engineers. The highlighting of problems and identifying problems by comparing actual performance to the scheduled performance allows the problems to be identified and solved quickly, leading to continuous improvement and organizational learning.

Case Study 2: Turbine Gen Standardization Efforts

Case Description

Turbine Gen selected two product development programs as pilots for lean. One was a component—an injector to inject fuel into the turbine. While it may sound simple it is actually a very complex device requiring deep knowledge of combustion. The second was an uprate of a turbine to increase its power generation and efficiency. The culture of Turbine Gen was quite organic and teamwork was common, though teamwork across functional silos was not nearly as strong as within functions. They had a standardized stage-gate process, but did not impose the details on programs. Both programs started with value stream mapping and both established *obeya* (big room) processes for weekly cross-functional meetings to increase coordination and teamwork across functions. Beyond that they decided to take an organic, enabling approach to implementation and did not prescribe a process used in the *obeya*.

Enabling Support Processes: Speeding up the Experimental Learning Cycle via Testing

Within Turbine Gen in the value stream mapping workshop they identified the iterative testing-redesign stage as a bottleneck for fuel injector development. The complexity of the fuel injector required several iterations of design and testing. The future state value stream map led to the development of a dedicated prototype test cell, which included the development of an innovative visual *kanban* board to schedule the work through the test cell. Turbine Gen standardized the requirements necessary to be scheduled in the test cell, which enabled predictability in the completion of jobs. Color coded dots were used to highlight problems, orange for an issue – red for a bad issue. This highlighted problems, so they could be addressed in the daily 10 minute meetings.

Standardization in Obeya

Turbine Gen effectively used an *obeya* to execute a product development project for the turbine uprate project which was more all encompassing. The team utilized visual management to display targets for cost, quality, and schedule thereby establishing standards. Actual performance was compared to the standard target conditions during weekly cross-functional meetings. The gaps between actual and target performances highlighted problems and directed attention to solve the problems. Additionally, "*Andon* lights" were used to highlight problems, to bring awareness that they needed to be solved.

Within and across *obeyas* the standards that were developed at Turbine Gen emerged from the borrowing and improving of tools that effectively supported the work. For example, "Nick Charts" were created to provide a visual display of deliverables, status, and who is accountable for the work. Originally, Nick created this tool and others within that *obeya* started to use the tool. Additionally, it was improved by Jill with the addition of "Jill's cool mint green", which was used to show that work was on schedule, but not actively being worked on, to further improve the effectiveness at conveying information.

The standards from one *obeya* were borrowed and used in other *obeyas*. This was the case with "Nick charts" and "*Andon* lights". The tools being used varied across *obeyas* since different tools or adapted tools best supported the work of each project team.

Case Analysis

Similar to Consumer Goods the use of standardization was effective to reduce the lead time of knowledge creation through speeding up the rate of learning cycles at Turbine Gen. Faster learning through quicker experimental testing cycles allows more knowledge to be created in a shorter timeframe. However, Turbine Gen did not stumble like Consumer Goods by creating detailed structure where it did not fit.

Visual management within the *obeya* and prototype test cell enabled managing by exception to occur. By only focusing on an issue when it deviates from the target standard condition, thus identifying a problem (Liker and Hoseus 2008; Rother 2010; Liker and Franz 2011), energy can be focused on solving problems rather than discussing things that are on target. By establishing "*Andon* lights" as the standard for highlighting problems it was immediately obvious that a problem existed when a yellow or red "*Andon* light" was displayed. This facilitates problems to be identified and solved quickly, leading to continuous improvement and organizational learning. The establishment of target conditions by a cross-functional team enabled coordination & integration to occur as team members established a mutual understanding of how their work fit together and the resulting impact of not meeting commitments.

The standardization of deliverables and the status of those deliverables facilitated coordination and integration as a mutual understanding of the tasks and the interdependencies amongst those tasks are understood by the cross-functional team that uses them. The visual indicator of when tasks are not on target highlights when problems need to be solved.

By the development of a standard for an effective way to capture deliverables, status, and accountability the organizational knowledge was captured and able to spread within that *obeya* and across *obeyas*. The improvement of the standard and capturing it as the new standard also allows the knowledge of that improvement to spread across the organization. By adapting the standard to best support the work within each *obeya* the *yokoten* (across everywhere) process of sharing practices in organizations considering the environmental context is practiced (Liker and Hoseus 2008; Liker and Franz 2011).

Discussion

For standardization to be effective it needs to fit with the task requirements, intent of the effort, and used in an enabling way to support work. If this is achieved innovation can occur while maintaining predictability, which facilitates coordination and integration across functions while the standards transfer the organization's explicit knowledge across the organization.

The Bureaucracy of Consumer Goods: Coercive and/or Enabling?

Product development is a complex activity with high levels of reciprocal interdependence across functions. Attempts to control the inherent variation from the uncertainty that exists in this environment through detailing all required tasks was not effective at Consumer Goods as it was cumbersome to follow the detailed processes and didn't allow for adjustments as new information was obtained. It should be expected that a coordination mechanism appropriate for pooled interdependence that didn't support the task demands in a reciprocal interdependence environment would not be effective (March and Simon 1958; Thompson 1967).

In addition to the poor fit with the environment the approach towards informing engineers of their accountabilities and auditing for process compliance is expected to lead to a coercive bureaucracy as predictability is sought through controlling engineers' actions (Adler and Borys 1996). Coercive bureaucracies typically result in employees being de-motivated and the stifling of creativity (Adler and Borys 1996). Additionally, the controlling of all variation through the detailing of all tasks doesn't allow for innovation to occur.

The development of standards by a centralized function to be deployed throughout the organization aligns with the scientific management principle that predictability can be achieved through the design of processes by experts (Taylor 1915). These principles were developed in a more routine environment with lower levels of interdependence than product development. Though Taylor was open to updating and improving standards if a better way could be found and proven scientifically, the standards were still controlled by experts and given to the people doing the work. Within the lean literature it is emphasized that standards should be controlled by the people closest to the work with continuous improvement of the standards and with adaptation to unique contexts (Sobek, Liker et al. 1998; Liker and Franz 2011).

Additionally, the auditing of processes on an annual basis to ensure process compliance assumes that any deviation is a result of people not following the process with the proper countermeasure being that the process should be followed. Part of an effective problem solving process is ensuring that the standards are effective at supporting the work and continuously improving the standards to better support the work or to develop greater capabilities (Liker and Hoseus 2008). Furthermore, auditing on an annual basis will likely result in problems being identified far from the root causes of problems, both in time and personal, making it difficult for those closest to problems to solve them.

Since the auditing of processes hadn't yet begun at the time of this study, the processes that didn't effectively support engineers in doing their work were frequently not used and the expected negative effects of a coercive bureaucracy were not evident. Rather the standardized processes that were used effectively focused on the routine aspects of the product development process that had the characteristics associated with an enabling bureaucracy. This was the case with FMEAs and A3s that were used by engineers as needed to support development projects with coaching available and 'best practice' examples (Adler and Borys 1996) Similarly, Design Guides standardized the common routine aspects needed for coordination and integration, while being adaptable to support people to work effectively.

A Comparison of Bureaucracies: Consumer Goods and Turbine Gen

In addition to having the right fit for the task requirements and to support the intent standardization should be used in an enabling way to support the work. An effective way to ensure that standards are enabling and to get engagement in parallel is to have the people using the standards develop, maintain, and update the standards. Updating the standards includes both continuously improving them as well as adapting them for use in different environmental contexts. This was the approach used for the development of design guides within Consumer Goods and for all of the standardization that emerged within Turbine Gen.

Within both Consumer Goods and Turbine Gen standardization was used effectively to support the work of engineers to effectively develop products. Though the development of the standards within Consumer Goods was lengthy and many standards were not effectively utilized, those that were effective supported the work across the organization and were enabling. Through Turbine Gen's organic approach to lean the standards that emerged were all enabling, but with low levels of bureaucracy and limited spread across the organization.

Conclusion

Standardization is a foundational piece to the creation of an enabling bureaucracy, which supports problem solving and people development within a lean system. This research has shown examples of how standardization used with an enabling formalization and fit with the task requirements can be used to create predictability while enabling innovation; achieve integration and coordination; support problem solving; and enable organizational learning, which all support the effective execution of work in complex environments such as product development. Future research should look more closely at the role of standardization to enable the development of people through the problem solving process.

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Chapter 5
Conclusion

Summary of Findings

Many organizations seek to introduce lean principles in product development in order to improve quality, lower costs, and shorten lead time (Wheelwright and Clark 1992; Morgan and Liker 2006; Barrett, Musso et al. 2009; Morgan and Liker 2011). Although there has been extensive research into understanding and defining lean product development systems (Ward, Liker et al. 1995; Sobek 1997; Sobek, Liker et al. 1998; Sobek, Ward et al. 1999; Morgan 2002; Morgan and Liker 2006; Ward 2007) there has been limited investigation into how organizations can transform to lean product development systems (Baker 2011; Morgan and Liker 2011). This study seeks to expand this research by analyzing the lean deployment activities of two organizations in the early stages of deploying lean in complex product development.

It is emphasized in lean that there is no one right way to do something and that the approach needs to fit with the objective, culture, and internal and external environments (Liker and Meier 2006; Liker and Franz 2011). Chapter 2 is a comparative case analysis of rational planning and disciplined problem solving approaches to lean deployment that sought to understand advantages and disadvantages to different deployment approaches along with organizational characteristics that enable successful deployment. The rational planning approach created an infrastructure that enabled common routine tasks to be standardized across the organization for greater predictability, coordination, and integration. The disciplined problem solving approach facilitated the learning of lean as a socio-technical system with adaptability to make adjustments in the uncertain environment of product development. Within both organizations the efforts that were successful had characteristics of an enabling bureaucracy of supporting people to do their work (Adler and Borys 1996).

Two of the most commonly used lean product development tools are value stream mapping and *obeya*. Chapter 3 is an in-depth case study within one project of how value stream mapping and *obeya* played a role in the introduction of lean principles while achieving cross-functional integration, one of the biggest barriers to fast and effective cross-functional problem solving. These tools were used in a manner that engaged team members while enabling them to develop and modify tools to best support their work. This approach provided the opportunity to use and learn lean as a socio-technical system with the technical system effectively supporting the culture of problem solving and people development as people learned through the effective development of the product.

Attempts to transform to lean product development systems are attempts to establish an enabling bureaucracy with structures and standards effectively supporting people's work while being adaptable to the unique needs of each development project. Standardization is used within lean for many purposes including enabling problem solving, establishing stability allowing for continuous improvement, and enabling integration. It is a common misunderstanding that standardization kills creativity and establishes coercive bureaucracies, which use standards to control employees to ensure that they do the right thing (Adler 1999). Rather it is the formalization approach and fit with task requirements that influence if bureaucracies are enabling or coercive (Adler 1999). Chapter 4 examines how standardization was used within two organizations and if it was used in enabling or coercive ways. Having the people using the standards develop, maintain, continuously improve, and adapt the standards is an effective way for standards to be enabling and to get engagement.

Future Research

The generalizability of these research findings is limited by the use of case studies, which seek to expand and generalize theories rather than providing statistically significant generalizable conclusions (Yin 2003). The use of contrasting case studies in chapter 2 and multiple case studies in chapter 4 increases the external validity with theoretical replication (Yin 2003). The intent of this research wasn't to determine a cause and effect relationship between lean methodologies and tools, but rather to understand the challenges, organizational characteristics, and approaches that resulted in effective use of lean principles. This understanding can help serve as an example to be learned from when introducing lean principles in other complex environments. This includes other product development and research environments as well as healthcare and any complex environment seeking to transform into a lean organization.

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