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A Framework for the Development of a Model for Successful, Sustained Lean Implementation and Improvement

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A FRAMEWORK FOR THE DEVELOPMENT OF A MODEL FOR SUCCESSFUL, SUSTAINED LEAN IMPLEMENTATION AND IMPROVEMENT

by

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ABSTRACT

Lean is a business philosophy focused on shortening lead times by removing waste and concentrating on value-added processes. When implemented successfully, it not only allows for cost reduction while improving quality, but it can also position a company to achieve tremendous growth. The problem is that though many companies are attempting to implement lean, it is estimated that only 2-3% are achieving the desired level of success. The purpose of this research is to identify the key interrelated components of successful lean transformation. To this end, a thorough literature review was conducted and the findings indicate six key constructs that can act as enablers or inhibitors to implementing and sustaining lean. A theoretical framework was developed that integrates these constructs and develops research propositions for each. A multiple-case study analysis then was used to test the framework on four companies that have achieved successful, sustained results from their lean implementation in order to validate the model. The resulting model provides companies who are planning to implement lean with tangible actions that can be taken to make their lean transformations more successful.

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LIST OF ACRONYMS (or) ABBREVIATIONS

AIW: Accelerated Improvement Workshop

CI: Continuous Improvement

HR: Human Resources

IRB: Institutional Review Board

JIT: Just In Time

NUMMI: New United Motors Manufacturing, Incorporated

PDCA: Plan, Do, Check, Act

PI: Process Improvement

ROI: Return on Investment

SIPOC: Suppliers, Inputs, Process, Outputs, Customers

SME: Subject Matter Expert

SMED: Single Minute Exchange of Dies

TMMK: Toyota Motor Manufacturing Kentucky

TPS: Toyota Production System

TQM: Total Quality Management

VOC: Voice of the Customer

CHAPTER ONE: INTRODUCTION

Lean

Lean is a business philosophy focused on shortening lead times by removing waste and concentrating on value-added processes. When implemented successfully, it can help enable a learning culture engaged in continually improving all aspects of the organization. Lean not only allows for cost reduction while improving quality, it can also position a company to achieve tremendous growth. For these reasons, it has become a key business strategy that many companies are attempting to implement.

Toyota and Lean

Toyota is the company that is recognized for being the epitome of lean. Toyota has created a lean learning culture of employees at all levels focused on continuous improvement in everything they do, every day. At Toyota, "the work is really threefold: making cars, making cars better, and teaching everyone how to make cars better... [Toyota] is always looking to improve the process by which it improves all the other processes" (Fishman, 2006/2007, p. 86).

Toyota has achieved tremendous growth and financial success. They have been profitable every year between 1950 and 2012 except 2009 (Liker and Convis, 2012 and Hoover's, Inc., http://www.hoovers.com/). Toyota has also recently edged out GM for the largest percentage of market share in the U.S. automotive industry (Danova, 2013). Fishman

(2006/2007, p. 87) says about Toyota, "Continuous improvement is tectonic. By constantly questioning how you do things, by constantly tweaking, you don't outflank your competition the next quarter. You outflank them the next decade." A large amount of the literature on lean focuses on the Toyota Production System (TPS) and Toyota philosophies and tools.

In spite of all the literature published on Toyota and lean, very few U.S. companies implementing lean have come close to achieving the level of success that Toyota has. According to Spear and Bowen (1999, p. 97),

> "What's curious is that few manufacturers have managed to imitate Toyota successfully - even though the company has been extraordinarily open about its practices. Hundreds of thousands of executives from thousands of businesses have toured Toyota's plants in Japan and the United States. Frustrated by their inability to replicate Toyota's performance, many visitors assume that the secret of Toyota's success must lie in its cultural roots. But that's just not the case. Other Japanese companies, such as Nissan and Honda, have fallen short of Toyota's standards, and Toyota has successfully introduced its production system all around the world, including in North America..."

One of the gaps in the literature is an analysis of how the few companies other than Toyota that have successfully sustained large-scale Toyota-like improvements have achieved this accomplishment. In general, while the literature provides a number of examples of small, short-term lean improvements made at various companies, there is more research needed on maintaining the gains made through lean improvements. Alagaraja and Egan (2013, p.3) stated that their literature review "exposed the need for examining the sustainability of lean strategy implementation over time." They also stated, "The review identified commonalities and differences, which point to the need for more research specifically as it relates to better understanding the factors that facilitate/hinder lean implementation" (p.6). The goal of this research is to help address both of these gaps.

Problem Statement

Scherrer-Rathje et al. state, "Given that lean is a multi-faceted concept and requires organizations to exert considerable effort along several dimensions simultaneously, it is not surprising that successfully implementing lean is a complex task" (2009, p. 80). There have been very few companies in the world that have even come close to the success that Toyota has achieved through lean. In the U.S., there are only a small number of companies that have approached a similar level of success with lean implementation. In a 2005 survey by the Association for Manufacturing Excellence, only 3% of North American manufacturing companies stated that they were achieving great results with their lean transformation (Koenigsaecker, 2005). Badurdeen and Gregory (2012) suggest that the success rate for lean implementation is around 2%. Therefore, the problem is that though many companies attempt to implement lean, very few achieve the desired results and fewer still are able to sustain those results.

Research Question

In order to explore how more U.S. companies can achieve successful, sustained lean improvement similar to the level of Toyota, it is necessary to look at the limited number of lean implementation success stories to understand how they have managed to achieve this success.

Therefore the overarching research question is:

- How have the few manufacturing companies in the U.S. who have achieved sustained, successful lean performance improvements managed to do so?

- What aspects do they have in common?
- What can other U.S. companies implementing lean learn from them?

Relevance of the Research

The intent of the research is to provide a broader understanding of how U.S. companies can achieve Toyota-like success with lean improvement. The goal is to help provide tangible actions that companies implementing lean can take to help make lean successful and sustainable at their business. To assist with this, a conceptual model was developed and tested.

Research Constructs and Conceptual Model

The research constructs and conceptual model define and describe the focus of the research. To understand what makes lean improvement implementations successful and sustainable, one must understand the enablers and inhibitors of lean improvement. The conceptual model proposes that the following constructs are key enablers or inhibitors of lean improvement:

1. Deployment,
2. Engagement,
3. Training,
4. Processes,

5. Drivers, and
6. Culture

Research Objectives

This research is intended to provide a framework of the key interrelated strategies that contribute to successful lean transformations. The framework can help organizations who are planning on undertaking a lean transformation understand the many factors that contribute to successful and sustained implementation and improvement.

High-Level Research Methodology

To answer the research question and generate the research objectives, a multiple-case study research methodology has been employed. Documents from several cases of companies that have achieved Toyota-like lean improvements were collected and analyzed. Additionally, interviews with key personnel at the case companies were conducted and analyzed.

The quality of the case study analysis is judged based on the four major requirements of case study research (Yin, 2009):

1. Construct validity,
2. Internal validity,
3. External validity, and
4. Reliability

The high-level research methodology is summarized in figure 1, and contains the following major steps:

1. Conduct literature review: The purposes of this step were to determine to what extent the literature addresses the research question and to assist in developing propositions to address the research question.
2. Develop initial model: The purpose of this step was to create a framework for successful, sustained lean improvement based on the propositions developed in the prior step.
3. Develop case study protocol: The purpose of this step was to define the detailed research plan, including what types of data will be collected and analyzed. This step was also a key to establishing construct validity.
4. Collect and analyze documents: Based on the protocol, appropriate documents were collected from each of the case study companies and analyzed.
5. Conduct and analyze interviews: To expand on the data conducted and allow for more in-depth understanding of the cases, interviews were conducted and analyzed.
6. Summarize individual cases: The purpose of this step was to draw conclusions about each individual case, prior to looking for patterns across cases.
7. Compare findings across cases: Once the individual cases were analyzed, the next step was to determine if there are patterns across the cases. The data analysis performed in steps 4-6 also served to achieve internal validity.

8. Draw conclusions: The purpose of this step was to summarize all the case study findings and determine to what extent they support or refute the research propositions. This step also provided external validity.
9. Refine model based on analysis: The purpose of this step was to make any needed modifications to the initial model based on the findings from the case study analysis to make sure the final model aligns with the research findings.
10. Make final recommendations: The purpose of this step was to summarize the relevant findings and how they can be applied in an organization to support successful, sustained lean improvement.

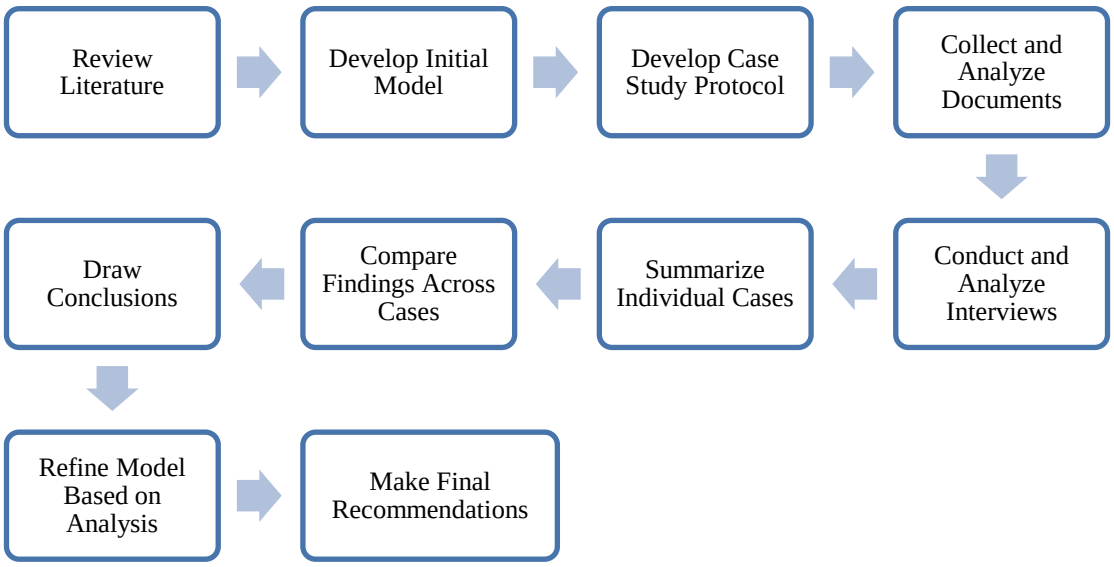


Figure 1: High-Level Research Methodology

Limitations of the Research

Case study research involves in-depth examination of one or more cases to better understand a contemporary phenomenon (Yin, 2009) and extend the findings to broader theory. Utilizing multiple-case studies, as is the case with this research, helps to better enable generalization of the research findings and is more robust than a single-case study approach (Yin, 2009 and Eisenhardt and Graebner, 2007). Additionally, multiple-case studies allow for pattern-matching to be performed in order to reduce potential researcher bias and increase internal validity.

However, though this research is intended be broadly applicable to a variety of manufacturing companies, it would not be possible to test the model on all types of companies. Therefore, two additional techniques were used to help mitigate the risk of the research findings not being applicable to a wide variety of companies. The first was the use of purposeful selection to choose companies that are unusual cases that provide rich information on issues that are critical to the research (Patton, 1990). The second mitigation method was the use of cases from several very different types of industries - two conglomerates with a wide variety of businesses including industrial, medical, dental, environmental, construction, and security equipment – as well as one automotive components manufacturer and one aerospace company. These two approaches increase the likelihood of the research findings to be applicable to a wide set of manufacturing companies.

Definitions of Key Terms

Provided below is a list of key terms that will be utilized in the research and their definitions:

5S: A process of organizing an area so that it contains only the needed materials and a place for everything is clearly designated. The 5S's (roughly translated from Japanese) are: Sort, Straighten, Shine, Standardize, and Sustain.

Andon: A signaling method - audio, visual, or both - to indicate that help is needed because there is an issue.

Gemba: A Japanese word that translates as "actual place." Lean practitioners will frequently refer to the need to "go to the gemba" in order to understand and improve a process. The idea is that it is not possible to improve something from afar; a person needs to go out and experience it to understand what it going on and what needs to be done.

Hoshin Kanri: The Japanese process of policy deployment, which identifies key strategies and needed resources and translates them into specific objectives.

Kaizen: The Japanese term for continuous improvement.

Kanban: A signal to produce or deliver what a downstream customer has taken away. The term kanban roughly translates to "sign" in Japanese. In a kanban system, an important rule is that nothing may be produced or moved without a kanban.

PDCA: Plan, Do, Check, Act – A structured method for problem solving and business improvement popularized by Dr. W. Edwards Deming.

Sensei: The term for a Japanese master teacher who assists in the implementation of lean.

SIPOC: A type of process map used to document a process at a high level. It visually shows the process from suppliers' inputs to the product or service received by the customer. SIPOC stands for Suppliers, Inputs, Process, Outputs, and Customers.

SMED: Single Minute Exchange of Dies – Another term for quick changeover. It is the systematic process of optimizing changeovers to minimize the amount of time that the machine needs to be down (called "internal" time) during the changeover.

Standard Work: The established single best method and sequence for performing a task or process. It represents the optimal, most efficient way to do a job while ensuring quality and safety.

Takt Time: The pace of customer demand; the rate at which the customer pulls a product or service.

Value-Added: Any activity that the customer perceives as enhancing the worth of the final product or service.

Value Stream Mapping: The process of documenting the information and material flows of the value stream as they exist in the current state, identifying opportunities to reduce waste and improve flow, and developing the plan to achieve the improvements (future state).

Visual Management: Management based on tools that provide clear indicators of current process status at a glance so that abnormal conditions can quickly be addressed. Common forms of visual controls include color-coding, andon lights, and labeled outlines taped on the floor.

Voice of the Customer: The process of gathering and understanding customer requirements through various techniques such as market surveys, focus groups, customer interviews, etc.

Waste: Anything that does not add value to a product or service. The seven types of waste are correction, overproduction, motion, inventory, waiting, transportation, and extra processing.

CHAPTER TWO: LITERATURE REVIEW

Introduction

This chapter provides an overview of relevant literature related to the research topic. In order to address the gap of why so few companies in the U.S. have achieved Toyota-like success with their lean improvement, it is important to determine what impacts the success and sustainability of a lean implementation. The literature suggests six key constructs that can act either as enablers of or inhibitors to sustained, successful lean improvement. These constructs are:

1. Deployment,
2. Engagement,
3. Training,
4. Processes,
5. Drivers, and
6. Culture

The literature that relates to each of these constructs is discussed below.

Deployment

Implementation and sustainment of lean improvement requires considerable effort, and begins with deployment. There are instances where someone in an organization who is

passionate about lean or has experience with lean who is not a senior executive will begin a "grass-roots" effort to deploy lean in an organization. The chances for success using this method are slim. Mann (2010) indicates that though it is possible for a lean advocate not in a leadership position to drive enough lean improvement to eventually get some attention and support from top management, it is a precarious proposition with much less chance of succeeding than an effort sanctioned by executive leadership. It is by far preferable for lean transformations to be led from the top down.

Since lean should be strategic rather than tactical, this is another reason why it is critical that executive leadership set the direction. In their single-case study research at a Swiss manufacturer of food processing equipment, Scherrer-Rathje et al. "found that the bottom-up implementation approach to the lean project produced a cascading effect of problems, including lack of senior management commitment, lack of team autonomy, lack of organizational communication of – and interest in – lean" (2009, p. 81).

It is important for people in an organization to see that top leadership supports the change that is being made. Koenigsaecker (2013) indicates that the level of leadership commitment in a lean transformation is a key factor in success, and one of the best ways that senior leadership can demonstrate their commitment is to become directly involved in the implementation by participating in lean improvement activities. Timans et al. (2012) noted that personal experience of top management with lean was a critical success factor in the manufacturing companies they studied in the Netherlands. Emiliani and Emiliani (2013) indicate that top level managers must have a good understanding of lean and not just support it without knowing enough about it to be

effective. They suggest that leaders need to practice lean, similar to practicing an instrument when learning to play it, by applying lean regularly in their day-to-day activities. Art Byrne, former CEO of Wiremold, is cited in Katz (2012) as saying that one of the reasons CEOs need to develop personal lean expertise is to know what is achievable so it is not necessary to accept excuses from employees as to why they cannot make significant improvements. Lindquist (2011) says that continuous improvement begins and ends with top leadership.

Another lean deployment strategy that can have tremendous benefits is the use of senseis. According to Koenigsaecker (2013), senseis should be utilized to help coach executive leaders on lean. One of the early tests of a leader's commitment to lean is his or her willingness to become the student of the sensei (Mann, 2010). Both Koenigsaecker and Byrne (2013) utilized Japanese consultants to help guide their initial lean learning and progress at the companies they led. Jerry Bussell, who is the president of a lean advisory service for CEOs, indicates that another advantage of working with a sensei is being able to be coached by an objective outsider who is not caught up in the politics of the organization (cited in Malone, 2013). Bussell had John Shook, the first American manager at Toyota, mentor and coach him early in his lean development.

Brown (2012) indicates that there are multiple benefits to hiring a sensei. The sensei can be a guide during lean implementation and help a company generate some quick wins to achieve buy-in that lean works. Additionally, having a multiple year contract with a sensei helps to demonstrate that lean takes time and that management is committed to the process.

However, it is important to make sure that external consultants are used appropriately as guides and coaches, not as decision-makers or policy enforcers. Consultants should teach, offer advice, critique, stretch people's thinking, etc., not design the system, make major decisions, or implement the improvements (Mann, 2010).

Another key to successfully implementing lean is to make sure it is a corporate-wide effort. One of the reasons that lean implementation can fail is that some organizations focus their efforts only in manufacturing areas and do not extend lean to the rest of the business. If lean improvements are not made in the front and back ends of the business, to areas like product development, sales and marketing, procurement, shipping, and customer service, then it will be difficult to sustain the improvements in the processes that lie between them. According to Byrne (2013, p. xx),

> "Most people see lean as some 'manufacturing thing,' and so they simply make it one element (usually a minor one) of their overall strategy. Lean gets delegated to operations and gets an increasingly narrow focus on cost or inventory reduction. This greatly reduces its effectiveness. It also explains why only 5 to 7 percent of the companies that attempt to implement lean do so successfully. They are doomed before they start because they see it as only operational and not strategic."

Once an organization has made significant progress implementing lean, a logical next step is to extend lean to its key suppliers. This provides benefits not only in terms of cost and delivery, but provides a company's lean experts with even more opportunities to expand their lean knowledge. Toyota is known for working with its key suppliers to make sure their processes are lean, recognizing that their suppliers are an important part of the extended value stream. They have two specific groups that work with their suppliers on lean improvement

activities and implementing appropriate TPS processes, the Operations Management Consulting Division (OMCD) and the Operations Management Development Division (OMDD) (Marksberry, 2012). These two groups help share TPS philosophies and tools with suppliers and also provide support for making lean improvements there.

Based on the literature review, the following propositions are suggested as keys for deploying lean:

P1 = Successful lean companies drive lean implementation from the top down

P2 = Successful lean companies utilize consultants from established lean companies like Toyota as senseis to help guide their initial learning and lean improvement

P3 = Successful lean companies implement lean in both manufacturing and non-manufacturing areas

P4 = Successful lean companies recognize that once they have made progress on becoming lean internally, they should extend lean implementation to their suppliers

Engagement

Engagement is how people get involved in lean. The level of involvement throughout the organization is one of the important factors in successful lean transformations. People from all areas of the organization need to be engaged in the change to make implementation successful. Research has also shown that employee engagement and sustainment of lean are strongly correlated (Lucey, 2009). Miller (2011) indicates that lean culture results from engaging employees from all parts and levels of the organization in a consistent means of continuous improvement.

Lean implementation and sustainment requires engaging dedicated resources. Koenigsaecker (2013) believes that it is critical to have full-time resources to achieve the desired level of performance with lean. He recommends that 3% of an organization be dedicated full-time to lean. As a company frees up more resources due to lean productivity gains, these resources can be added to the full-time lean group; however, the best resource should be added to the lean group rather than the specific individual freed up by an improvement activity. Koenigsaecker suggests that the full-time improvement team contain some industrial engineers because of their process improvement expertise and some technical people who can do things like build fixtures or design tools to support the lean improvements.

When any major change is being made, communications regarding why the change is being made and what will be involved are keys to getting everyone on board. This is especially true of lean implementation, where people are being asked to think differently about their work every day. Choi and Liker's research (1995) concluded that communication was strongly related to successful implementation of continuous improvement initiatives. In their case study research at a Swiss manufacturer of food processing equipment, Scherrer-Rathje et al. (2009) concluded that the biggest lesson learned when implementing lean is the importance of communicating to employees.

According to Koenigsaecker (2013), it is impossible to over-communicate when making a big strategy change in a business. He recommends using a variety of formats, such as face-to-face communications, company newsletters, and videos. Brown (2012) suggests that

communication, particularly getting feedback on the messages delivered, should occur many more times than one might think is required.

Along with providing regular, ongoing communication on lean, there are a number of essential Human Resource (HR) aspects to successful lean implementation. For example, it is critical that pay and profit-sharing be tied to performance to lean goals, rather than having a piece-rate pay system that leads to the waste of overproduction. It is also necessary to make it clear that there will be no layoffs as a result of lean improvements. If people think they may be working themselves out of a job, they have no incentive to improve. Even Toyota does not guarantee lifetime employment, but does make it clear that layoffs will only occur when it is absolutely necessary for the survival of the business and after all other measures are exhausted. Additionally, when Toyota frees up a person due to kaizen, the best person from the area is removed and given an opportunity to work somewhere else, rather than the traditional western practice of handing the worst person off to some other area (Koenigsaecker, 2013).

HR policies can also be used to support lean through things such as requiring senior leadership participation in a certain number of kaizen events in order to be eligible for bonuses. Promotions and development opportunities can be based on recognizing key contributors to the lean transformation. Hiring practices can support the selection of candidates based on lean values such as problem-solving ability, communications skills, and the ability to work well in teams. In their case study research of lean implementation at an automotive and parts distributor, Alagaraja and Egan (2013) identified that selecting, hiring, and retaining individuals with lean skill sets were keys to the success of implementation in the company they examined.

Oprime et al. (2012) concluded that HR was vitally important when developing implementing continuous improvement programs. Alagaraja (2013) indicates that HR should have a role in developing and deploying lean training programs and also be engaged in designing a reward and recognition system that encourages lean improvement. Liker and Hoseus (2010, p. 35) state that:

> "Toyota's view is that lean management requires more highly developed people and deeper trust than in a mass production system. People become the most critical part of the system and their willingness to identify and solve problems is what drives continuous improvement. As such, HR is arguably the most critical function in the enterprise."

They later expand on this by stating:

> "The Toyota Way views the way the team members are developed as the key competitive competency of the company. And since developing exceptional people is the most important work of the company, the organization charged with that responsibility had better be exceptional."

Though it is imperative that HR be involved in the process, Alagaraja and Egan (2013) indicate that the HR function is frequently left out of major strategy changes. Clearly, there are a number of ways in which HR policies can influence lean implementation and sustainability. It is necessary to recognize that part of getting HR on board with policy changes like these is making sure that they have been given the rationale behind converting to lean (Mann, 2010).

Based on the literature review, the following propositions are suggested as keys for lean engagement:

P5 = Successful lean companies dedicate full-time resources to lean improvement

P6 = Successful lean companies seek to provide regular communications on lean throughout the organization

P7 = Successful lean companies adopt HR policies that support lean goals

Training

Training is a critical part of implementing any new business strategy, and it is particularly necessary with lean. The training required will need to be hands-on wherever possible, be supplemented by classroom training, and be on-going. According to Liker and Convis (2012, p. 16), "[I]f there is a recipe for success, it is a deep time-consuming and expensive investment in developing everyone in the organization." When both NUMMI (a former joint venture between Toyota and GM in California) and TMMK (the first Toyota plant in the U.S.) were first starting up, Japanese leaders from engineering and management were sent to train the leaders at the new plants. An individual trainer was assigned to each executive and each group leader on the production floor. This went on for the first few *years* at both sites - a clear indicator of Toyota's commitment to training leaders about lean. It is also important to note the training method that Toyota uses - trainers are senseis who do not take over when a problem occurs, but instead ask the trainees questions to coach them and provide guidance to help them solve the problem (Liker and Convis).

Bhasin's research showed that lack of adequate training is one of the main factors that negatively impact the success of lean implementations (2012a). Bonavia and Marin-Garcia's

study (2011) of Spanish manufacturing companies showed that those with the highest level of lean implementation were those who had invested in a higher level of training. Training needs to be ongoing and regularly reinforced. In order to build on lean training, it is necessary to provide regular opportunities for employees to participate in improvement events that strengthen the training concepts. Koenigsaecker (2013) indicates that studies show buy-in is increased once people have been involved at least two well-run lean events. Akbulut-Bailey et al. (2012) also recommend that key employees enhance their training by attending seminars on lean and touring other companies to view their lean implementations.

It is also crucial to make sure that lean activities become a way of life, rather than isolated projects. A Toyota Georgetown manager (cited in Fishman 2006/2007, p. 86) says "...improvements aren't 'projects' or 'initiatives.' They are the work...every day, every week...You don't stop. There's no reason to be satisfied." Also, by keeping very little inventory, Toyota does not need to come up with training situations for employees because anything that stops production is a development opportunity for people to solve and learn from (Liker and Convis, 2012).

Another important part of training involves taking key leaders to Japan to tour and learn from lean plants there. Byrne (2013) says that each year he took around twenty of his managers to Japan for a week to tour lean businesses because even those with significant lean experience would still be amazed to see how high the bar was set by companies there.

In addition to utilizing external senseis to guide the initial lean implementation, it is necessary to develop internal senseis that will be able to lead lean implementation and

sustainment once the external sensei is gone. This means that a key part of the lean training process is to identify and develop a group of internal leaders who ideally would be trained by the external senseis. According to Liker and Franz (2012, p. 95), "The best companies realize the value of a strong, intentional culture of continuous improvement and find ways to build a deep bench of leaders who in succession maintain and improve the culture."

Based on the literature review, the following propositions are suggested related to lean training:

P8 = Successful lean companies invest in training for employees to learn about lean

P9 = Successful lean companies see the value in developing internal lean leaders and senseis

Processes

Lean is a process-based strategy. Processes are what take inputs and convert them to outputs that satisfy customer needs. One of the major ways to focus on processes and how they can satisfy customers with the least amount of waste is Value Stream Mapping. Value Stream Mapping is the process of documenting the information and material flows of the value stream as they exist in the current state, identifying opportunities to reduce waste and improve flow, creating a desired future state, and developing the plan to achieve the improvements. Value Stream Mapping helps create a vision of how to work towards creating an ideal or at least improved state.

Value Stream Mapping is a core lean tool that helps identify where to focus improvement efforts on to remove waste and shorten lead time. Koenigsaecker (2006) believes that a key activity when beginning a lean transformation is to hold a workshop with executives to create an enterprise-level Value Stream Map. This activity will help to get leadership to begin seeing what the customer views as value-added and where opportunities to remove non-value added steps exist.

Another important process for lean implementation and sustainment is standard work. Standard work is the current, single, best method for performing a task. Standard work is one of the key components of Toyota's success. Spearman and Bowen (1999, p. 98) identify four "rules" which describe and underlie the Toyota Production System:

> Rule 1: All work shall be highly specified as to content, sequence, timing, and outcome.
>
> Rule 2: Every customer-supplier connection must be direct.
>
> Rule 3: The pathway for every product and service must be simple and direct.
>
> Rule 4: Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level of the organization.

As one can see, these rules identify how processes utilize standard work. Additionally, one of the famous sayings attributed to Taiichi Ohno - a key contributor to the development of the Toyota Production System - is, "Without standards, there can be no kaizen." In other words, improvements cannot be made unless there is a current single, best method of doing something to improve upon.

A Vice President of HR for Toyota manufacturing in North America is cited in Fishman (2006/2007) as saying that the rule at Toyota is that one must first understand the process before suggesting an improvement. Otherwise, one may not actually be making a true improvement. According to Liker and Convis (2012, p. 115), at Toyota "they say there are no problems without standards. Problems are the gaps between the standards and the actual."

Standard work is also a key part of developing the problem solving capability and culture of continuous improvement at Toyota. An important step of root cause analysis is capturing what was learned and making sure that it is sustained, so the last step of the problem solving process is to document the new method as a standard (Liker and Hoseus, 2010). Then everyone is trained on and follows that standard until a better way is identified.

Koenigsaecker (2013) believes that though standard work seems simple, it is the key eliminating waste and achieving productivity gains. Mann (2010) takes this even further by stating that if forced to choose between providing lean training for a new hire or providing him or her with well documented standard work, he would choose standard work.

Another core process that contributes to Toyota's success is policy deployment. Pascal Dennis, a former manager at Toyota Motor Manufacturing in Canada, believes Toyota's policy deployment system - called hoshin kanri - is one of the key practices that continue to make Toyota such a strong competitor (cited in Jusko, 2007).

In general, policy deployment is the process of formulating clear corporate strategic objectives and goals, disseminating and aligning those objectives throughout all levels of the organization, and creating plans to achieve the objectives (Jusko, 2007). Hoshin kanri takes

broad corporate-wide strategies and translates them down to "meaningful objectives at the working level of the organization" (Liker and Morgan, 2006, p.15). Policy deployment makes it explicitly clear what the organization needs to focus on to achieve its goals and achieve performance improvement. (Deluzio and Hawkey, 2006) indicate that hoshin kanri allows lean strategies to be tightly linked to specific improvement projects that in turn help achieve positive financial results. Koenigsaecker (2013) also indicates that policy deployment is a key to achieving breakthrough results.

Based on the literature review, the following propositions are suggested as key lean processes:

P10 = Successful lean companies utilize value stream mapping to identify and drive improvement opportunities

P11 = Successful lean companies utilize standard work as the baseline for continuous improvement

P12 = Successful lean companies utilize hoshin kanri or policy deployment to align company goals and lean strategies

Key Drivers

There are a number of key drivers of lean, and one of the most crucial is the customer. Jim Womack (cited in Quinn, 2005, p. 30) says, "[T]he most important question is what value the customer wants. So managers need to start with the customer and begin walking backwards from there." Many companies do not explicitly consider the Voice of the Customer (VOC) when developing products and processes. Miller (2011) indicates that creating a culture where the

customer is the focus of every process is a key differentiator of lean organizations. Clearly in order to do this, an organization must consider what the customers want and what is of value to them.

Another key driver of lean is to use kaizen as means of creating a culture focused on continuous improvement. At Toyota, kaizen is so important that there are always a percentage of shop floor workers working full-time in kaizen events instead of performing their normal production job duties (Liker and Convis, 2012). Koenigsaecker (2013) says that having people with kaizen experience is part of the development of self-sustaining lean improvement. Koenigsaecker also says that when executives participate in lean events and see firsthand how much waste exists, it further motivates them to drive lean improvement. He clarifies that the senior leaders should be participants on the team rather than team leaders.

Both Koenigsaecker and Byrne are advocates of the traditional week-long kaizen format, where participants are focused full-time on improvement. Koenigsaecker recommends a kaizen pace of n/10 events per year, where n is the number of people in an organization. He also reinforces the need to make sure that there are sufficient resources allocated to follow up on kaizen activities after the workshop in order to insure success.

In addition to utilizing kaizen to help create a culture of continuous improvement, defining expectations and how people will be measured against them is another critical aspect of successful lean implementation (Mann, 2010). Fullerton and Wempe (2008) note the importance of using both financial and non-financial metrics to measure lean performance. Koenigsaecker (2013) indicates that it is essential to identify which performance indicators are tied to achieving

customer satisfaction. He believes many organizations measure far too many things, which makes it hard to focus on the most important goals. Koenigsaecker recommends following Toyota's example, and having metrics that are aligned with the "True North" metrics. At Toyota, the four True North metrics focus on human development, quality, lead time/cycle time, and cost/productivity. Toyota's metrics measure the items that give them the best indications of whether they are achieving progress on these four key goals. By concentrating on only a few metrics, it is easy to focus efforts as well as get a clear picture of how well a company is doing in achieving its goals.

Visual management is one of the foundations of the Toyota Production System (Liker and Hoseus, 2010). Visual management is designed to provide quick, clear status information on processes so that when deviations from standards occur, they can be quickly noticed and reacted to. In a lean system with little inventory, it is critical that any issues be immediately obvious so they can be resolved right away. Visuals clarify expectations and insure everyone is focused on meeting them. According to Liker and Convis (2012, p. 115), "It is impossible to overstate the importance that Toyota gives to visual management. Every metric that matters throughout the company, especially those on the shop floor, is presented for everyone involved in meeting the goal to see."

Visuals are also enablers of process discipline. Liker and Convis (2012, p. 115) also state, "A key reason for the dedication to visual management at Toyota is that it clarifies expectations, determines accountability for all the parties involved and gives them the ability to track their progress and measure their self-development."

Based on the literature review, the following propositions are suggested as drivers of lean:

P13 = Successful lean companies use the Voice of the Customer (VOC) as a driver of improvements

P14 = Successful lean companies utilize kaizen at a regular cadence to drive continuous improvement

P15 = Successful lean companies utilize appropriate metrics and visual management to drive lean improvements

Culture

A lean culture is the ultimate result of successful lean implementation. Culture can be roughly defined as how people get their work done (Mann, 2010). According to Koenigsaecker (2013, p. 196), "Building a long-term learning culture is the most difficult part of any lean journey, but is also the most powerful and personally rewarding part."

Another way to define culture is as a shared set of beliefs and practices. One of the important aspects of getting everyone to have a shared set of practices is to create your organization's own version of the Toyota Production System. However, be cautioned that blindly trying to copy what Toyota has done without understanding it and how it applies to a particular company's needs will not result in success. Liker and Convis (2012) compare copying the technical systems at Toyota without fully understanding them and how they came to be to ignoring the engine that drives the system. Liker and Convis (2012, p. 13) also state,

"Not only does Toyota not think that others should copy its processes exactly; it doesn't even think that its own plants should copy from each other exactly. Seeing practices that work in other contexts can be useful as a way to stimulate ideas, but will not produce commensurate results unless a practice solves a real problem and is adopted or ideally improved by the work group to fit a specific context."

It is important to learn from the Toyota Production System, and create a version of it that is adapted to the particular company. A key to this is recognizing the purpose and principles behind the Toyota Production System, and then looking at how they could be relevant to the particular company and business model (Lander and Liker, 2007). The system also has to go beyond just being a diagram or document; it has to be a true system that guides day-to-day operations of the organization and is embedded in its DNA. Toyota recognizes the importance of this step, and how critical it is to make sure Toyota sites all around the world all operate with the same principles and values. To this end, "they have deployed around the world thousands of "coordinators" whose primary job is to transfer the DNA" (Liker and Morgan, 2006, p.16). Koenigsaecker (2013, p, 92) says, "[A]ll of this comes together as a new way of running your enterprise - in other words, you establish a new management system, like the Toyota Production System...Although you can look at models from other companies, you have to build the system yourself. And this takes time and energy."

Developing the lean culture takes a significant amount of time. Lean is not a quick fix. Jim Womack (cited in Quinn, 2005) says that one of the challenges for U.S. companies implementing lean is that implementing lean takes time and U.S. managers like to see fast results. Developing a lean culture and insuring success means that there has to be a long-term

focus when implementing lean. Putting too much emphasis on short-term cost savings will derail lean implementation. Liker and Convis (2012) caution that companies that only focus on activities that have a quick ROI will not engage in the training and development required to create lean leaders and a strong lean culture. Koenigsaecker (2005) indicates that a lean learning culture that will require a decade or more to create. According to Byrne (2013, p. 24), "It will take years before you can even start to think you will be successful."

One final important aspect of implementing and sustaining lean is to recognize that lean implementation never ends. Stamm (2003, p. 22) believes that a company should "[p]ersevere - it takes years to accomplish the changeover to the lean enterprise and when you get there, you realize that you never really get there." Lean needs to become the day-to-day way of doing business:

> "Lean is not a destination but a journey, as they say…a really long journey at that. So it's almost pointless to try to do this as a program. This isn't a one-year program; it isn't a five-year program or a ten-year program. In fact, don't even call it a program. Don't give it a label. Don't call it anything. Just do it, and make it part of your everyday life" (Jim Womack, cited in Quinn, 2005, p. 32).

As an organization progresses along the lean journey, it will reach a point where constantly seeking improvement becomes an everyday habit. Mann (2009) indicates that an organization will see more and more opportunities the longer it continues down the lean path. As Koenigsaecker (2013, p. 182) says,

> "At this stage in the transformation continuum, one might be tempted to ask 'Are we finished?' Naturally the answer is 'We're never finished with this journey.' Leaders often realize this when, at this stage of their personal lean journey, they become incurably committed

to pursuing perfection through lean. There will always be new layers of waste to uncover and new challenges to overcome, as the journey along the transformation continuum has taught us."

Based on the literature review, the following propositions are suggested related to establishing a lean culture:

P16 = Successful lean companies have their own version of the Toyota Production System (TPS) that is not just a document, but a significant part of the company's culture

P17 = Successful lean companies recognize that developing a lean culture is a lengthy process and that lean is never-ending

Conceptual Model

The problem definition and the propositions supported by the literature review were the basis for the development of an initial conceptual model for successful, sustained lean improvement. The intent of the research is to test the conceptual model on several cases of companies that have successfully utilized lean as their operating strategy for more than a decade. By testing the model using cases drawn from the small number of successful, sustained lean implementations in the U.S., the aim is to provide answers to the research question of how the few U.S. companies that have achieved Toyota-like success with lean improvement have done so. The initial conceptual model is shown in figure 2.

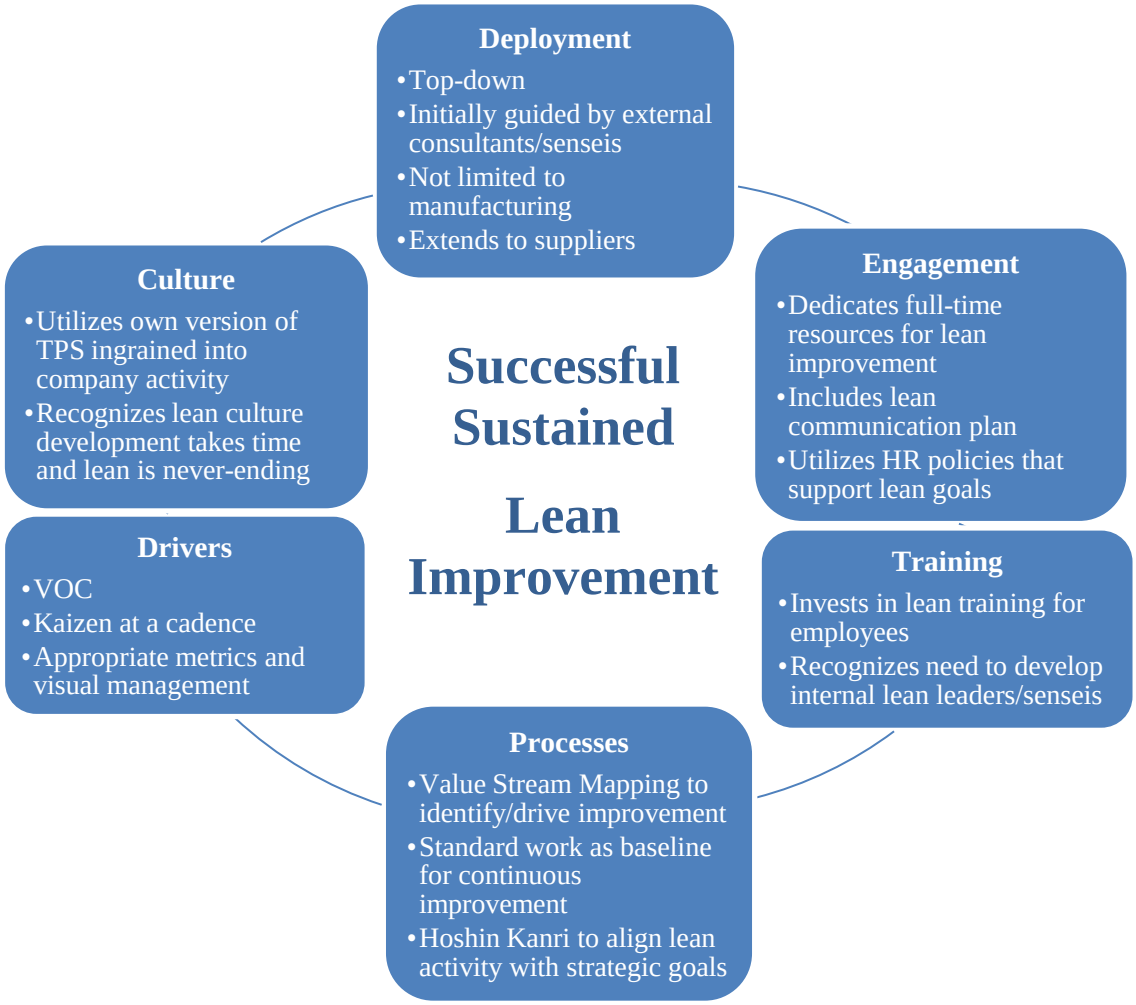


Figure 2: Initial Conceptual Model for Sustained Lean Success

Models in the Literature

There are several models found in the literature, many focused on Continuous Improvement (CI), quality, TQM, or other topics related to lean rather than specifically on lean itself.

Models focused on continuous improvement include Liker and Choi's (1995) proposed "theoretical model relating value orientations, CI communications, and the effectiveness of CI." They analyzed seven cases of manufacturing companies in the U.S. and concluded that process orientation and worker communications are "strongly related to CI effectiveness." Upton (1996) developed an improvement map that is a matrix with seven improvement focuses and five improvement processes. He then showed three different improvement curves that represented increasing, linear, and decreasing gains, and indicated for each type of curve which steps would be taken in which order on the improvement map. Bessant and Caffyn (1997 and 1999) proposed a "CI Capability Model" that used an assessment process to identify an area's level of CI maturity based on six core abilities and ten key behaviors deemed necessary to develop CI capability.

Kaye (1999) developed a model focused on continuous improvement and quality that was based on the criteria for awards such as the Malcolm Baldrige quality award. He identified ten key items related to CI and quality and proposed which were drivers, enablers, or results. Similarly, Lee (2002) developed a model for sustaining TQM that was also based on the criteria for quality awards. Lee's case studies focused on companies who won the Singapore Quality Award (SQA). His model suggested identifying core values and goals based on the award criteria, then using a PDCA cycle to deploy them.

Bateman and Rich (2002, 2003, & 2005) developed a model for sustaining gains from continuous improvement and process improvement workshops. Their research was based mainly on automotive manufacturing companies in the U.K. Ljungström (2005) proposed a model for

continuous improvement and work development that was a house with software structure as the base, hardware and implementation structures as the pillars, and continuous improvement and work development as the roof. Following case studies of implementing 5S at two Swedish companies, he updated it to add competence development, team goals, and cross-functional work with peers as additional components of the model.

There are also several models focused on lean. Lathin and Mitchell (2001) proposed a matrix for lean implementation focused on the integration of social and technical factors. They recommended using surveys to determine if each cell in the matrix was an enabler, neutral, or an inhibitor to implementation, and then developing plans to address inhibitors. Motwani (2003) created a theoretical framework for lean implementation based on Kettinger and Grover's model of Business Process Change (BPC) management. Lucey, Bateman, and Hines (2004) proposed a "Long Term Sustainability Model" that consists of six steps: Learn from past failures, Engage Staff, Get Feedback, Embed Ownership, Engagement Survey, and Feedback to Staff. Lucey later expanded on this work (2009) to propose a "Lean Sustainability Zone" based on a range of employee engagement scores.

Sawhney and Chason (2005) proposed a "Personnel Behavior Based Lean Model" that was a matrix of human behavior components required for change and lean implementation stages. They suggested using a survey approach to get scores for each cell in the matrix and then developing strategies for those with the lowest scores. Simpler Consulting (2008-2010, cited in Koenigsaecker, 2013), a lean consulting firm, created the "Simpler Transformation Continuum" as a roadmap for lean implementation based on the four stages of learning. Hines (2010)

developed the "Lean Sustainability Iceberg Model" that showed two aspects above the waterline (visible) and three aspects below the waterline (enabling). Technology, Tools, & Techniques and Process Management were above the waterline and Strategy & Alignment, Leadership, and Behavior & Engagement were below the waterline. Hines contended that "the sustainable lean thinker needs to learn to see and act below the waterline, as well as above it."

Ramakrishnan and Testani's (2012) research focused on the "IBM Path Forward Lean Deployment Framework" with three stages: Readiness for Change, Lean Skills Development, and Continuous Learning. The bulk of their research focused on assessing an area's readiness for change. Finally, Karim and Arif-Uz-Zaman (2013) proposed a "lean implementation methodology" that took Womack and Jones' (1996) five lean principles and created a process flow map with general steps for each principle. For example, under value proposition, they included "define system"; under value stream, they included "identify wastes"; under flow they included "implement new method", etc. (2013, p. 176).

A summary of the models found in the literature review is shown in table 1.

Table 1: Summary of Models in the Literature

Authors	**Construct**	**Model**	**Perspective**
Liker & Choi, 1995 (U.S.)	Continuous Improvement (CI)	"Theoretical model relating value orientations, CI communications, and the effectiveness of CI"	Focused on propositions regarding process orientation and communications
Upton, 1996 (U.S.)	Continuous Improvement (CI)	"Three models of Continuous Improvement Initiatives"	Models were curves that show decreasing, linear, and increasing gains.
Bessant & Caffyn, 1997, and Caffyn, 1999 (U.K.)	Continuous Improvement (CI)	"CI Capability Model"	Based on 10 key behaviors deemed necessary to develop CI capability, then assessing level of CI maturity in an organization
Kaye, 1999 (U.K.)	Continuous Improvement (CI)	Model for CI based on criteria for awards such as the Baldrige Award	Identified 10 key criteria and which were enablers or inhibitors to CI
Lathin & Mitchell, 2001 (U.S.)	Lean Implementation	"Lean Implementation Planning Matrix"	Focused on integrating social and technical aspects of changes
Lee, 2002 (Singapore)	TQM	"Framework for Excellence Model"	Based on criteria for awards like Baldrige, Singapore Quality Award
Bateman, 2002 & 2005 and Bateman & Rich, 2003 (U.K.)	Continuous Improvement (CI) & Process Improvement (PI)	"Model of Sustainability"	Based on sustaining gains from CI/PI workshops
Motwani, 2003 (U.S.)	Lean Implementation	Theoretical framework for lean implementation	Based on Kettinger & Grover's model of Business Process Change (BPC) management
Lucey, Bateman, & Hines, 2004 (U.K.) & Lucey, 2009	Lean Sustainability	"Long Term Sustainability Model"	Utilized employee engagement scores to predict lean sustainability & propose a sustainability zone
Ljungström, 2005 (Sweden)	Continuous Improvement (CI)	House model for CI and Work Development	Consisted of software Structure, Hardware Structure, and Implementation Structure
Sawhney & Chason, 2005 (U.S.)	Lean Implementation	"Personnel Behavior Based Lean Model"	Human behavior
Simpler Consulting, 2010 (U.S.)	Lean Implementation	"Simpler Transformation Continuum"	Roadmap for lean implementation based on the four stages of learning
Hines, 2010 (U.K.)	Lean Sustainability	"Lean Sustainability Iceberg Model"	Aspects of lean implementation that are visible vs. "below the waterline"
Ramakrishnan & Testani, 2012 (U.S.)	Lean Implementation	"IBM Path Forward Lean Deployment Framework"	Focused on assessing readiness for change prior to implementing lean
Karim & Arif-Uz-Zaman, 2013 (Australia)	Lean Implementation	Lean implementation methodology	Takes Womack & Jones' five principles of lean and adds a flow chart of general steps for each principle

Contributions of the Research Model

As one can see, many of the existing models focused on topics related to lean, such as continuous improvement and quality, rather than on lean itself. A number of the models were based on cases outside of the U.S. Several of those focused on lean viewed it from a single perspective such as a socio-technical or human behavior approach. Some of the models were fairly generic and contained broad categories rather than specific actions that should be taken. Others focused on assessment of readiness for change or maturity of the transformation more than on successful implementation and sustainability.

The model proposed by this research consists of six different constructs with seventeen propositions that are specific actions that a company can focus on if it wishes to achieve a successful, sustained lean improvement. It approaches lean implementation and sustainment from multiple perspectives. Furthermore, by testing the model on cases drawn from the very small number of companies in the U.S. that have achieved successful, sustained lean improvement, the model will be verified using proven lean success stories. The conceptual model provides a set of related tangible actions organizations can focus on to insure a successful implementation and sustainment of a lean transformation.

CHAPTER THREE: METHODOLOGY

Introduction

Chapter one provided the problem statement, research question, and a high-level overview of the research methodology. The literature review in chapter two provided the background for the development of the research propositions. To answer the research question, an empirical research methodology was needed, which is the subject of this chapter. The research methodology was based on analyzing case study data from a variety of documents and from interviews. The case study research method was selected because it is "the preferred method when (a) "how" or "why" questions are being posed, (b) the investigator has little control over events, and (c), the focus in on a contemporary phenomenon within a real-life context" (Yin, 2009, p. 2).

Objective of the Research Design & Methodology

According to Yin (2009), the four key measures of the quality of a case study design are:

1. Construct validity,
2. Internal validity,
3. External validity, and
4. Reliability

Construct Validity

Construct validity refers to the development of the appropriate operational measures for the research being undertaken. It can be achieved by utilizing several different sources of evidence, maintaining a chain of evidence, and asking key informants to review a draft of the case study report (Yin, 2009). Additionally, having subject matter experts review interview questions prior to conducting the interviews adds to construct validity.

Internal Validity

Internal validity refers to the need to establish appropriate causal relationships when performing the data analysis portion of the case study. It can be achieved by pattern matching and explanation building as the cases are examined, as well as looking for rival explanations (Yin, 2009). The goal is to minimize researcher bias as the conclusions are being drawn.

External Validity

External validity refers to the ability to generalize the research findings beyond the case studies. The goal is to be able to "generalize a particular set of results to some broader theory" (Yin, 2009). The replication logic of a multiple-case study helps to achieve external validity; therefore, a multiple-case study is typically stronger than a single-case study.

Reliability

Reliability refers to the ability to show that the case study methodology could be repeated by a different investigator, who would be able to draw the same conclusions. The best ways to achieve this are to develop a case study protocol and to maintain a case study database of all the data collected (Yin, 2009).

Research Design & Methodology

Four cases were selected for the multiple-case study research and analysis. The cases were selected based on several criteria. Yin (2009) identifies exemplary case studies as those that are unusual cases of general public interest and in which the underlying issues are important. For this research, the desire was to select cases that are from the short list of companies who have demonstrated the "unusual" ability to achieve sustained, successful lean improvement. Additionally, the researcher was interested in focusing on this phenomenon within companies in the U.S. The underlying issue of sustained, successful lean improvement is important because as Toyota has demonstrated, it is a business strategy that allows corporations to achieve tremendous growth and exceptional operating performance.

The cases that were selected for this research are: Danaher, Autoliv ASP, United Technologies Corporation (UTC), and Boeing. Each of these companies has successfully utilized lean as their operating strategy for at least fifteen years. All four cases have had multiple CEOs during this time, indicating that their lean transformations are not the results of just a

single, strong leader, but rather a system put in place that can be sustained over time. Each of the companies has also experienced strong business performance since implementing lean. Historical stock pricing for the four cases since 1997 - the earliest available date in history via Google and Yahoo Finance - is provided in Appendix A. Finally, the four companies represent a wide variety of manufacturing industries to assist with increasing the likelihood of the research being able to be broadly generalized and applied. Further discussion of the companies is included in the introductions to each case in the data analysis section in chapter four.

Research Method

Data in the form of documentation and interviews was collected from each of these companies and analyzed individually. Then the technique of pattern-matching was used to compare "an empirically based pattern with a predicted one (or with several alternative predictions). If the patterns coincide, the results can help a case study to strengthen its internal validity" (Yin, 2009, p. 123). In other words, if the research propositions are supported by all or most of the cases, then pattern-matching between the data and theory has occurred (Eisenhardt and Graebner, 2007).

Documents

Documents analyzed for the case study included articles from academic and trade journals, news articles, financial data and annual reports, and select data from the websites for

the cases. Data from these documents was entered into a case study database in the form of an Excel spreadsheet, and summarized in a matrix to assist with pattern-matching.

Individual Interviews

The initial interview questions were developed based on the literature review and the propositions to be investigated. Once the case study documents were analyzed, interview questions for each company were updated based on gaps found in the case documentation. A few generic interview questions were also generated for all the companies, with the goal of identifying anything missing from the model that could be of importance. The proposed interview questions were reviewed by a panel of subject matter experts to assess their clarity and relevance. The final list of questions for each company was provided to the Institutional Review Board (IRB) at the University of Central Florida for approval for exempt research.

Once the interview questions were finalized and the individuals to be interviewed had read the summary explanation of exempt research approved by the IRB, the interviews were initiated. The interviews were conducted by Skype®, Outlook MeetingPlace®, or by phone. The researcher recorded the interviews and/or took notes during the interviews. If the interviewees were able to provide additional contacts to interview, the process was repeated with these individuals.

Data Collection Methods

Documents

A model for the collection of documentation is shown in figure 3.

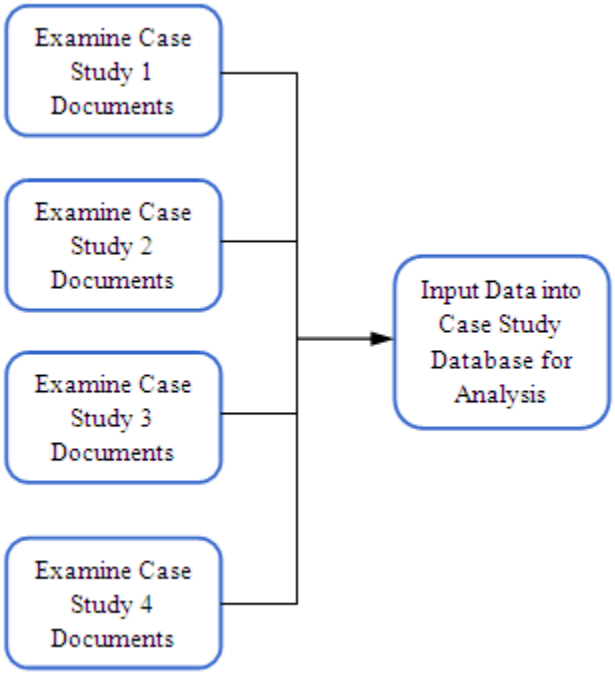


Figure 3: Model for Collection of Document Data

Interviews

A model for the collection of interview data is shown in figure 4. Some of the interview questions varied based on the specific company and which propositions were lacking information in the case study documentation for that company. There were also some generic questions

asked for all companies, designed to gain insight into whether any major success factors for sustained lean improvement are missing from the proposed model.

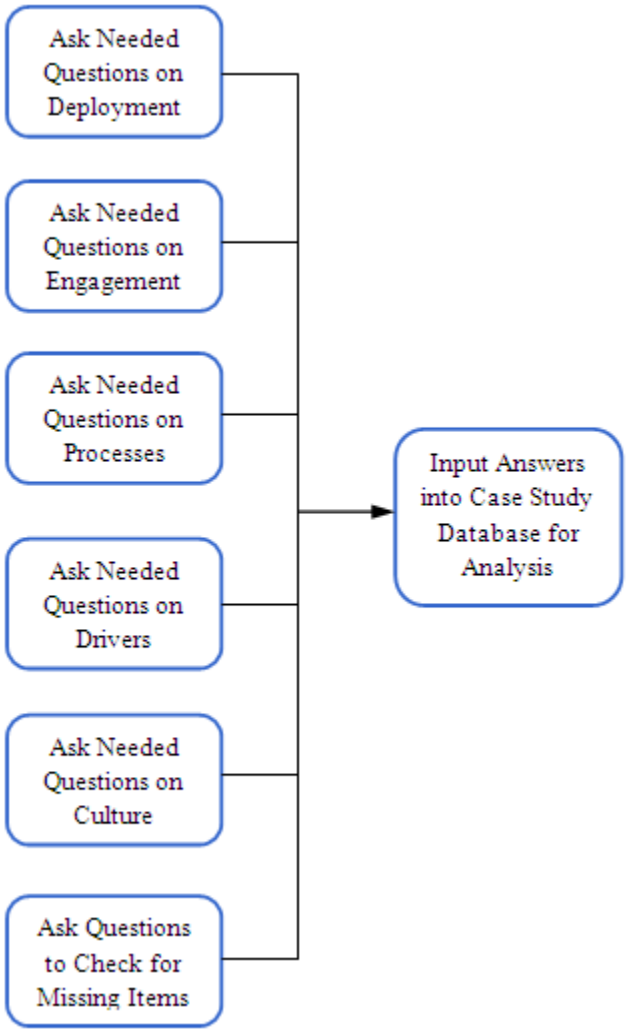


Figure 4: Model for Collection of Interview Data

Sample of Data Collection Instrument

The generic questions that were asked in all the case study interviews are shown in figure 5 below. The questions that were asked for each specific company are shown in chapter four in the data analysis summaries for each of the cases.

1	What do you consider some of the key facets of deploying a lean transformation? Can you provide some examples of how they were used at your company?
2	What are some of the keys that have helped sustain the lean improvements made at your company?
3	How long would you say it took to firmly establish the lean culture at your company, and what are some of the keys that helped create that culture?
4	Are there any other key points or lessons learned that you'd like to bring up with regards to implementing and sustaining lean success?
5	Who else would you recommend that I interview?

Figure 5: Generic Interview Questions for All Case Study Companies

Data Collection Plan

The purpose of developing the data collection plan was to create a step-by-step process for collecting the necessary research information. This step also assists in maintaining construct validity. The high level data collection plan for each of the data types is provided below.

Documents

The steps for collecting document data were:

1. Identify the appropriate documents for each of the cases,

2. Review the documents,
3. Obtain the relevant data from the documents, and
4. Enter the data into the case study database for analysis

Interviews

The steps for collecting interview data were:

1. Identify the individuals to be interviewed,
2. Explain the reason for the research (utilize introductory letter),
3. Contact the individuals to arrange the interviews,
4. Obtain consent from the individuals,
5. Conduct the interviews,
6. Transcribe the interviews, and
7. Provide the transcriptions back to the interviewees for review

Data Analysis Plan

The purpose of developing the data analysis plan was to create a step-by-step process for analyzing the collected data. This step also assists in maintaining internal validity. The high-level data analysis plan for each of the data types is provided below.

Documents

The steps for analyzing document data were:

1. Code the data (by proposition number) to assist in the analysis,
2. Utilize the case study database to organize and analyze the data
3. Perform pattern-matching,
4. Perform explanation building, and
5. Summarize results

Interviews

The steps for analyzing interview data were:

1. Validate the construct measures,
2. Utilize the case study database to organize and analyze the data,
3. Perform pattern-matching,
4. Perform explanation building, and
5. Summarize results

Implement Data Collection Plan

The purpose of this step is to carry out the data collection plan described above.

Identify Case Study Companies & Interview Candidates

As indicated, the four companies selected for case study analysis were: Danaher, Autoliv ASP, UTC, and Boeing. The researcher desired to interview consenting representatives currently employed at those companies, as well as key individuals who have worked with or at those companies in the past. As is typical with qualitative research, the goal was "to select a few participants who might best shed light on the phenomenon under investigation" (Leedy and Ormrod, 2013, p. 97). Initial interview candidates were identified through connections the researcher could establish based on contacts she, her co-workers, and her professors had at the case companies. Potential candidates were also identified from the literature review as well as through reading company and financial documentation.

Prepare Case Study Companies

The selected companies and/or interview candidates who had worked with those companies were contacted and provided with an overview of what the research entailed and the intent of the research. Times for the interviews to be conducted were arranged with each individual. Potential interview candidates were also given a list of topics to be discussed.

Conduct Interviews

The selected individuals were interviewed by phone, Outlook MeetingPlace or Skype®. Interviews were designed to fit within an hour. A semi-structured format was selected where specific questions were developed ahead of time, but where the researcher asked follow-on questions as needed to elaborate on points that the interviewees brought up. If the interviewees suggested other potential interview candidates for the company, the process was repeated with those individuals as well.

Obtain Data from Interviews

Interviews were recorded to assist with data capture. The interviewer also took notes during the interviews, particularly where note-taking could add context to the data. Transcripts were provided back to the interviewees for review.

Implement Data Analysis Plan

The purpose of this step was to carry out the data analysis plan described earlier.

Documents

Document analysis involved analyzing the data for each case individually, then performing cross-case analysis to look for areas where the companies were similar or different.

Data was coded with the proposition number that the item supported. Triangulation was employed; if the documents contained multiple references to a particular proposition, this was deemed as evidence that the proposition was supported. Where there was only one reference to a particular proposition, this was quantified as providing "some" support for the proposition. Data for the four cases was summarized in a matrix. Pattern matching and explanation building were performed. The case study database in Excel was used to assist with this process.

Interviews

Interview analysis began with analyzing the responses for each individual company. Then responses were analyzed across cases to again look for similarities and differences. Results were summarized in a matrix. Pattern matching and explanation building were performed.

Interpret Findings

The purpose of this step was to determine what conclusions could be drawn from the analyzed data. A key step was to establish which of the research propositions were supported by the data analysis. Any limitations identified in the data analysis were indicated.

Identify Managerial Implications

The purpose of this step was to determine the relevance of the findings to organizations who are considering implementing lean or who are in the process of implementing it. The goal

was to provide implications of the research that organizations can apply to their lean implementations.

Share Results

The purpose of this step was to provide an opportunity for key individuals to review the findings. This step assists with establishing construct validity.

Identify Opportunities

The purpose of this step was to discuss potential opportunities for further research.

Complete Research Enhancements

The purpose of this step was to make any needed modifications to the research propositions and the initial conceptual model as a result of the research conducted.

CHAPTER FOUR: DATA COLLECTION AND ANALYSIS

Introduction

This chapter will review the results of the data analysis for the case study companies. The four cases selected for this research were Danaher, Autoliv ASP, United Technologies Corporation (UTC), and Boeing. These cases were used to test the proposed model for successful, sustained lean improvement.

Description of Data Sources for Cases

Case study data included documents in the form of articles from journals and trade publications, data from financial resources, and data from the websites for each of the corporations. Additionally, interviews with key employees from the case study companies were conducted to provide further insight into the contributors to successful, sustained lean improvement at each corporation.

Document Collection and Analysis

The documents were read and analyzed to look for the predicted enablers of successful, sustained lean improvement. The data was summarized in a case study database maintained in Excel. Whenever one of the documents contained data to support one of the propositions, it was captured in the database along with the supporting information. As the documents were

analyzed, the researcher also looked for any other major enablers of successful, sustained lean improvement that were not part of the model. None were found, so the researcher made sure that some of the interview questions that would be posed would specifically address this possibility.

Interview Data Collection and Analysis

Once the case study documents had been analyzed for each case, they were summarized in a matrix. Based on any gaps where the data did not contain information on a particular proposition for a specific company, the researcher developed an interview question designed to provide insight as to whether the proposition was supported or not. In addition, some generic interview questions were created for all the case companies to explore whether there was anything potentially missing from the model.

The results of the analyses of both the case study documents and interviews are summarized for each case below. This is followed by a section that makes comparisons of the data and interview responses across cases.

The Cases

Danaher

Background

Danaher is a conglomerate, or as CEO David Culp prefers to call it, "a family of strategic growth platforms" (Anand, Collis, and Hood, 2011, p.1) that continually outperforms venerated

rivals such as GE and Berkshire Hathaway. Danaher has grown from revenues of $845 million to more than $18 billion in the 20 year period from 1992-2012, and Art Byrne (2013), former group executive at Danaher, believes lean is a major reason for their growth. Jim Womack has referred to Danaher as the most Toyota-like of U.S. companies, saying "We see a lot of partially lean businesses, but not many totally lean ones. Danaher probably comes the closest [in the U.S.]" (cited in Blanchard, 2007, p. 54). George Koenigsaecker, former president of Danaher's Jacobs Vehicle Systems, (2013, p.80) states:

> "If you look outside Toyota for models of successful transformation - organizations whose financial metrics have demonstrated that their lean practices generate additional customer value on a continuing basis - the list is pretty small. Many organizations have made incremental gains, but few have shown that they can get continuous gains and fewer still have demonstrated that they can do this on a regular basis with new companies they acquire or create. In this regard, Danaher is perhaps closest to the mark. Danaher has had compounded increases in earnings in the mid-20 percent range since starting its lean efforts in 1987. And every year, the company acquires new non-lean organizations that it gets onto this path."

Danaher's lean performance even allows them to sometimes bid higher for companies it is looking to acquire, because they know that they will be able to recoup the investment by applying lean to the new company to increase its margins (Hindo, 2007).

Danaher was the first U.S. company to undertake a lean transformation, which began in 1987. The founders of the company, brothers Steve and Mitchell Rales, recognized that lean could have a revolutionary impact on their business (Womack and Jones, 1996). A key step in beginning the lean implementation at Danaher occurred when Byrne and Koenigsaecker attended a seminar and kaizen event taught by proponents of the TPS. These former Toyota industrial engineers and production managers were "disciples of Taiichi Ohno" (Emiliani, 2006, p. 172) and had formed Shingijutsu Consulting. Danaher became Shingijutsu's first U.S. client after

both Koenigsaecker and Byrne spent significant time persuading the consultants to come and work with them. Spending time with the Shingijutsu consultants performing kaizen activities on the production floor was the beginning of implementing lean at Danaher.

Document Analysis Results

Though the Rales brothers (now board members of Danaher) are notoriously publicity-shy and have tried to keep Danaher's success under the radar, the somewhat limited case study documents available on Danaher's lean implementation do provide support for a number of the propositions of the research model. Those that were supported by the case study documents are shown with an "X" in figure 6 below.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Danaher	X	X	X			X	X	X	X	X		X	X	X	X	X	X

Figure 6: Research Propositions Supported by Danaher Case Study Documents

The Danaher Business System, or DBS, is Danaher's version of the Toyota Production System. According to Loftus (2006, p. 46), the DBS "emanates from the top of the organization" at Danaher. Culp is a huge proponent of the DBS, and promotes and teaches it constantly. Koenigsaecker (2013) indicates that Culp was involved in the early development of the DBS and is a big advocate for application of the DBS throughout Danaher. These statements provide evidence to support the first proposition:

P1 = Successful lean companies drive lean implementation from the top down

As stated in the background section above, Danaher engaged Japanese senseis from Shingijutsu Consulting to assist with their initial lean implementation. The first time that Shingijutsu visited one of the Danaher facilities is described in *Lean Thinking* and discusses how the consultants arrived at the plant at 10 p.m. and indicated that the cell they were asked to look at needed major rearrangements to flow properly. The Danaher team worked with the consultants and had the cell rearranged by 2 a.m. Recalling that night, Koenigsaecker stated "My whole notion of how much improvement was possible in a given period of time was fundamentally and permanently altered. I also realized that these guys could be a gold mine for the Danaher group" (as cited in Womack and Jones, 1996, p. 129). After Danaher executives demonstrated their commitment to making the changes the Shingijutsu consultants recommended, Danaher became Shingijutsu's exclusive North American client in the late 1980s. This provides support for the 2nd proposition:

> P2 = Successful lean companies utilize consultants from established lean companies like Toyota as senseis to help guide their initial learning and lean improvement

Lean implementation at Danaher began in the manufacturing areas, where the Shingijutsu consultants focused initial efforts on getting Danaher to make modifications in production cells. However, lean practices eventually spread to other areas of Danaher outside of manufacturing. Loftus (2006) indicates that though it started in operations, lean is now part of every function at Danaher. The Danaher corporate website corroborates this, and states that "DBS is utilized by every operating location, function, and level at Danaher." In their 2011 Harvard Business Review case study, Anand et al. indicate that Danaher is now using lean for functions such as

product development and sales and marketing. These statements provide evidence to support the third proposition:

> P3 = Successful lean companies implement lean in both manufacturing and non-manufacturing areas

Danaher has a DBS Office (referred to as DBSO) of 15-20 executives whose role is train managers in the DBS and facilitate kaizens, both with existing operations and newly acquired ones (Anand et al., 2011). This item provides some evidence of support for the fifth proposition:

> P5 = Successful lean companies dedicate full-time resources to lean improvement

Anand et al. (2011) indicate that assessing alignment with DBS values is part of determining management promotion opportunities at Danaher. This would imply that adherence to the lean business system at Danaher is valued in determining promotion opportunities and therefore provides some support for the 7th proposition:

> P7 = Successful lean companies adopt HR policies that support lean goals

Koenigsaecker (2007) indicates that Danaher requires new senior executives to take a lean immersion course. Anand et al. (2011) says the immersion program focuses on the DBS and related lean tools and culture. Koenigsaecker (2013, p. 81) provides further detail on the immersion program, saying,

> "At Danaher, the immersion process for new leaders is a formal thirteen-week process. In the process, about two-thirds of the time is spent on kaizen event teams operating in a variety

of different Danaher businesses. About one-third of the time is spent on lean governance, benchmarking good lean operations and management practices at various locations, joining strategy deployment sessions, and going to a week of formal Danaher Business System (DBS) Leadership Training. The immersion is conducted under the guidance of a personal mentor (a senior Danaher manager who is deeply knowledgeable and committed to DBS) who constructs the specific plan for the new manager and coaches him or her through the thirteen weeks of immersion."

Once this course is complete, lean training is not over for Danaher executives. According to Anand et al. (2011, p. 9),

"After the initial training period, the process shifted into a maniacal focus on DBS which seeks to drive sustainable improvement over an indefinite time period. This involved both an operating philosophy and ongoing management development. The intent was to create a culture where every executive was continually looking for opportunities to improve any and every aspect of the business."

Loftus (2006) indicates that this rigorous DBS training goes on for two years for executives. Hindo (2007) indicates that new Danaher managers are frequently sent to Japan, and that Culp began his career at Danaher spending a week in Japan working in an assembly area of a lean manufacturing plant. Additionally, Culp also delivers some of the DBS training to newly acquired Danaher businesses (Anand et al., 2011). These items provide support for the 8th proposition:

P8 = Successful lean companies invest in training for employees to learn about lean

In addition to the immersion training that it provides to executives as described earlier, Danaher provides other assistance to develop managers. According to Loftus (2006, p. 46), "If someone works hard to use the DBS tools, but results aren't as hoped for, Danaher works closely with that person to get the results on track. Danaher has helped many people through their

cultural transition into the organization who became exceptional leaders." This is because "Danaher believe[d] that building a managerial mindset of continuous improvement was ultimately the most important result of the [training] process" (Anand et al., 2011, p. 9). These items provide support for the 9th proposition:

> P9 = Successful lean companies see the value in developing internal lean leaders and senseis

Radiometer CEO Peter Kurstein indicates that Value Stream Mapping was utilized early in the Danaher acquisition of Radiometer, saying,

> "The first key event, which took place four weeks after the acquisition, was the Executive Champion Orientation (or ECO). That was a positive, team-building eye-opener. Having the top 40 managers at Radiometer split into six groups to do a value-stream mapping and seeing the absolutely obvious improvement opportunities from simple changes was very powerful." (Anand et al., 2011, p. 11)

This provides some support for the 10th proposition:

> P10 = Successful lean companies utilize value stream mapping to identify and drive improvement opportunities

The case study documents indicate that one of the distinctive features of the DBS that has led to Danaher's success is policy deployment (Blanchard, 2007 and Loftus, 2006). In fact, Culp is quoted in Anand et al. (2011, pp. 10-11) as saying

> "Indeed, if there were only one DBS tool to use, it would be PD [Policy Deployment]. This is at the root of sustained performance improvement since it does not accept a low bar as sufficient. We set very high expectations and have a bias for action while maintaining a competitive sense of winning. It demands that management have experience and commitment to DBS to lead from the front, as well as the confidence and thick skin required to truly stretch the organization."

Anand et al. (2011, p. 9) describe the policy deployment process further, stating

"Once the strategy for a business was agreed upon, a policy deployment (PD) tool was used to drive and monitor its implementation…PD reviews took place once a month for every business and PD objectives were directly linked to the strategic plan. First were a series of three to five year objectives that would dramatically improve firm performance. Next were annual objectives that had to be met in order to keep the strategy on path, particularly those objectives that tracked the breakthrough initiatives essential to achieving a step change in performance. In turn, these objectives triggered a series of process improvements that were needed, and whose performance was tracked against specific output measures."

Loftus (2006) indicates that Danaher uses tracking boards in each production area that indicate progress made toward the breakthroughs set in policy deployment. These items provide support for the 12th proposition:

P12 = Successful lean companies utilize hoshin kanri or policy deployment to align company goals and lean strategies

According to Hass et al. (2006, p. 40), Danaher places a "strong focus on customer needs." In fact, the Danaher corporate website indicates that the Voice of the Customer (VOC) drives its strategic plan. And the DBS logo explicitly states "Customers talk, we listen." Loftus (2006, p. 46) says that,

"The company employs a number of methodologies – some very precise and analytical, others broader and more exploratory in nature – that help them solicit input from customers so that they can characterize and segment markets. This ensures they have features that will excite particular customers in and around a specific market."

These items provide support for the 13th proposition:

P13 = Successful lean companies use the Voice of the Customer (VOC) as a driver of improvements

Loftus (2006, p. 45) indicates that kaizen is a foundation of the DBS, and "events run continuously, minutely examining business processes to identify all sources of waste and to develop a standardized repeatable working system that will avoid them in the future." When lean was first being implemented at Danaher, Art Byrne and George Koenigsaecker participated in many of the initial kaizens, attending for the entire week (Byrne, 2013). Early in the lean transformation, Byrne also had all the Danaher company presidents participate in a three-day kaizen. This event achieved great results, helped develop camaraderie among the presidents, and helped begin to spread a common culture throughout the different Danaher businesses (Byrne, 2013). Today, it is not unusual to see Danaher CEO Culp participating in a kaizen event (Brown, 2008). In fact, when asked what the key element in Danaher's success was in a 2001 interview with The Wall Street Transcript (http://www.twst.com/interview/9362), Culp stated "Kaizen is really the key." These items provide support for the 14th proposition:

> P14 = Successful lean companies utilize kaizen at a regular cadence to drive continuous improvement

Appropriate metrics to track lean progress at Danaher are established during the policy deployment process. In Anand et al. (2011, p. 10), Culp states "First there are financial variables we focus on…In addition, there are key performance indicators for each business - on time delivery, yield, etc. - which number around 15 for each business and are derived from the plan. Then there are elements driving the breakthroughs."

Radiometer CEO Peter Kurstein further elaborates on how metrics are established during policy deployment, stating,

"For each process change required, one or two metrics were defined that would effectively monitor progress towards these goals and monthly targets identified for each. These targets were posted on a single piece of paper outside the CEO's office and other locations, such as the lunchroom, and tracked monthly for all to see progress." (Anand et al., 2011, p. 12)

These items provide support for the 15th proposition:

> P15 = Successful lean companies utilize appropriate metrics and visual management to drive lean improvements

As indicated throughout this section, Danaher has its own version of the Toyota Production System, known as the Danaher Business System (DBS). Brown (2008, p. 7) indicates that Danaher focuses on "aggressively embedding the Danaher Business System in every person, process, plan, and performance metric." Drickhamer (2010, p.66) indicates that Danaher's tremendous success has come from "Growing through the acquisition of over 600 companies and the rigorous application of the DBS." Hass et al. (2006, p. 40) state that Danaher "accomplished [this] record by applying its own lean thinking culture, known as the Danaher Business System (DBS)." Anand et al. (2011, p. 8) indicated "The firm's investor presentations described DBS as 'defining our high-performance culture. DBS is who we are and how we do what we do.'" In a 2001 interview with The Wall Street Transcript (http://www.twst.com/interview/9362), CEO Culp mentioned the DBS fifteen different times and stated, "As you can sense, DBS defines our organization in a number of ways..."

According to Koenigsaecker (2013, p. 25), "…the application of the Danaher Business System (DBS) to the core business and to each new acquisition has led to compounded sales and earnings growth of roughly 25 percent per year, with a high level of consistency. This is the best

track record in corporate America; it is superior to Warren Buffet's Berkshire Hathaway, GE, and so on." One of the ways that Danaher gets new acquisitions assimilated into the lean DBS culture is by beginning the DBS training immediately – often even before the deal is finalized.

> "Danaher spends a lot of time early on, sometimes even before they own the company, providing DBS training so that the senior leadership team and the mid-management ranks understand what it is about. It makes the post-merger work much easier. For example, before its 2002 acquisition of Gilbarco was complete, the company was introducing Gilbarco executives to DBS. Within 60 days of closing the deal, the continuous improvement events that form the system's core were well under way across the acquisition." (Loftus, 2006, p. 47)

Danaher's corporate website provides a number of statements on the DBS, indicating that the DBS is an important part of both Danaher's history and how it operates today. "We use DBS to guide what we do, measure how well we execute, and create options for doing even better - including improving DBS itself." One of the statements in their comments when reporting financial results says "The Danaher Business System provides a foundation to our 63,000 associates around the world…" Finally, the most telling statement on the Danaher website is "The Danaher Business System IS our culture." These items all provide strong support for the 16th proposition:

> P16 = Successful lean companies have their own version of the Toyota Production System (TPS) that is not just a document, but a significant part of the company's culture

Finally, Danaher's systematic, ongoing application of the DBS to all areas of its business and to new acquisitions is a good indicator that the company recognizes that lean is never ending. Even though they have been on this journey longer than any other U.S. company,

Koenigsaecker (2013, p. 80) indicates that "Danaher is still learning and building its culture." These items provide some support for the 17th proposition:

> P17 = Successful lean companies recognize that developing a lean culture is a lengthy process and that lean is never-ending

Gaps in Document Results

The case study documents provided evidence to support fourteen of the seventeen research propositions. In order to see if there was support for the other three propositions, the Danaher-specific interview questions were directed at the topics not found in the case study documents. These were asked in addition to the generic questions that were asked of all case companies to look for any missing items in the model.

Interview Questions

Provided below in figure 7 is the list of interview questions specific to Danaher.

1	Does Danaher work with its suppliers to implement lean improvements there? If so, can you provide some examples?
2	What types of communications on lean did you provide during deployment? Is ongoing communication on lean being provided today? If so, can you provide some examples?
3	I see that one of the DBS tools is standard work. Can you provide some examples of how it is used and why?

Figure 7: Interview Questions Specific to Danaher

Interview Results

Art Byrne, Former Group Executive at Danaher and author of *The Lean Turnaround*, was interviewed to help fill in the gaps in data for Danaher's document analysis. He was asked the questions in figure 7 to achieve this purpose, as well as the generic questions in figure 5 that were asked of all interviewees. Additionally, since Art was instrumental in the initial implementation of lean at Danaher, he began the interview by providing some background on how lean started there:

"Lean implementation at Danaher began with two sister companies, Jacobs Brake (known as Jake Brake) and Jacobs Chuck. Danaher had been trying to run them as one company, but it wasn't working. So I split them into two and made George Koenigsaecker head of Jake Brake and Dennis Claramount head of Jacobs Chuck.

Jake Brake initially employed Arthur Anderson as consultants, who performed in the manner typical of consultants, lots of money but limited help. We did have some success, however, setting up the first production cell and starting 5S. It wasn't called lean yet; we called it either JIT or the Toyota Production System.

Then George K. and I and several heads of Danaher operations attended a seminar in Hartford, Connecticut given by *Kaizen* author Masaaki Imai. Imai was not a lean guy; he was a book writer, so he brought the Shingijutsu consultants with him. They'd worked directly for Ohno at Toyota, implementing the Toyota Production System in the Toyota supplier network, and they knew their stuff.

George K. badgered them until they came to the plant and he and I showed them the production cell at Jake Brake. Eventually, Shingijutsu agreed to do consulting with both Jake Brake and Jacobs Chuck. The first Shingijutsu consulting visit was at Jacobs Chuck in Clemson, South Carolina. Dennis and I hired some interpreters from Clemson University to assist with translation. It was August in South Carolina in a machining plant without air conditioning. We started in the conference room describing the workings of a drill chuck, but the consultants said they were familiar with drill chucks so we stopped the presentation and went out on the floor for a plant tour.

We only spent a few minutes in the plant and the Shingijutsu consultants asked to go back to the conference room where they wrote "No good" on the white board. They then turned around and said "Look, everything here is no good. What do you want to do about it?"

We then split into two teams, one for assembly and one for machining, and went back out on the floor. Dennis and I were in assembly, where all the operations had conveyors between them. The consultant said "I hate conveyors. Get rid of all the conveyors." and then he explained why.

The consultants on the machining team said all of the equipment needed to move during lunch, and this was equipment that hadn't moved in 15-20 years. As a result, the managers and engineers on that team were very nervous.

After lunch, Dennis and I visited the machining team to see what was going on. The Shingijutsu guys were out there in their white shirts and ties in this un-air conditioned plant with machining oil dripping on them using pry bars to lift and move the machinery. There were no reports or PowerPoint presentations, they just jumped right in. This created the first production cell at Jacobs Chuck. After this initial start, Shingijutsu worked exclusively at just Jacobs Chuck and Jake Brake for two years, where they made huge improvements.

There were P&L issues when inventory started to drop at Jake Brake (typical when starting lean) and this caused the Rales brothers to call an emergency meeting. George K. and I planned to give them a plant tour to show them what they were doing. George K. had the idea to have the UAW guys on the floor give the tour to talk about what we'd done. The UAW guys were enthusiastic and excited about what they'd done and the tour ended up lasting three hours. At the end, Steve and Mitch Rales just said "How fast can you do this in the rest of Danaher?" We were relieved that we still had jobs and asked Shingijutsu for more involvement to help the other Danaher sites. Shingijutsu refused to work with other plants until they did more to fix Jake Brake and Jacobs Chuck. So we knew that in order to spread lean to the other sites, we needed to do something else.

Therefore, George K., John Consentino [the other Danaher Group Executive], and I came up with the idea of taking all thirteen Presidents and their VPs of Operations to Japan for a week. While there, we visited Toyota plants and other Shingijutsu clients who were well down the lean path. When we returned from Japan, John and I ordered all the company Presidents to attend a Presidents' kaizen that lasted for three days every six weeks. The kaizens took place in John's factories since I had the benefit of working with Shingijutsu at Jake Brake and Jacobs Chuck. The Presidents would go to the sites and lead kaizens and move equipment themselves. They made astronomical gains.

One of the first Presidents' kaizens took place at a tire changing business that had requested $750,000 for a new paint line, which was very close to being approved. In three days, the team proved that not only did they not need the new line, but they could get 50% more capacity out of the existing one. The other two teams got similar savings during that first Presidents' kaizen.

So along with the Presidents' kaizens and being the only North American customer of Shingijutsu for four years, this was how we helped spread lean across Danaher."

Next, Art was asked what he considered to be some of the key facets of deploying a lean transformation. Art responded that the three principles he discusses in *The Lean Turnaround* are the most critical: Lean is the strategy; lead from the top; and transform the people. He indicated that for Danaher, the Presidents' kaizens (described above) were good examples of putting these principles into action. Art also stated, "Additionally, you have to deal with the people – how do you get them to think differently? Shingijutsu helped drive the fundamentals – drive to takt time, pull, one-piece flow, set-up reduction, standard work."

When asked what some of the keys to sustaining the lean successes at Danaher were, Art responded:

"Sustaining is one of the hardest things about lean, especially when going from a batch operation to flow. We had to develop a methodology to follow-up on kaizens, which included a kaizen newspaper with actions and owners and the Kaizen Promotion Office. [According to The Lean Turnaround (2013, p. 66), "The full-time job of the people in this office is to run and follow up on kaizen projects, and to train the rest of the organization in Lean Principles and techniques."] We also used standard work and visual controls, for example, have the operators record the set-up times and make sure they're meeting or beating the time established in the kaizen."

Next Art was asked if Danaher works with its suppliers to implement lean improvements there and if so, could he provide some examples? He responded:

"Yes; it's important to work with both customers and suppliers. You need to focus on getting daily deliveries from suppliers. I can't think of specific examples with suppliers at Danaher, though we must have gone to steel vendors. An example of working with a customer was with Caterpillar on order frequency – we asked them to go from monthly orders to weekly orders. Initially Caterpillar resisted and had said their computer system didn't support weekly orders. We kept working with them and taking it higher up the ladder and eventually got them to go weekly and then even twice weekly."

This provides only very limited support for the 4th proposition:

> P4 = Successful lean companies recognize that once they have made progress on becoming lean internally, they should extend lean implementation to their suppliers

Next Art was asked what types of communications Danaher provided on lean, and he responded that "Having the Presidents' kaizen every six weeks and then having the Presidents present what they did at the yearly Presidents' meeting was a key communication tool." He further elaborated, saying:

"One of the things that happened with the Presidents' Kaizen is that people in the cell that was being focusing on would be very impressed to see all the Presidents at their cell, but couldn't understand how they would make improvements since they'd already been working there for many years. But by the last day of the kaizen, the people from the cell would be asking if the Presidents could stay longer. The reason was because they listened and fixed things. The best ideas come from the people who do the work, and people have to listen to them and do something about it.

The key to getting people on board, such as working with the union to reduce the number of job classifications, is to make sure people know why the changes are being made and involve them. Also show how lean benefits them; for example, reducing the amount of set-up required on a machine is ultimately less work for them."

This response provides some support for the 6th proposition:

> P6 = Successful lean companies seek to provide regular communication on lean throughout the organization

Next, the researcher said to Art that she noticed that standard work is one of the DBS tools, and asked if he could give some examples of how it is used and why. Art responded:

"It's a simple concept – for every job, create a standard and a time frame for it, all the steps in sequence and then you want everyone to do it that way to create a repeatable foundation. It's not like batch where you just need 1000 a day and that's the measurement and everyone may do it differently so there's no consistent quality or productivity.

At Danaher, we created standard work everywhere for the new cells and set-ups. But it's the hardest thing in lean to maintain – easy to write it, hard to get it to stick. We had shop floor management monitor it and had visual controls and posted things like set-up times to make sure it was staying in a range. We had daily meetings around it and what the issues were. It's a different mentality for both shop floor managers who are used to just focusing on making the numbers and on the people doing the work who are used to doing it their way. It should also be used as the baseline for improvement – how do we change to the next standard?"

This response provides support for the 11th proposition:

> P11 = Successful lean companies utilize standard work as the baseline for continuous improvement

Finally, Art was asked if there were any other key points of lessons learned with regards to implementing and sustaining lean that he wanted to mention. He responded:

"It's a strategic thing, so leadership is the most important. It also needs to not just be a manufacturing thing; it has to be enterprise-wide, which is why the CEO is the right person to lead it. But it takes the right kind of personality; typically, it can't be someone who is insecure since you need to have some blind faith."

<u>Overall Conclusions for the Case</u>

Provided in figure 8 is an updated matrix that indicates which of the research propositions are supported for Danaher.

Propositions: D = supported by document analysis; I =supported by interviews

Case	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Danaher	D	D	D		D	I	D	D	D	D	I	D	D	D	D	D	D

Figure 8: Final List of Research Propositions Supported for Danaher

Support was found at Danaher for all propositions except the 4th proposition which had only very limited support. In addition to the actions mentioned in the remaining propositions, an interview with Art Byrne indicated that making lean the strategy, having it driven by a CEO with the right type of personality and who gets personally involved in lean implementation, and finding ways to transform people to the lean way of thinking, were also keys to implementing lean at Danaher. Further, the improvements at Danaher were sustained by following up on kaizens through a combination of kaizen newspapers, a kaizen promotion office, and standard work and visuals.

Autoliv ASP

Background

Autoliv ASP is the North American subsidiary of parent company Autoliv, a Swedish manufacturer of automotive safety systems. Numerous Autoliv ASP plants have won Shingo prizes for operational excellence, largely due to the company's ongoing success with lean. In fact, the Autoliv Ogden Airbag assembly plant won the coveted prize twice, first in 2003 and then again in 2009. As Hogan (2009) indicates, this is a good indicator of Autoliv's ability to sustain its lean culture.

Autoliv ASP has had so many tour requests after winning multiple Shingo awards that it set up a group to coordinate the tours and began charging for them (Panchak, 2007). Additionally, the Non-Disclosure Agreement (NDA) form that Autoliv requires anyone touring its facility to complete even specifies that employment offers cannot be made to Autoliv employees without written permission from Autoliv management.

Document Analysis Results

The case study documents for Autoliv provide support for a number of the propositions of the research model. Those that were supported by the case study documents are shown with an "X" in figure 9 below.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Autoliv	X	X		X	X	X	X	X	X		X	X		X	X	X	X

Figure 9: Research Propositions Supported by Autoliv Case Study Documents

Like Danaher, Autoliv also has a lean business system, known as the Autoliv Production System or APS, which has been a foundational element of its lean success. And according to Tim Ambrey, Director of APS (cited in Panchak 2007, p. 25), "The COO is the No. 1 proponent of the APS within the corporation...I've never been in a meeting with him, regardless of the audience, where he has not reiterated that top management must be on board with APS and will be held accountable for it." This provides some support for the first proposition:

P1 = Successful lean companies drive lean implementation from the top down

In the late 1990s when Autoliv was beginning its lean transformation, they worked with a Toyota sensei (Purdum, 2003). According to Panchak (2007), Autoliv worked with Toyota consultant Takashi Harada from 1998 through 2001. Mr. Harada spent a significant amount of that time working with Autoliv managers to help them understand the TPS and develop their own APS. In typical sensei fashion, Mr. Harada did not tell Autoliv managers what to do, but rather taught them the tools and philosophies of the TPS and let them figure out how best to apply them. This provides support for the second proposition:

> P2 = Successful lean companies utilize consultants from established lean companies like Toyota as senseis to help guide their initial learning and lean improvement

According to Hogan (2009), Autoliv shares important aspects of the APS with its key suppliers and provides them with facility tours to help show them the APS principles in action. This provides some support for the 4th proposition:

> P4 = Successful lean companies recognize that once they have made progress on becoming lean internally, they should extend lean implementation to their suppliers

Autoliv has APS directors for each region, as well as APS managers, facilitators, and coordinators at the various sites. There is also a consulting group at Autoliv that coordinates tours (Panchak, 2007). This provides support for the fifth proposition:

> P5 = Successful lean companies dedicate full-time resources to lean improvement

The case study documents indicate that Autoliv uses a variety of means to communicate about lean and share lean results and best practices. According to Panchak (2007, p. 30),

> "…all ANA (Autoliv North America) facilities have 'monthly topic-focused training,' a review of a particular lean concept throughout the month. The goal is to study some aspect of every lean concept at least once per year. During that month, every regular stand-up meeting will briefly review that concept. The newsletter features articles on the topic."

Additionally,

> "Each of the four [APS] directors conducts a quarterly APS Forum in their region to regularly and consistently promote the exchange of ideas. All plant managers and APS coordinators from a region convene at a host plant, which demonstrates its progress in meeting the APS intent, and in following the APS manufacturing vision. All four directors attend each others' regional meetings, both to assess the host and to learn the best practices created there. Thus each new best practice is regularly translated into new global APS standards." (Panchak, 2007, p. 31)

Autoliv also shares best practices in kaizen events by having each site choose its best workshop, then sending the members of that team to an annual Autoliv excellence expo. There, the teams present their results to each other and compete to win the prize for the best workshop in North America (Panchak, 2007). These items provide support for the 6th proposition:

> P6 = Successful lean companies seek to provide regular communication on lean throughout the organization

Autoliv recognizes the need to make a commitment not to reduce the workforce as a result of lean improvements. Scott Saxton, continuous improvement manager at the Ogden plant, states "We avoid letting people go as we make improvement. If we reduce our headcount, it will kill our employees' willingness to engage in kaizen" (cited in Hogan, 2009, p. 73). Autoliv also includes lean performance as part of management promotion opportunities.

"Development goals for each associate include serving on a specified number of 8D [a problem solving method] workshop projects and suggesting a certain number of process changes" (Panchak, 2007, p. 29). These items provide support for the 7th proposition:

P7 = Successful lean companies adopt HR policies that support lean goals

The case study documentation indicates that Autoliv engages employees at all levels in its lean improvements through both its training and suggestion programs. According to Hogan (2009, p. 72), "Each month's training is transmitted though all levels of the organization." Peterson (2011, p. 1) states that "Autoliv engages employees throughout the company for input." This is evidenced by the fact that in 2010, more than 215,000 improvement ideas were received from Autoliv employees in North America (Peterson).

Along with the monthly training topic mentioned earlier, Autoliv provides a significant amount of training that helps support its lean performance. The training begins on day one (Hogan, 2009). According to Panchak (2007, p. 30),

> "Employee education begins with a three-day orientation on basics - learning the lean philosophy, terms, and tools, as well as spending some time building parts in a training cell. Throughout the world, each new employee is given a 40-page book that both describes and explains the intent of the APS and its primary components. Translated into over a dozen languages and employing easy-to-understand graphics, this book ensures that all new Autoliv employees begin with the same understanding of APS and its importance to Autoliv's and the employee's future success."

Training continues after the initial orientation as well. Panchak (2007, p. 30) says, "Continuous learning is the heart of the APS. It follows seamlessly from standardized work, on-the-job training, and consistent follow-up." According to Koenigsaecker (2013, p. 225),

> "…all associates regularly attend training designed to reinforce the fundamentals of the company's APS processes. Hundreds of associates enroll each year in intensified training at "APS University," where, through hands-on experience in their work cell, they learn to apply such principles as first-time quality, poka-yoke, and six sigma."

Hogan (2009) indicates that Autoliv has a "boot camp" training program for team leaders who have been identified through the annual succession planning process. According to Panchak, (2007, p. 30),

> "…formal training also is delivered to smaller groups of associates through APS University (APSU). There associates who've been recommended by their supervisors attend a program that runs two hours, once a week for nine months. The coursework involves classroom instruction, reading assignments, games, and hands-on workshops – "make it stick" activities says Howell [Todd Howell, APS Facilitator], who started APSU. More important, APSU students learn to teach the concepts by "teaching back to the class what they've learned."

According to Howell, graduates of the APSU are expected to help provide training on the monthly topic and provide lean guidance to others in their area (Panchak, 2007). Autoliv also utilizes regular improvement workshops to provide on-hands application of lean (Hogan, 2009). Additionally, Panchak (2007, p. 30) indicates,

> "All associates attend APS Forums for sharing knowledge. They participate in the APS workshops, which primarily create knowledge…Following lean teaching philosophy, 'students' describe, in their own words, what they've learned. Teaching not only demonstrates that [they've] learned, but deepens the learning."

All of these items provide support for the 8th proposition:

P8 = Successful lean companies invest in training for employees to learn about lean

The case study documentation provides indication that leadership development training is valued at Autoliv. One of the reasons for this is that:

"Every leader at AOA (Autoliv Ogden Assembly) is a coach and a teacher. Successful creation of a lean culture is based on the idea that managers must dedicate time to teach employees to improve their skills and abilities. Every manager is expected to train and lead employees in the philosophies of the APS" (Hogan, 2009, p. 73).

Additionally, an Autoliv handout at the 2012 AME Champions Club Presentation includes a quote from their Toyota sensei, Takashi Harada, that states "Good leaders do not create followers, they create more good leaders" (Hartman, slide 26). These items provide support for the 9th proposition,

P9 = Successful lean companies see the value in developing internal lean leaders and senseis

The case study documents indicate that standardized work is important at Autoliv and provides significant benefits:

"'We really have good standards,' says Yoana Avila, an AMT [Autonomous Management Team] leader in Molding at the Airbag Module Facility in Ogden. "'I've worked in three different plants, and it's the same for everything - they have the same steps, the same paperwork. Even if I haven't done, say, a 5S audit at Brigham City, I could do one there.'" (cited in Panchak, 2007, p. 28)

In order to assist with disseminating and sharing standards, Autoliv has an intranet site where employees can view all the approved standards (Panchak, 2007). Importantly, Autoliv employees also recognize that standardized work reflects the current best practice, but needs to continuously improve. Panchak indicates, "At the cell, standardized work changes continually. 'If this process hasn't changed, then we're not doing it right.' Wasden [Fred Wasden, Director of APS Consulting] says" (2007, p. 29).

At Autoliv, standardized work is not limited to just the production workers. Standardized work is also used by management, including a standard daily "to-do" list. According to Hogan (2009, p. 74), "Implementation of a standard work process for all levels of management has been very important to the establishment of a lean culture. This standard work process ensures that management follows up on the processes that have been adopted in the plant to meet objectives." These items provide support for the 11th proposition:

> P11 = Successful lean companies utilize standard work as the baseline for continuous improvement

According to Panchak (2007), policy deployment is one of the key aspects of Autoliv's lean implementation that sets it apart from many other companies. Hogan (2009) indicates that Autoliv's policy deployment is based on Toyota's practice of hoshin kanri. Koenigsaecker (2013, p. 225) states that policy deployment allows Autoliv managers to "align strategies in a systematic way, reaching out to their associates to create desired results through focused problem-solving and improvement activities." Managers work with their teams to identify which

specific projects are needed to help them get to the goals identified in policy deployment. Through this process, "Autoliv uses policy deployment not only to disseminate lean principles, but to gauge understanding and use-with-intent of lean tools" (Panchak, 2007, p. 32). These items provide support for the 12th proposition:

> P12 = Successful lean companies utilize hoshin kanri or policy deployment to align company goals and lean strategies

According to Blanchard (2008, p. 36), "Autoliv is practicing what might best be described as 'extreme kaizen'," holding an estimated 160 workshops at their facility in Tremonton, Utah site alone in 2007. Hogan (2009, p. 75) says managers believe that kaizen "is the engine behind" Autoliv's success. Autoliv plants find creative ways to recognize employees for participating in kaizen events, such as the excellence expo mentioned earlier. Results of kaizen workshops are posted on employee communication walls (Hogan, 2009). Purdum (2003, p. 34) also indicates that at the Columbia City Autoliv site, "It's not unusual to see Kaptain Kaizen, dressed in a red smock and mask, running around the plant shaking hands with employees who have successfully completed a kaizen event."

In addition to the formal week-long kaizen events, Autoliv also encourages the practice of daily kaizen – finding small ways each day to improve the process. Autoliv has a kaizen suggestion program where employees submit their ideas for these small improvements, and the program has been a tremendous success. For example, in 2008, Autoliv's Ogden facility implemented an average of more than sixty kaizen suggestions per employee (Hogan, 2009).

The kaizen ideas are evaluated and implemented based on the objectives established during the policy deployment process. Autoliv's goal is to have 100% employee participation in the kaizen suggestion program, and teams are encouraged to submit group suggestions as well (Hogan, 2009). These items provide support for the 14th proposition:

> P14 = Successful lean companies utilize kaizen at a regular cadence to drive continuous improvement

The lean reporting metrics at Autoliv are called Operational Performance Indicators (OPIs). Hogan states, "All Autoliv OPIs are standard for the entire global business" (2009, p. 73). The OPIs include things like employee suggestions, labor minutes per unit (LMPU), on-time delivery, and inventory turns (Hogan). Hogan adds, "Autoliv…uses Units Produced per Person and LMPU to measure improvements in labor productivity and the impact of kaizen" (p. 76).

Autoliv displays the OPIs on "Blue Walls" that are standard communication tools in their facilities (Hogan, 2009). Autoliv also employs a number of other visual management techniques, since according to Blanchard (2008, p. 36), the "visual workplace is part and parcel of the Autoliv Production System." According to Hogan (p. 73), at Autoliv, "Visual systems are widespread, and are intended to create a self-directing, self-explaining, and self-improving visual workplace."

Purdum (2003, p. 34) indicates that Autoliv's initial collaboration with Toyota resulted in a visual workplace that "enables managers to walk around the plant and spot problems right

away." Another example of an important visual management tool at Autoliv is their "Production Performance Analysis Boards (PPABs)" that are used to "track how well each production line is doing. Managers can follow performance as production takes place, and react to problems. The boards also serve as a communications tool to tell the following shifts how things are going" (Hogan, p. 75). These items provide support for the 15th proposition:

> P15 = Successful lean companies utilize appropriate metrics and visual management to drive lean improvements

According to Peterson (2011, p.1), "Autoliv's success is built largely on the lean principles of the Autoliv Production System." The APS is fundamental to how Autoliv operates; as Autoliv's Scott Saxton says, "Without APS it would be difficult to know where we would be as a company" (cited in Hogan, 2009, p. 72).

Purdum (2003, p. 34) indicates that "The Autoliv Production System has also been a big factor in the plant's success. The APS is modeled after the Toyota Production System." However, an important point is that the APS is not just a blind copy of the TPS, rather

> "The key to why Autoliv succeeds is that we have come to understand not just what to do, but why you want to do it, the true intent behind it," Ambrey [Tim Ambrey, Director of Autoliv Production System] declares. "We're good at taking the intent of the TPS and turning it into our own APS, and then using those tools to their ultimate intended result, rather than just copying the tools." (cited in Panchak, 2007, p. 25)

These items provide support for the 16th proposition:

P16 = Successful lean companies have their own version of the Toyota Production System (TPS) that is not just a document, but a significant part of the company's culture

Autoliv has been utilizing lean as their business strategy since the late 1990s. According to Panchak (2007, p. 31), "After nearly a decade of learning, implementing, standardizing, and changing its lean implementation throughout the globe, Autoliv has attained a level of excellence that few other companies match. Still, the managers who oversee the company's lean efforts balance their pride in the company's accomplishments with the knowledge that more work remains." In his 2004 article *Elite Factories*, Lustgarten provides an excellent example of Autoliv's never-ending lean journey as he describes Takashi Harada's engagement with one of the Autoliv sites:

"When Toyota Motor Corp.'s Takashi Harada arrived at the Autoliv airbag module factory in April 1998, he made a quick survey of the plant's operations. Then the Japanese production specialist posed a question to production supervisor Bill Webb: "On a scale of one to ten, how strong is the facility?" Webb pondered his answer. Autoliv was a leader in automobile airbag manufacturing. It had a commanding share of the market, and Toyota was a big customer. Autoliv's production system, assembling the airbag modules on linear automated production lines, could stand some improvement, but the company was successful. "A three?" Webb suggested, humbly low-balling his new mentor. "Maybe a minus three," Harada replied." (p. 1)

In the ensuing years, Harada mentored the facility as they made numerous improvements. Then Lustgarten (p. 2) states,

"One of the lessons Webb learned from Harada is that the journey to lean production is an endless one. When Harada was leaving the Autoliv plant to return to Japan in 2001, he posed his question to Webb again. "How strong is the module facility?" Webb replied, "Maybe now it's a three?" "No," said Harada. "Now it is a zero."

These items provide support for the 17th proposition:

> P17 = Successful lean companies recognize that developing a lean culture is a lengthy process and that lean is never-ending

Gaps in Document Results

The case study documents provided evidence to support fourteen of the seventeen research propositions. In order to see if there was support for the other three propositions, the Autoliv-specific interview questions were directed at the topics not found in the case study documents. These were asked in addition to the generic questions that were asked of all case companies to look for any missing items in the model.

Interview Questions

Provided below in figure 10 is the list of interview questions specific to Autoliv.

1	Does Autoliv apply lean and the APS to areas outside of manufacturing? If so, can you provide some examples?
2	Does Autoliv utilize value stream mapping? If so, can you provide some examples of what it is used for?
3	Is the VOC used to drive any activities at Autoliv? If so, can you provide some examples?

Figure 10: Interview Questions Specific to Autoliv

Interview Results

Marie Turner, APS and Lean Consulting Manager for Autoliv's Ogden facility, was interviewed to help fill in the gaps in data for Autoliv's document analysis. She was asked the questions in figure 10 to achieve this purpose.

In regards to whether the Autoliv Production System is applied outside of manufacturing, Marie indicated that the APS is "absolutely" used in other areas. She added,

"Probably another one of the biggest mistakes that we made because you hear Toyota *Production* System, you hear the Autoliv *Production* System, so of course we started in production. And the example that I love to use is I actually had a production cell that I called the fiddler cell. We called it the fiddler cell because you had to be able to fine-tune the equipment every single day to get it to run. And what that did to me is it totally limited my flexibility. I couldn't cross-train everybody, I had an expert system, and if somebody called in, we went into overtime immediately. I just didn't have the flexibility I needed because each tool was so unique, even from a maintenance standpoint. We always had to have the same maintenance men. We just had zero flexibility and that's where it started to come in. We had to have defined standards for design and our machine build. So it didn't take long to realize that we're not going to be successful if we don't apply it to all aspects within Autoliv."

Marie provided additional examples as well, such as how lean and the APS were applied in Finance:

"Probably the example we use the most, that I just absolutely love, is I always call our accounting group our rock stars. They kind of laugh at me, but they really are our rock stars of continuous improvement. Because when you think of something as simple as SMED (Single Minute Exchange of Dies) you definitely think production with the way that's worded. But if you follow really the five steps of SMED where you want to identify internal, external, and work on making some changes and what can be done internally and what can be done externally. For our Finance teams, month end, a typical very stressful time for anybody in Finance, they've been able to identify: "hey what can we do prior to month end" and have standard work for that and

have ownership and have a back-up person there so if I want to take vacation, I can actually take vacation. They did an awesome job."

Marie concluded the response to this interview question by stating:

"Any aspect of what you look within APS, we've been able to take that and apply it. Our launch team, our design teams, you could go in any of those areas and at a glance see normal from abnormal. I mean think about designing something that's as technical and advanced as an inflator for our airbags. And I can walk into a design room and see if they're on track to develop an entire new product and see how they're doing. So definitely they have applied it throughout all of Autoliv."

These statements provide evidence to support the third proposition:

P3 = Successful lean companies implement lean in both manufacturing and non-manufacturing areas

In regards to whether Autoliv utilizes Value Stream Mapping to drive improvement actions, Marie indicated that it was used heavily early in their lean journey:

"Early on we did a ton of value stream mapping. Our processes were not connected and so we did a lot more value stream mapping initially. Today, not as much, but I'll give you an example of where it's probably been strongest for us. We mold our own steering wheel covers, and last we year we actually purchased a paint supplier and so now we mold the covers, paint, and then bring them into the manufacturing assembly area. So to understand the lead time there with paint being a batch system, how could we reduce our batches to make us more flexible? The same with molding. It's been a huge undertaking to get that whole connected loop and understanding not only what the value stream is but what's our lead time? We use it as a measurable to drive improvements on and identify what areas we need to be focused on. We're regularly completing at least one workshop each quarter or two or multiple workshops but from a continuous improvement team, at least one workshop a quarter and focused just in that focus of connected loops."

This provides support for the 10th proposition:

> P10 = Successful lean companies utilize value stream mapping to identify and drive improvement opportunities

In regards to whether Autoliv utilizes the Voice of the Customer to drive actions, Marie indicated:

"Yes; our customers are our bread and butter. We take what they say very seriously. We listen to what they say. Some of our customers are probably our best mentors. We value their input. Of course we have regular reports on Voice of the Customer and how they think we're doing. We actually have a couple of deliverables where we measure how we're doing by listening to their voice. The one thing that's key is everybody typically has some kind of scorecard coming in from their customer, but we actually measure the perception of the customer as well. And that's just as important as the number of defects. Do they perceive us as a good, key supplier? And are we listening to them to make sure that we reach our customers' expectations? We're not a typical company; I mean we have a handful of customers and they are very important to the work that we do."

When asked how Autoliv measures customer perception, Marie stated:

"Well, we don't have a traditional marketing-type group, but we have what we call a business unit. The business unit team works very closely with the customer, interacts with them, really working with the customers to not only make sure that we're hearing them, but trying to proactively look at what they want or need from us based on what they're telling us. So we can give them product or services that they never even thought that they needed but understand once we work with them that they truly do need it. So our business unit is very key in what we do and in understanding not only that voice of that customer, but understanding what the customer maybe hasn't said, what they want and what they need from us as a supplier."

These statements provide support for the 13th proposition:

> P13 = Successful lean companies use the Voice of the Customer (VOC) as a driver of improvements

In addition to answering the Autoliv-specific questions from figure 10, Marie was also asked the generic questions from figure 5. These questions were aimed at identifying the other characteristics that were important to implementing and sustaining lean as well as creating the lean culture.

When asked about the key facets of deploying lean and how they were used at Autoliv, Marie indicated:

"This is a pretty open question. If you want to go back to the basics of lean, we have the foundation in our house where of course we have teamwork which is very key, TPM, 5S, standards, and muda elimination. So when you look at that foundation, it's really important to build on that. But even prior to that, before you start working on lean and that foundation, you must be very stable and capable. You've got to look at the variables that make you unstable and really focus on that. And I'm not saying that you can't start, but with that is level-loading so you eliminate that variation in your process. Once you start that foundation that is really key.

And it's funny, everybody tends to start with 5S, which is perfect because 5S, I mean we use APS which is our continuous improvement method, it's the Autoliv Production System, very comparable of course to the Toyota Production System, and we have a saying that 'APS begins and ends with 5S' for a good reason. 5S is a key factor in seeing normal and abnormal and as you are able to see when you are abnormal, you are able to develop standards and continue to improve upon them. So a key part of 5S is seeing that normal from abnormal and developing standards.

But over time, I think it's the teamwork. I think one of the key elements we missed early on, if we were to deploy lean or continuous improvement (I kind of prefer that word) again, what we would do much, much earlier is that teamwork factor and make it an expectation that it's each and every person's job to drive improvement.

So, examples…early on, when you talk innovative improvements versus continuous improvements, there's a big gap there if you're only focused on innovative improvements. And we were doing that when we first started making this change, and we heavily relied on our engineering, our leadership teams. So we were getting those big wins when we first started continuous improvement, but early 2000 when we really started, made an expectation and got the teams involved in continuous improvement, all those little incremental changes just really started adding up. And we actually in our facility in Ogden at AOA have about 1475 people currently and everyone here is a problem solver. And even if you're spending 20 seconds a day looking for something as silly as a pen, that's wasted time and here where we're building a part every 15 seconds that adds up; we just lost a part because somebody's off looking for a pen. So those

little seconds, every incremental improvement, if we're eliminating waste even by a half a second, it adds up. Probably our biggest thing if we were to do it again would be to get the teamwork, the team involvement, with it being the expectation and a part of your job."

In response to what helped sustain the lean transformation at Autoliv, Marie indicated that "follow up, follow up, follow up" was the key. She expanded on this, saying:

"It really is our biggest strength and our biggest weakness. I always say that because it's hard, especially when you're in firefighting mode. You always have tomorrow to go verify that they're following the standards. There's always tomorrow and then pretty soon tomorrow never comes, so with that comes I guess it's kind of a key word, but it's always been how we do work, and it's leader standard work. And having that follow-up and expectation on a daily basis to go and make sure 1) that the standards are adhered to and if they're not following the standards, why not and 2) how can improve upon those standards? Are we setting clear expectations and the expectations that we've established, are they getting the results that you need?

So how do we sustain? It's our follow-up but not only that, we have pretty robust methods of questioning the standards and improving upon the standards. I mean a standard that's more than six months old and hasn't changed, we're becoming stagnant. Not only how do we sustain it, but how do we continue to improve upon it? We can't be stagnant. We have to continue to improve.

So with leadership being involved and understanding what the issues are and setting those clear expectations and really letting the teams know. Follow up is not micro-managing by any means; it's showing the teams that you care and that you're listening to them. And anytime anyone should be able to walk up to, whether it's the plant manager, or myself, the continuous improvement manager, at anytime and be comfortable coming up to say hey we have this issue, and I have a great idea to fix it, and then to work with them and give them the resources they need to drive that improvement."

When asked how long it took to firmly establish the lean culture at Autoliv, Marie stated "It's still going; it never ends." She expanded on this, saying:

"It's such a gradual process. Everybody wants that silver bullet, that magic pill, whatever you want to call it, that makes you successful. And you know we've been at this for seventeen years and the more knowledge or understanding you have of continuous improvement, the better

eyes you have. You just continually see more opportunities. So do we have a culture? You bet we do. If we had a new leader come in tomorrow, there's no way our teams would let them lead us in the wrong direction. We have that culture. We've really focused on growing our people internally to maintain that culture. Growing our people internally is really key. What's kind of neat is once you have the culture, if somebody (we always hire through our temp agency) and if somebody new comes in off the street, the teams actually set the expectations for us. Hey, we need kaizens out of you, hey, this is our expectation. We're there, but there's always, it's not something that you're there and you're done, you stop. You've got to continue to support it because you could lose it."

Finally, when asked if there were any other lessons learned with regard to implementing and sustaining lean successes at Autoliv, Marie indicated:

"It all goes back to leadership. Not only are we following up, giving the teams the tools they need, setting those clear expectations, but when we set those expectations we've got to think about and make sure that the expectations we're setting support the behavior that we're looking for. Is it going to get the results that we want? Because believe me, it's like magic when you give the teams the expectations. They're going to reach those goals. Everyone wants to be on a winning team. It's kind of awesome. So we have to give the teams a way daily to regularly assess how they're doing, not wait until the end of the month, so they can always make sure that they're on track and focusing in the right direction. It's making sure that we're achieving the goals that we're looking for as a company based on those expectations that we've set. So each year we constantly reassess the team's goals and make sure that are we, this is such a corny word but it's so true, are we focused on True North? Are the expectations that we have for our teams, are we pointing them in the right direction? Pretty key in what we do here, definitely. And it's funny; you'd think we'd have it nailed by now, but each year we kind of put a new twist on it. We're always learning and growing."

Overall Conclusions for the Case

Provided in figure 11 is an updated matrix that indicates which of the research propositions are supported for Autoliv.

Propositions: D = supported by document analysis; I =supported by interviews

Case	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Autoliv	D	D	I	D	D	D	D	D	D	I	D	D	I	D	D	D	D

Figure 11: Final List of Research Propositions Supported for Autoliv

As indicated, support was found for all of the research propositions at Autoliv. In addition to the actions mentioned in the propositions, an interview with an APS and Lean Consulting Manager indicated that having a stable and capable foundation, utilizing 5S to identify abnormal conditions, teamwork, setting expectations, and focusing on all continuous improvement activities (rather than only big projects) were also keys to implementing lean at Autoliv. Further, the improvements at Autoliv are being sustained through a combination of leader standard work, regularly reviewing and improving upon standards, and giving people the resources they need to make improvements.

United Technologies Corporation (UTC)

Background

UTC is similar to Danaher in that it is also a conglomerate. According to UTC's corporate website, "United Technologies Corporation (UTC) is a diversified company that provides a broad range of high-technology products and services to the global aerospace and building systems industries." As an indicator of UTC's success,

"From Jan. 1, 2000 through 2005, UTC, best known for its Otis elevators, Pratt & Whitney jet engines and Carrier heating and air-conditioning systems, had a compound annual

earnings growth rate around 13% - more than double that of arch-rival General Electric (GE) in the same span. Other industrial conglomerates, including Tyco (TYC) and Honeywell (HON), suffered negative growth over those six years." (Laing, 2006, p.26)

Additionally, Roth (2013) indicates that between 2001 and 2011, UTC performed better than any other Fortune 50 company.

Document Analysis Results

The case study documents for UTC provide support for a number of the propositions of the research model. Those that were supported by the case study documents are shown with an "X" in figure 12 below.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
UTC	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X

Figure 12: Research Propositions Supported by UTC Case Study Documents

Like Danaher and Autoliv, UTC utilizes a lean business strategy, guided by a system they call ACE. ACE stands for "Achieving Competitive Excellence" and is UTC's version of the Toyota Production System. ACE first began at Pratt & Whitney in 1996, and was spread across UTC by the end of 1998 (Roth, 2011). According to Roth (p. 5),

"During the last two decades, many corporations have restructured and adopted continuous improvement methods, but few have attained and sustained UTC's performance. Its leaders have taken an unequivocal stance the development and implementation of ACE has produced these results, and the continued use of ACE will sustain them."

Roth also indicates (p. 10) that former UTC CEO "George David drove consensus around ACE." This provides some support for the first proposition:

P1 = Successful lean companies drive lean implementation from the top down

Like Danaher, UTC utilized Shingijutsu Consulting during its lean implementation. This came about primarily because one of the operations managers from Danaher, John Consentino, moved to UTC to become president of Otis North America (Emiliani, 2006). Consentino convinced George David to hire Shingijutsu to begin consulting with Otis and Pratt & Whitney in the early 1990's (Emiliani).

In addition, ACE was built on principles from Yuzuro Ito, a quality consultant who reported directly to David and worked with UTC for seven years (Holstein, 2005, Roth, 2010, and Bhuiyan et al., 2006). Ito had been the vice president of Matsushita Electric in Japan prior to retiring and moving to Connecticut at David's request to join UTC (Roth).

These items provide support for the second proposition:

P2 = Successful lean companies utilize consultants from established lean companies like Toyota as senseis to help guide their initial learning and lean improvement

Laing (2006, p. 26) states that as CEO, David went "far beyond…most…corporations, by attacking bloat and redundancy far beyond the factory floor." Destefani (2005, p. 161) indicates that "ACE guides both [UTC's] manufacturing plants and [their] business practices." Roth (2010, p. 43) says, "ACE had evolved from the original manufacturing oriented program deployed at Pratt & Whitney in 1996 to UTC's business operating system" and that now "UTC uses ACE across all aspects of its business operations" (p. 6). Additionally, training courses at

UTC contain "examples of overall operation improvements, including improvements in the business functions supporting operations" (Roth, p. 36). These items provide support for the third proposition:

> P3 = Successful lean companies implement lean in both manufacturing and non-manufacturing areas

According to Falkowski (2001), UTC decided that supplier management should be one of its core competencies, which would require helping UTC's suppliers become lean. Part of working with suppliers included making some ACE training courses available to them (Roth, 2010). Current UTC CEO Louis Chênevert noted that:

> "As ACE was deployed internally at UTC, it became clear to me that our ACE journey would not stop at our own facility walls, but rather needed to include our supply base. We needed to leverage every opportunity available across the UTC value chain to optimize performance and ensure customer loyalty." (Roth, p. 45)

Each division at UTC was expected "to help suppliers establish and develop improvement initiatives. The model for supplier improvements was UTC's own ACE experience" (Roth, 2010, p. 34). UTC initially estimated this would require 250 to 300 of its employees to work on supplier initiatives (ibid.). They believed this effort would be worth the investment in UTC resources, since more than 75% of product costs came from supplied material and "The extension of ACE-like efforts to UTC's suppliers provides operational performance and stability for UTC to achieve its own improvement goals" (ibid, p. 44). Roughly 300 managers were assigned to focus on supplier improvements and received extensive training on

ACE (Roth, 2013). As a result, "UTC's supplier improvement program soon became as effective as that of any Japanese company" (ibid., p. 6).

As part of providing training and assistance to suppliers, the expectation was that suppliers would be assessed for criteria related to quality, on-time delivery, lean, and customer satisfaction. This was part of the Supplier Gold program that suppliers could participate in, where UTC would assess them on the above criteria and rate them as gold, performing, progressing, or underperforming. Gold was the highest level and would require meeting the criteria for twelve consecutive months (Roth, 2010). The ability of suppliers to participate in the program and strive for gold certification became even more important when in 2009, Chênevert announced to analysts that by the end of 2011, 70% of supplier spend would be with gold or performing suppliers (Roth).

These items provide support for the fourth proposition:

> P4 = Successful lean companies recognize that once they have made progress on becoming lean internally, they should extend lean implementation to their suppliers

UTC has a full-time ACE Director position and an ACE office of full-time resources (Roth, 2010). At the corporate level (in 2008), UTC had an ACE Director with an administrator and four ACE experts (ibid.). Divisions also have an ACE Director, ACE Managers and Client Managers (consultants); for example, in 2006, Pratt & Whitney had an ACE Director, three ACE Managers, and fourteen ACE Client Managers (ibid.). There is also an ACE Council made up of the overall ACE Director and ACE Directors from each division that "makes policy decisions,

updates and changes ACE criteria, monitors ACE assessments, and reviews...training programs for managers, basic ACE training for all employees, and specialized tool training for ACE specialists, coordinator, consultants, and assessors" (ibid., p. 56). These items provide support for the fifth proposition:

P5 = Successful lean companies dedicate full-time resources to lean improvement

The case study documents indicate that communication is an important part of ACE. According to Roth (2010, p.34),

> "To achieve the goals set out for Operations Transformation required more communications and greater transparency on improvement progress and current performance. Some ACE methods, specifically one and five year roadmaps, were used in developing aligning, and communicating business-specific strategies."

UTC established an ACE council, and one of the key responsibilities of the ACE council was to provide a forum for communicating and sharing ideas. Destefani (2005, p. 165) indicates that at ACE council meetings, leaders from each division "go over what each group is doing in terms of ACE activities, and that's one way we develop standard work and share best practices." Roth (2010, p. 37) corroborates this, adding:

> "Another function of the ACE Council's regular, one-day, monthly meetings were as a forum to discuss progress, issues, and test new ideas or practices. The council drew upon experiences in different divisions to assess ideas that, if successful, would be promoted across all of UTC."

These items provide support for the sixth proposition:

> P6 = Successful lean companies seek to provide regular communication on lean throughout the organization

The case study documents provide a number of examples of how HR policies at UTC support and sustain lean improvements. New employee orientation includes a required one-day "ACE at work" course (Roth, 2010). Destefani (2005) indicates that UTC will not lay off any employees as a result of lean improvements; instead, they will be moved to another area that needs people. Additionally, UTC provides proficiency levels in ACE quality and lean so employees have career tracks and can move up based on training and experience in those areas (Destefani). Roth also indicates that "Incentive compensation and advancement criteria for managers included achieving ACE goals" (p. 36), and, "ACE achievements are part of everyone's bonus" (p. 39). These items provide support for the seventh proposition:

> P7 = Successful lean companies adopt HR policies that support lean goals

UTC created "Ito University" (named to honor Ito for all his contributions to developing ACE) as a mechanism for providing training in ACE. In addition to the one-day ACE at Work class that all new hires take, more than 20,000 UTC employees have completed a more in-depth three-day course on ACE principles and philosophies (Roth, 2010). The program involves classroom training, simulations, and field work and is taught at UTC sites all around the world

(ibid). Ito University also "offers more than 120 unique courses in 22 different countries" (ibid., p. 28). According to Roth (2010, p. 65),

> "People develop their individual ACE proficiencies through training courses, applying what they learn in training, and continuing to apply that knowledge to ongoing projects that seek to achieve desired organizational outcomes. To develop ACE skills, the ACE council defined three proficiency levels: Associate, Practitioner, and Master. These levels relate to skills in using tools and leading improvement events. People achieve these proficiency levels by enrolling and completing a curriculum and through successful performance assessment. These curriculums include on-line, classroom, and applied on-the-job training. The applied training, depending on the level, requires either participating in or leading improvement events and demonstrated abilities to use ACE tool and organizing, lead[ing], and complet[ing] ACE improvement events."

These items provide support for the eighth proposition:

P8 = Successful lean companies invest in training for employees to learn about lean

Roth (2010, p. 25) indicates that leadership at UTC "had learned the importance of selecting, training, and equipping leaders from work groups to make and sustain changes." They developed ACE Pilot training to help with this. Bhuiyan et al. (2005) indicates ACE Pilot training is a two-week ACE competency course for team leaders. Additionally, expert ACE Pilots are developed for each department to focus on continuous improvement (ibid.). UTC also developed a week-long Ito University class to help disseminate ACE because "engaging leaders would spread ACE across UTC" (Roth, p. 26). The CEO at the time, George David, and 25 other senior managers attended the first one. Then David even taught the course to the board.

Kip Wyman, Chief Manufacturing Engineer at Pratt & Whitney (cited in Destefani, 2005, p. 165) also says, "We rotate our lean manufacturing experts through other United Technologies

companies to share our best talent and share lean manufacturing concepts." These items provide support for the 9th proposition:

> P9 = Successful lean companies see the value in developing internal lean leaders and senseis

Wyman also states that "Whether it's a business process or a manufacturing process, we start with value stream mapping as a base. We identify all the processes, the handoffs, the influences, and the lead times. That's a good example of one of our standard lean tools" (cited in Destefani, 2005, p. 164). Roth (2010, p. 88) indicates that,

> "Consistent with the broader value stream context, UTC uses tools that it calls Value Stream Management to achieve process effectiveness, efficiency and agility through waste elimination and the standardization of work. The goal is to identify and focus on improvements to the group of processes that delivers value to customers by taking a system-level view and focus on creating lean processes by eliminating waste."

Additionally, Roth (2013, p.6), describes a conference with 350 UTC executives in January, 2003 where George David "closed the conference by asking all the executives to write him directly, stating what they would do to personally learn and apply the value stream concept." Those who did not follow up within a few weeks were contacted by David to get their commitment. David then also made sure that when he toured UTC facilities, "he would look for the management team's value stream maps, ask questions, and often instruct managers on finer points of the technique" (ibid.). These items provide support for the 10th proposition:

> P10 = Successful lean companies utilize value stream mapping to identify and drive improvement opportunities

Milward and Teti (2008, p. 7) indicate that "At UTC standard work is defined as the creation of repeatable, effective, and efficient processes. Various documentation formats are presented for this purpose." They also state that at the UTC division they work at, Hamilton Sunstrand, there is a Standards Work Team that helps develop standard work (ibid.). Roth (2010, p. 93) indicates that "UTC's ACE standard work tool is described as 'the method by which work is simplified and structured to ensure maximum quality, productivity, and repeatability over time.'" Further, "Documentation and regularly reviewing and improving standard work is what enables both the flexibility that leads to continuous improvement and the rigid scripting that leads to efficient operations" (ibid.).

Importantly, UTC recognizes the need for standard work to be dynamic, updated as continuous improvements are made. Roth (2010, p. 94) indicates that "People also keep their standard work fresh by benchmarking other locations doing similar work. If the instructions are not accurate, or better ways are devised to perform that work, then a change is made." Also, "The regular and timely reporting of turnbacks [defined as any event that prevents timely completion of a required process step] provides data that teams use to make changes in standard work and other process documentation and procedures" (ibid., p. 95).

Pratt & Whitney even developed Engineering Standard Work (ESW), "based on six elements of engineering work that are documented - workflow maps, tools and methods, design criteria, design standards, lessons learned, and practitioner proficiency assessments - each of which has assigned owners to review and make ESW changes" (Roth, 2010, p. 95). After implementing ESW, Pratt & Whitney saw a 50% decrease in Engineering Change Orders

(ECOs), which contributes to the savings that the company has seen. "An assessment in 2002 found that every $1 spent on ESW paid back $4 in cost savings" (ibid.). These items provide support for the 11th proposition:

> P11 = Successful lean companies utilize standard work as the baseline for continuous improvement

Though it is not explicitly referred to as policy deployment in the case study documents, UTC uses one-year roadmaps, which "through a flow-down of goals or roll up of metrics, provide strategic direction for continuous improvement guidance" (Roth, 2010, p. 60). "There is also a five-year roadmap. Each site has a one-year and a five-year Roadmap, where the five-year Roadmap sets long-term direction and the one-year Roadmap flows directly into the site's activity plans and metrics scorecard" (ibid, p. 61). These items provide support for the 12th proposition:

> P12 = Successful lean companies utilize hoshin kanri or policy deployment to align company goals and lean strategies

Roth (2010, p. 83) indicates, "Kaizen is a part of ACE as a philosophy, but it is not included in UTC's list of ACE tools." However, kaizens still appear to be part of the standard practice at UTC. For example, Destefani (2005) indicates that Pratt & Whitney averages three week-long kaizen events per month across the three sites. This provides some support for the 14th proposition:

P14 = Successful lean companies utilize kaizen at a regular cadence to drive continuous improvement

According to Roth (2010, p. 61) "All UTC organizations use a metric scorecard." The metrics are established as part of the roadmap process discussed earlier. Similar to Toyota's True North metrics, the metrics "cover the four key roadmap areas: customer focus, employee fulfillment, quality processes, and business results" (ibid.). Additionally, UTC uses a web-based system called the ACE Management System that "allows ACE Council members or UTC executives to view ACE status by divisions, applications area, or geography, find information on specific sites and their status, and view trends by these categories. The ACE Council uses the information from this system to focus its efforts in advancing ACE" (ibid., p. 57).

Roth (2010) indicates that the key UTC metrics are also displayed on standard metrics boards in each area. The metrics "are regularly updated so that employees, or visitors, can see plans and performance. On the operations floor, daily cell meetings occur with the use of ACE boards to address issues or anticipate changes" (ibid., p. 62). These items provide support for the 15th proposition:

P15 = Successful lean companies utilize appropriate metrics and visual management to drive lean improvements

The case study documents provide a number of instances where UTC's ACE business system and its importance are discussed. ACE started at Pratt & Whitney in 1996 and spread to rest of UTC through 1998 (Roth, 2010). Canaday (2009, p. 74) says, "UTC's Achieving

Competitive Excellence program is the foundation for Pratt & Whitney's improvements in its engine centers and repair shops." Holstein (2005, p. 33) indicates, "In 1998, the company created Ito University to help it implement the Achieving Competitive Excellence (ACE) method, which is based on Japanese systems." Stacy Hall, a lead at the North Berwick Pratt & Whitney plant says, "We knew that we could not just unplug Toyota's TPS method and put it in. That was Toyota's and it had to be Toyota's. We had to utilize best practices but make them ours" (cited in Roth, p. 25). Destefani (2005, p. 161) states that "ACE is always evolving and growing, and it's our base toolbox. We learn as we go and adjust our standard work."

George David, former UTC CEO says, "We have invested lots of money, effort and care in [ACE] in the last years. It is repetitive, formal, disciplined, taught, and it doesn't change. It is the basis of more than half the shareholder value increase in UTC" (cited in Roth, 2010, p. 1). UTC Operations VP Jothi Purushotaman states that "ACE is our strategic, competitive weapon and is our operating system. The key aspect of ACE is that it engages and empowers all of our employees to achieve world-class products and processes to delight our customers, shareholders, and associates" (cited in Roth, p. 35). Roth (p. 46) indicates, "ACE is dynamic, evolving in response to UTC's needs, and through that experience, becoming its "operating system." Feedback guided that evolution, as the ACE Council collected data and held discussions to adjust, adapt, and extend ACE." These items provide support for the 16th proposition:

> P16 = Successful lean companies have their own version of the Toyota Production System (TPS) that is not just a document, but a significant part of the company's culture

Establishing ACE and the supporting culture at UTC took time. Roth (2013, p. 2) indicates, "It took 10 years for UTC's leaders to fully develop the methods that Ito and others taught them, to make those methods their own, and to extend the resulting approach across the company and the rest of its value chain." As Roth (2010, p. 37) states, "Guiding ongoing activities required considerable time, coordination and communication from ACE Council members." He elaborates on this (page 51), stating,

> "The ACE operating system has evolved over more than a decade. What Pratt & Whitney employees first created and designated as ACE in 1996 is considerably different from what UTC calls ACE today…What gives ACE longevity is that the meaning of the terms has evolved with the needs and maturity of UTC's divisions."

Since first establishing Ito University in 1998, the ACE council has continuously "worked to improve ACE criteria, upgrade Ito university courses, develop new training, a curriculum for Associate, Practitioner, and Master proficiency levels, and improve the site assessment process" (Roth, 2010, p. 37). Destefani (2005, p. 165) states, "We continue to look for opportunities to expand our lean initiative." Finally, former CEO David says "There is no limit. It will go on forever and ever and ever" (cited in Roth, 2010, p. 1). These items provide support for the 17th proposition:

> P17 = Successful lean companies recognize that developing a lean culture is a lengthy process and that lean is never-ending

Gaps in Document Results

The case study documents provided evidence to support sixteen of the seventeen research propositions. In order to see if there was support for the remaining proposition, the UTC-specific interview question was directed at the topic not found in the case study documents. This question was asked in addition to the generic questions that were asked of all case companies to look for any missing items in the model.

Interview Questions

Provided below in figure 13 is the interview question specific to UTC.

1	Is the VOC used to drive any activities at UTC? If so, can you provide some examples?

Figure 13: Interview Question Specific to UTC

Interview Results

A former Vice President of Product Management, Engineering, and Sales & Marketing, a former Director of Quality and Operations from a division of UTC, and a Principal Engineer at UTC's Research Center (UTRC) were interviewed to help fill in the gaps in data for UTC's document analysis. They were asked the question in figure 13 to achieve this purpose.

When asked if the Voice of the Customer was used to drive activities at UTC, the former VP of Product Management, Engineering, and Sales & Marketing indicated that the "VOC was an explicit requirement in the early stages" of UTC's product development process. He elaborated, saying:

"Yes, very much so, especially given that I had engineering at UTC and product management. That's one of the things that we would do, Voice of the Customer. As an example, one of our businesses is Kidde, which makes smoke detectors and fire extinguishers and we're the market leader in that area. But we would do a lot of market research; we would do a lot of competitive analysis before we would launch a new product. One example would be we launched a kitchen fire extinguisher and the problem you have with kitchen fire extinguishers is that they can't put out grease fires normally because there's so much pressure coming out that you splatter the grease all over the place and spread the fire. So that's one of the things we did; we went to Home Depot and we went to Lowe's as our customers and said 'What do you guys want as far as your customers?' And we went to the end customers and we said 'Ok, what is going to be useful for you as far as the form factor, as far as the way you pull the trigger and so forth?' We did a lot of market research there. We went to the fire departments and asked them for their input on things. And I think it's a Class E, but it's the first rated home extinguisher that came out that's very ergonomically comfortable for the person to use and it has a big horn or a big bell on the end so it kind of mists out versus coming out at a high pressure that would splatter the grease. So it would lay over the fire versus pushing the fire out of the pan and so it's rated for kitchens where there is no other extinguisher that's out there. That was a market need that we identified."

"On cruise ships, we provided the smoke and fire systems, the integrated fire alarm system, which would be the smoke detectors, the flame detectors, the heat detectors, along with all the annunciation devices, the things that would be blaring, along with the system that controlled all that. And so what we did is we worked very closely with Carnival and Royal Caribbean and Norwegian and the other cruise lines to say 'Ok; what are the features that you want in your software package to control this whole system?' To the point where the firefighter would enter the fire on a ship and it would have location detection for the firefighter so the captain on the ship could direct the firefighters in and you'd have a visual display of where the fire was and the smoke. And he'd know where all the firefighters were. It was something that the owners of the ship on the shore would be able to watch real time. It's something that we looked at again the Voice of the Customers and they wanted to have a record that they could show the insurance companies that would prove that they fought the fire in the appropriate way and there were no questions about it. But for us it was a matter of talking to the cruise lines, the insurance companies, the ship owners, the actual firefighters on the ship to define those requirements that we needed for our system."

"We bought GE Security and one of things that they do in the US is they have fire panels and they do fire alarm systems for buildings and we entered the low end market and there again we brought our customers in, our distributors in to understand this new segment we were going into and what they needed to do going into that segment. How did they define the product features, and what were the price points? Product management was very important to us and that's where we funneled the voice of the customer through."

The former Director of Quality and Operations also indicated that the Voice of the Customer was used in his areas of responsibility at UTC and that it was a key part of the ACE system. He stated:

"The Voice of the Customer is everything. The ACE operating system really focuses on the Voice of the Customer and it's a quality system. And the Voice of the Customer is measured at every step of the ACE system. Inside ACE you need to understand who your customer is because everybody has a customer and a supplier. You need to clearly understand who your customer is. Your customer may be someone inside the company, but if you don't have some customer who's using the output of your activity then we don't need you was the idea. So to become ACE certified, you had to understand what your process was, you had to map out using a typical SIPOC process…And then you had to figure out what were the key processes and you'd have to go to your customer and get your customer to agree on that. And then you would have to agree with your customer on quality metrics. And then you would have to find a way to report those metrics on a regular basis to measure the continuous improvement and to take action on non-conformances. That was a key bedrock."

The Principal Engineer at UTC's Research Center also indicated that the VOC was utilized there, and stated,

"Even in our projects we are doing this research. We are a research environment; we have to start getting more innovative ideas and applications. And believe me, one of the main things we have is for each project, there is a customer or several customers. We have like a questionnaire even inside UTRC or between UTRC and divisions. We have by the end of the year the evaluation of the customer satisfaction; we look at it I think three times per year. There are about six or seven questions regarding how we are communicating with the customer. Are we listening to the customer requirements? Did we deliver what the customer asked us to do?

What is the fashion we delivered it, the communication, the reporting, and the data we delivered? Is it considered acceptable by the customer? Not only that, but we actually have a record for this. Every year it evaluates UTRC's, all the people there, we have a part of the evaluation that looks at customer feedback. We have it from I think like one to seven, and if it is below five or five there is root cause analysis for why this happened."

The responses from all three UTC interviewees provided support for the 13th proposition:

> P13 = Successful lean companies use the Voice of the Customer (VOC) as a driver of improvements

In addition to answering the UTC-specific question from figure 13, the interviewees were also asked the generic questions from figure 5. These questions were aimed at identifying the other characteristics that were important to implementing and sustaining lean as well as creating the lean culture.

When asked about the key facets of deploying lean and how they were used at UTC, the former Director of Operations and Quality responded:

"The biggest thing at UTC was there was a clear champion at the top. The CEO of the company said we're going to do this and it was very important and he put it in people's objectives and told Wall Street we were going to do it which is kind of the UTC strategy where the Chairman would declare to the analysts that we're going to do something and then he'd turn around to the Group President bosses and say we have to do this because we already committed to it. And that creates the alignment at the top which was very important. But combined with that was a pretty clear framework and methodology and measures of what success meant. We had a pretty clear definition of the tools that we would use and the way we would measure progress. So we created the sense of urgency, the accountability, and then we created a pretty rigorous framework or tool kit of the how-to practical implementation."

[Interviewer asked if he was referring to ACE:] "It became ACE; we called it the ACE operating system which is an operating system, it was a culture and it was the DNA of the

company. People didn't even talk about ACE as a program because it was the way we did things. It wasn't even called out as something special. I worked with a lot of joint ventures and acquisitions and so I would be going in and helping people get with the program so for those folks it was a program to be administered, but inside the bigger UTC it was just the way we did things."

Note that this item also provides additional support for the 1st proposition that successful lean companies drive lean from the top down.

When asked about key factors in sustaining lean improvements at UTC, the former Director of Operations and Quality responded:

"Some of the keys that helped us sustain…I think that the well used cliché of 'what gets measured gets managed' is very true in this case. We had metrics; we had certification and we had levels of achievement that were based on audits and those levels of certification that needed to be renewed on a periodic basis, typically annually. So we had different levels of achievement, we called them basically something like beginning and then bronze, silver, gold were the levels of ACE achievement. And to achieve the gold level of ACE certification internally was very difficult, and to maintain it was difficult. But the level of certification was known by everyone and in people's objectives and very important. And there were cases where people would get de-certified because they didn't maintain the performance criteria, so that whole measurement system really created the sustainability of the program."

Note that this item also provides additional support for the 15th proposition that successful lean companies utilize appropriate metrics to drive lean improvement.

When asked the same question, the former VP of Product Management, Engineering, and Sales & Marketing responded:

"There are a couple things. The one is that just having the operating system was very helpful, having ACE. The second is we had something called the Passport Process, which was a staged gate review process and we pretty much ran everything through a passport. Stage gate 0

for example was your business case; stage gate 1 was a conceptual design where you set your budget, your resources; stage gate 2 would then be a preliminary design; 3 would be a detailed design; 4 is where you looked at the results and also did testing and trials, but you would do your launch of the program or the product and then 5 would be a post-look back. But we used to put everything through that, whether it was a sales force launch, it was a factory floor initiative, it was launching a new product, and so I think that was very important.

And the Passport Process was a governance process. It wasn't an engineering process or wasn't a functional process; it was a governance process and it was very cross-functional. And I think that was one of the keys to getting things to work, having that process in place. The process can go through anything and again it's having the operating system there that gives you a lot of tools that support the different processes you have in place…you're using some of the diagnosis tools that are in the tool kit."

When asked how long it took to firmly establish the lean culture at UTC, the former VP of Product Management, Engineering, and Sales & Marketing responded:

"One of the things I had was the luxury that it had been started in the 90s. And so it was firmly a part of the culture...I mean we did fifty plus acquisitions and so one of the things is we bring new companies in but we would bring them into the ACE culture. And I think that happened very quickly because as I said the luxury we had is that we had a base to work from.

[Interviewer asks how quickly the companies would be assimilated into the culture] "Depended on the company; for example we acquired GE Security and it was over a billion dollars of revenue but they had some lean and mainly six sigma, and that was actually in some ways harder to do because even though a lot of things were similar, there was a little bit of our way vs. your way and it was different. Small companies we would bring in, they assimilated very quickly. For example, we put their engineering directly into the Passport Process. We didn't have to change their engineering processes, we had to make sure that again we had the decision points and they learned over time by going through these gates, by going through the staged gates. But I would say probably within a year they were assimilated."

When asked if there were any other key lessons learned at UTC, the former VP of Product Management, Engineering, and Sales & Marketing responded, "I think the main thing is having the full tool kit; you need to build it up over time." The Principal Engineer indicated that

6S (5S plus safety), root cause analysis, and leveraging best practices and standard work were some of the keys at UTRC. And the former Director of Quality and Operations indicated:

"Well I think that again, I think the senior management sponsorship and involvement is key. Having a way to measure the continuous improvement is also key. If you don't have metrics that you agree on to demonstrate that you're getting better and to focus your attention on the areas that need improvement activities, then you're not going to move ahead in an orderly way. I think those are very important.

Commitment to spend the money on training people is important. It's expensive to train people, and if management views that training as an investment that will yield a return, that's an approach that encourages people to get proper training and utilize it. If you don't view it as an investment, and you view it as more of an expense, a check the box kind of activity, then you're not going to get the same focus and support from front-line managers. And you're not going to get the same participation.

To really be successful in this type of lean activity, you need to win the hearts and minds of the rank and file, which is very important. So the question is how do you do that? And everything I've talked about is tactics and strategies to win the hearts and minds of the people. You motivate them, you train them, you measure them, you reward them. I didn't talk about rewards yet, but rewards are an important part of the process cycle so that when people do have successes, you acknowledge them, celebrate them, get people excited to demonstrate that they're driving improvements."

When the interviewer asked for examples of how people were rewarded for lean success at UTC, the interviewee indicated that rewards were not monetary; they were typically forms of recognition. For example, the division's President had regular all-hands meetings and "there was always a section for ACE where we would talk about progress and we would always showcase a couple of success stories to give people credit for the good work that they've done. People would be publicly rewarded."

Overall Conclusions for the Case

Provided in figure 14 is an updated matrix that indicates which of the research propositions are supported for UTC.

Propositions: D = supported by document analysis; I =supported by interviews

Case	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
UTC	D	D	D	D	D	D	D	D	D	D	D	D	I	D	D	D	D

Figure 14: Final List of Research Propositions Supported for UTC

As indicated, support was found for all of the research propositions at UTC. Interviews with former UTC personnel indicated that having a champion at the top and a clear framework for lean, as well as investing in training and motivating people to change, were keys to implementing lean at UTC. Further, the improvements at UTC are being sustained through measuring levels of ACE achievement, leveraging best practices and standard work, and following the Passport Process.

Boeing

Background

Boeing first began to implement lean in the late 1990s, partially as a response to capacity issues (Leitner, 2005). According to Thomas (2001, p. 41),

"Lean manufacturing became critical for Boeing when its production lines became choked in 1997 because it still was using 1945 production methods and configuration control and it was bogged down in customer options. The classic examples were the 737 landing gear, which required 464 pages for the optional parts that are attached to each aircraft, and the 109 shades of

white paint that Boeing offered. The result was a $4 billion write-off and many disgruntled customers."

In the early 2000s, Boeing made a revolutionary lean leap when it began implementing moving lines for assembling planes that were paced at takt time, an assembly strategy previously unheard of for the airline industry. According to Jim Womack, "Boeing…really rethought the whole production process…to build a big airplane the way Toyota would…Boeing is an example of a company that has made a lot of progress in becoming lean..." (cited in Blanchard, 2007, p.54). Teresko (2002, p. 40) states, "Today, Boeing's C-17 complex is benchmarked as an example of the process excellence possible via employee involvement and lean manufacturing." And like Autoliv, multiple Boeing sites have won the Shingo prize for operational excellence (Leitner, 2005).

Document Analysis Results

The case study documents for Boeing provide support for a number of the propositions of the research model. Those that were supported by the case study documents are shown with an "X" in figure 15 below.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Boeing	X	X	X	X	X	X		X		X	X		X	X	X	X	X

Figure 15: Research Propositions Supported by Boeing Case Study Documents

Venables (2005, p. 28) says about Boeing, "It was a board awareness of the needs of the business that allowed the company to take the first tentative steps on the lean path." Steve Westby, vice president of manufacturing, elaborates on this, saying,

> "It first started at a corporate board level, there had to be commitment to get it started, getting a lot of the senior executives trained and Carolyn Corvi, vice president and general manager of our 737 line, was one of those students who went back and learned and continues to learn - she was in Japan this year." (ibid.)

This provides some support for the first proposition:

P1 = Successful lean companies drive lean implementation from the top down

According to Leitner (2005, p. 270), Boeing believed "External eyes [were] necessary, which is why consultants [were] utilized." This helps to explain why "Boeing, in addition to sending hundreds of its executives to study in Japan, took on retired Toyota people as consultants to such a degree that they now have hundreds of staff trained in kaizen" ("Boeing flies high," 2006, pp. 14-15). Venables (2005, p. 28) corroborates this, saying that in the late 1990s, Boeing "began contracting with consultants - predominantly retired from Toyota - who work with the company to this day." Like Danaher and UTC, Boeing utilized Shingijutsu Consultants early in its lean implementation. Boeing was introduced to Shingijutsu during a visit to Wiremold in 1995, and began working with them soon after (Leitner). These items provide support for the 2nd proposition:

P2 = Successful lean companies utilize consultants from established lean companies like Toyota as senseis to help guide their initial learning and lean improvement

According to Jenkins (2002, p. 2), "while Lean often is viewed as a factory floor concept, its philosophy stretches across the Boeing enterprise, touching everything from suppliers and procurement to engineering and design to manufacturing and delivery." In fact, Boeing changed the name of its Lean Manufacturing Office to the Lean Enterprise Office to help emphasize that lean didn't apply just to manufacturing (Leitner, 2005). Boeing has also established what they call "Lean+." According to Dunbar (2006/2007, p. 65), Lean+ is "Boeing's growth and productivity initiative to apply Lean not only on shop floors, but also in the office environment." These items provide support for the third proposition:

P3 = Successful lean companies implement lean in both manufacturing and non-manufacturing areas

Leitner (2005, p. 266) indicates that "The last several years have seen Boeing look outside its four walls, training suppliers and customers." Jenkins (2002, p. 4) states, "Across the company, Lean practitioners are sharing their knowledge with suppliers, helping them streamline their operations and thus become better partners to Boeing." According to Blake and Eash (2003, p.655), "Boeing Suppliers currently account for approximately 60% of a product's total cost." And that is estimated to reach 75% by 2016. They add, "Boeing suppliers also differ significantly in their ability and resources available to develop and deploy process improvement plans. Boeing has established teams of Lean experts across the company available to assist them

develop their Lean strategy and implementation plans" (ibid.). They even have a "Supplier Lean Transformation Model."

Value Stream Mapping is used to help identify which suppliers are keys to success that should be engaged. Behrens (2008, p. 2) elaborates on this, stating that:

> "to support suppliers, a Lean Engagement Model has been created that involves three different engagement approaches based on the strategic importance of suppliers and their ability to self-improve…Depending on the type of supplier and focus of the engagement, support may include business vision, strategy and goal alignment, plan and process improvements, and training and certification in lean tools and methods."

These items provide support for the fourth proposition:

> P4 = Successful lean companies recognize that once they have made progress on becoming lean internally, they should extend lean implementation to their suppliers

Mike Herscher, Boeing's Renton factory manager is quoted in Venables (2005, p. 28) as saying, "We now have between 300 and 400 well trained kaizen people, and many of these are dedicated full-time to carrying out continuous improvement work." This provides some support for the fifth proposition:

> P5 = Successful lean companies dedicate full-time resources to lean improvement

Boeing regularly provides communication on what lean is and how it is being used there through various online means such as their "Boeing Point-to-Point" and "Frontiers" weekly

newsletters. Boeing tried to emphasize the positive aspects of lean. According to Jan Martinson, a Lean Enterprise director in Seal Beach, California, "We communicate that we're not improving processes to eliminate jobs, but to improve our competitiveness and therefore create more jobs" (cited in Jenkins, 2002, p. 4). Another way that Boeing provides communication on lean is a cross-Boeing Lean Enterprise conference "where about 150 employees and mid-to senior-level managers, who champion Lean improvement activities across the enterprise, and outside experts…share their accomplishments and discuss ways to accelerate their successes" (ibid., p. 2). These items provide support for the sixth proposition:

> P6 = Successful lean companies seek to provide regular communication on lean throughout the organization

Boeing has sent executives to Japan for training on several occasions. According to Leitner (2005, p. 264), "The first Japan study tour, in which top managers visited Japan and benchmarked eight different companies there, took place in 1990." According to Leitner (2005, p. 265), as part of their engagement with Shingijutsu, "Shingijutsu consultants spent many weeks at Boeing and hosted many senior managers at Japan Kaizen seminars." Then after attending their first kaizen workshop with Shingijutsu in 1995, "Boeing managers traveled to Japan once more, this time to study Toyota's Production System (TPS)" (ibid., p. 265). According to Venables (2005, p. 28), "For the next three years Boeing sent over 1500 executives to Japan to study." Jim Luby, Quality and Lean Enterprise Site Manager at Boeing Mesa, describes the impact of a trip taken to Japan to visit the Hitachi Air Conditioning facility, saying,

"My boss, who is the site manager here, he looked at that, he saw these big air conditioning units and he said 'Jim, what do you see about those?' and I said, 'Well they are big air conditioning units with parts and they go down an assembly line.' He said, 'Exactly. They have metal, they have wiring, and they have tubes and so on. What does our helicopter have? They have metal, wiring, and tubes. Why can't we do that?' That's what helped my boss come up with the vision." (cited in Venables, 2006, p. 17)

Simulations are also a common method of training at Boeing. Dunbar (2006/2007) indicates that Boeing uses a game created by MIT's Lean Aerospace Initiative (now known as the Lean Advancement Initiative) to help teach lean to employees. During the training, Todd Burrow of Boeing's Lean Office indicates, "Besides learning basic lean concepts, students learn about the flow and complexity of business processes – and why sometimes the results of improvements may not be realized immediately" (as cited in Dunbar, p. 65). The class is a day-long event where "teams identify and implement improvements to reduce cycle time within simulated business processes" (ibid.). Boeing also developed what it calls "The Coffee Game" which is a simulation of a coffee value stream that is used to train executives in lean principles (Leitner, 2005).

Additionally, Boeing uses a mobile "Lean Green Training Machine" similar to a golf cart in their Renton facility that brings training to the operators instead of requiring them to go to a classroom (Jenkins, 2002). These items provide support for the eighth proposition:

P8 = Successful lean companies invest in training for employees to learn about lean

According to Leitner (2005), in 2000, Boeing developed what it calls the nine tactics for achieving continuous flow. They are: 1) Value Stream Mapping; 2) Balance the Line; 3) Standard Work; 4) Visuals in Place; 5) Point of Use Staging; 6) Feeder Lines; 7) Process Breakthrough Redesign; 8) Pulse Line; and 9) Moving Line. Value Stream Mapping is the first of the nine tactics. Waurzyniak (2005, "Lean Fighter", p. 80) indicates that "Lean manufacturing methodologies deployed by Boeing on its Raptor fighter effort included value stream mapping." Blake and Eash (2003, p. 655) state that when Boeing looks at lean opportunities with suppliers, it begins by value stream mapping the "production flow and highlighting critical supplier parts and assemblies." These items indicate support for the 10th proposition:

> P10 = Successful lean companies utilize value stream mapping to identify and drive improvement opportunities

Standard work is one of the nine Boeing tactics for achieving continuous flow mentioned above. Additionally, Boeing has worked with its customers to standardize the options it offers, which in turn allows them to standardize their processes. The Point-to-Point newsletter article "Boeing is Revolutionizing Airplane Manufacturing" says,

> "With the help of customer airlines, we've defined standard packages of options to match the requirements of the various airline business models and operating environments... Standardization of airplane configuration allows us to standardize our processes, which in turn, reduces the risk of part shortages, error, and out-of-sequence work on the production line. For suppliers, fewer airplane configurations means more predictable orders." (2008, p. 2)

This provides some support for the 11th proposition:

> P11 = Successful lean companies utilize standard work as the baseline for continuous improvement

The quotation above also indicates that Boeing utilized the Voice of the Customer to help improve its processes by developing standard option packages that met the customers' needs. This provides some support for the 13th proposition:

> P13 = Successful lean companies use the Voice of the Customer (VOC) as a driver of improvements

At Boeing, they refer to kaizen events by another commonly used name for them: Accelerated Improvement Workshops (AIWs). AIWs definitely play a role in Boeing's lean improvement, particularly early in their implementation. According to Leitner (2005, p. 265), "In the first two months of 1997, Commercial Airplanes conducted over 100 AIWs." Leitner also states that one of the lessons learned at Boeing was that "Measuring activity, such as the number of AIWs completed, though not a measure of lean's impact, does serve as a way to push people to learn and do lean" (p. 267). The Boeing Auburn plant discussed in the case study by Ross & Associates (2000) is cited as holding an average of 5 -10 AIWs per month. These items provide support for the 14th proposition:

> P14 = Successful lean companies utilize kaizen at a regular cadence to drive continuous improvement

"Visuals in place" is another of Boeing's nine tactics for continuous flow mentioned earlier. In a Boeing Point-to-Point article discussing Boeing's moving lines for the 737 and 777, Carolyn Corvi, Vice President and General Manager for Airplane Programs, "credits the visual cues built into the new system for much of the improvement…It's plainly visible that the necessary items are present. Colored lights…tell everyone on the floor whether an airplane is progressing down the line according to plan" ("Boeing is Revolutionizing…," 2008, p. 2). The article also indicates that there is a large "score board" that can be seen from anywhere on the production floor that indicates how the entire assembly process is functioning. These items provide support for only the second half of the 15th proposition:

> P15 = Successful lean companies utilize appropriate metrics and visual management to drive lean improvements

Like the other case study companies, Boeing has its own version of the Toyota Production System. Leitner (2005, p. 263) states that at Boeing, a "visual representation to show the entire company how all the elements of lean fit together has evolved. Based on the Toyota Production System, it is called the Boeing Production System." This provides some support for the 16th proposition:

> P16 = Successful lean companies have their own version of the Toyota Production System (TPS) that is not just a document, but a significant part of the company's culture

Leitner (2005, p. 263) says about Boeing: "Over two decades, lean tools have been developed and the culture of the workplace has evolved through education and hands-on involvement so that now, lean is part of the Boeing culture." Boeing's Westby says,

"A lot of the change had to do with culture and I think one way you can get at that is to ask people 'Do you think the way that we do things today is the best that it could be?' and people generally answer 'No, I think we can do better.' So now it's about what are the tools that we need? And how can we teach these tools? We start with small things and achieve success - you get fewer skeptics and more believers, and in the case of the 737 that flips over and you get a lot more people understanding the power of what teamwork and lean can do for you and it changes. I think it's small steps and if you are in it you don't even realize the change."

In his 2008 speech at Boeing's 93rd Annual International Supply Management Conference, Boeing's Senior Manager of Strategic Development, Rick Behrens (p. 1) adds:

"The ultimate goal in any business is to create a continuous improvement lean culture. This does not happen overnight. It is an evolution that starts with education and awareness that things can be improved. This is followed by learning how to improve and actually making sustained improvements."

In the same speech, Behrens states that "Boeing looks at lean as a continuous concept. It never ends, as there are always more improvements to be made" (2008, p. 1). And the Ross & Associates case study indicates that at Boeing "initiatives are also embedded in a continual improvement system that reflects a commitment to 'pursue perfection' and the belief that improvements and change are never complete" (2000, p. 14). Boeing's Steve Westby says,

"I think that people are becoming more comfortable with the fact that the way we do things today is not good enough and we have to continually figure out how to improve, and that they are getting more and more used to change - certainly in some areas more than others…The

further you come with change, the easier it is to come to change, and it has a momentum of its own." (cited in Venables, 2005, p. 30)

These items provide support for the 17th proposition:

> P17 = Successful lean companies recognize that developing a lean culture is a lengthy process and that lean is never-ending

Gaps in Document Results

The case study documents provided evidence to support fourteen of the seventeen research propositions. In order to see if there was support for the other three propositions, the Boeing-specific interview questions were directed at the topics not found in the case study documents. These were asked in addition to the generic questions that were asked of all case companies to look for any missing items in the model.

Interview Questions

Provided below in figure 16 is the list of interview questions specific to Boeing.

1	Do you think the HR policies at Boeing support or hinder lean? Can you provide some examples?
2	Are lean leaders developed at Boeing? If so, what does this process typically entail?
3	Does Boeing utilize policy deployment, and if so, can you provide some insight as to how it is used?
4	Do you think the metrics used at Boeing help or hinder lean? Can you provide some examples?

Figure 16: Interview Questions Specific to Boeing

Interview Results

A former member of Boeing's Quality Team and Lean Assessment Team was interviewed to help fill in the gaps in data for Boeing's document analysis. He was asked the questions in figure 16 to achieve this purpose.

In regards to whether Boeing's HR policies support or hinder lean, he stated:

"I think from my perspective, I believe that the HR policies certainly supported what was taking place. Particularly again I get back to the fact that you're talking about employees who are part of a union. Part of the company doing a pretty good job of driving it was the HR policy perspective. But I will say that I believe the most important aspect of the overall implementation and why it became so successful is because of the leadership commitment to it.

If I'm not mistaken, HR was a part of helping to get the training developed. If I remember correctly though, the Lean Offices at the particular sites were really the ones that were responsible for developing the training because obviously they had the lean expertise. But if I'm not mistaken, there were HR partners who were a part of the overall implementation teams, and they were involved in helping with the training and to make sure again that you weren't overstepping the bounds associated with the union agreements that were in place. So HR was actively involved in the implementation."

This response provides some support for the 7th proposition:

P7 = Successful lean companies adopt HR policies that support lean goals

When asked whether lean leaders were developed at Boeing, the interviewee answered:

"Yes. As a matter of fact, the Lean Offices that I spoke of, and let me just give you an example: St. Louis had a cadre of lean experts that were assigned to a functional Lean Office. They did not have any affiliation; only with let's say the weapons or missile side of the business. This function actually provided lean expertise to all of the major programs – the F-18 program, the weapons programs, the AV8 Harrier program – these folks actually were assigned to these programs to help the programs start the journey and to develop the lean acumen that eventually the businesses were expected to maintain. And these Lean Offices were actually reduced in size over a period of time."

This response provides some support for the 9th proposition:

> P9 = Successful lean companies see the value in developing internal lean leaders and senseis

When asked whether Boeing utilizes policy deployment, the interviewee responded:

"Typically what happened there is Boeing's corporate headquarters, which is located in Chicago, did not flow down lean-type goals to the businesses. What they did flow down were expectations as it related to Op Income and those kinds of goals. Even thought you may be challenged around the growth aspect of the business, we still expect you to eliminate waste in your business in order to benefit from that. So when the corporate headquarters would flow down their profit and loss goals, those did factor in an expectation that the businesses were implementing lean in order to become more efficient. Now, at the business level, for let's say the St. Louis site, and for the F-18 program, the site and the program would certainly have some goals that were specific to the number of lean events, the amount of dollars savings that were expected. They did have those kinds of specific goals around lean, but not from corporate down to the business down to the program level."

This response did not really indicate that policy deployment is utilized at Boeing. However, as a follow-up, the interviewee emailed the researcher an article on the Boeing-Mesa lean process. In this article, it indicates that the Boeing-Mesa facility uses an annual lean plan and a strategic deployment process (Arizona Quality Alliance, 2003). The lean plan and deployment strategies are based on the results of the lean assessments conducted throughout Boeing. According to the article (p.2),

"Similar to a Baldrige Assessment, this assessment culminates with a score and a feedback report. Boeing-Mesa uses the feedback report to develop the following year's Lean plan to ensure we continue to progress to our longer range strategic plan. The long range strategic plan identifies "Focus Elements" which describe areas for improvement, strategic interest, and overall company direction. Annual Lean projects are identified and planned according to those needed to meet our strategic needs as defined by the LMA [Lean Manufacturing Assessment]."

This article provides some support for the 12th proposition:

> P12 = Successful lean companies utilize hoshin kanri or policy deployment to align company goals and lean strategies

When asked if the metrics used at Boeing helped or hindered lean, the interviewee responded:

"They helped. And again what I would say around that is the businesses were always refining those metrics based on where they were in the journey. So the metrics that a business may have started out with in year one of the journey were not necessarily the same metrics they were using in year five of the journey. Some new metrics came about; some old metrics went away, and in some cases, the volume of metrics was reduced too. Because once they got the process baked into the culture, it just became a way of life. To the point where it started showing up in learning curves; it started showing up in many of the locations they had traditional Industrial Engineering activities whereby they knew that it typically took 45 minutes for an aircraft mechanic to perform this particular step. Well, it got to the point where they started to see those improvements even in the amount of time it would take for an individual to perform an inspection. It started getting down to where the cultural stuff was baked into them improving the amount of time it took to do a production step."

When the researcher asked if there were any metrics that were particularly helpful, the interviewee indicated:

"From my perspective, I absolutely believe that the metrics that they used to track the strength of the implementation and effectiveness and I talked about the lean assessments, I thought that was absolutely fundamentally key from a metric perspective and for the process being taken seriously and for people being held accountable. I think metrics around the amount of savings that were realized and one of the things that Boeing did too is initially they didn't get so caught up on something always having to be a hard savings. They also were really committed to where if it was a cost avoidance or more of a soft savings, that they were ok with that."

This response provides some support for the metrics half of the 15th proposition (note that the visuals part was already supported in the document analysis):

> P15 = Successful lean companies utilize appropriate metrics and visual management to drive lean improvements

In addition to answering the Boeing-specific questions from figure 16, the former member of Boeing's Quality Team and Lean Team was also asked the generic questions from figure 5. These questions were aimed at identifying the other characteristics that were important to implementing and sustaining lean as well as creating the lean culture.

When asked about the key facets of deploying lean and how they were used at Boeing, he indicated that:

"What was interesting is when they kicked it off on the aerospace side of the business, and we were probably the first part of the company to really focus on lean, what they actually did is they developed what I would call Lean Offices at all of the major sites around the aerospace and defense locations. So you're talking St. Louis, Philadelphia, Mesa, El Segundo, and Seattle. So they started by actually standing up these Lean Offices in all those major locations.

And one of the things that they kicked off besides standing up these Lean Offices is they also developed a Lean Assessment that was actually conducted across all of the major sites within the aerospace and defense industry. And that assessment was set up to where it didn't matter whether you were doing an assessment in Mesa or whether you were doing the assessment down in Macon, Georgia at their C-17 facility; it had the same criteria.

What was interesting was that the leadership made it clear that this was not optional for you to do; it was expected. Then they developed this assessment and I had an opportunity to become a part of the assessment team out of St. Louis. So we got a chance to actually go to do probably between five and seven of these assessments at the other locations. So I got a chance to see how the other divisions were implementing lean in their organizations.

I tell you that one of the big things is, and I would say this no matter what the initiative or cultural change is, is there was no doubt that there was leadership commitment to making it

happen. And one of the things that I would say in any change management activity is if the leadership is not committed to the change, it's better to not do it. Because if you do something and you do it half way, then it sends a signal to the organization that I can stay in place and stand here for a while and this too shall pass. So the leadership commitment was absolutely robust and there was no doubt that organizations did not have a choice as to whether they were going to do it or not."

The interviewer also added the following information (note that these statements provide further support for the 8th proposition on training and the 15th proposition on metrics):

"They also made a tremendous commitment to training, and they trained both exempt and non-exempt personnel in the concepts of lean. And what was interesting is and again obviously they developed the training that they did, orientation training for leadership and it wasn't something where they were in class for a day or two days, it was more of an overview. They also did training for people who were lean implementers, and obviously you can imagine that their training was much more detailed. They also did training for non-exempt employees and what was interesting is at Boeing their non-exempt employees are union represented. So they actually did training with their union-represented employees. They also did training for the union leadership to make sure that people understood that this was not about eliminating jobs; it was about becoming more efficient so you could do more work with the same number of people.

So leadership, the training, and also they established measures to measure how effective the various organizations were doing implementing their lean concepts. So I go back to this lean assessment that was developed. It was really interesting to watch the dynamic associated with that assessment because the organization did end up with an overall score. The tool would actually, based on what the assessor put in and what they observed, you could rate that area based on a numerical factor. I can't remember what it was; I think it was a score of one to ten but it was ranges maybe like 1 – 3.9, 4.0 – 6.9, or something like that. The tool would allow you to rate and give a red, yellow, or green score and an overall score for the organization.

And what was really interesting was to watch how that score almost became peer pressure for the various organizations and sites to really do their best to get the best score that they could because the leadership would actually have these annual strategic planning meetings and they would go over those scores [of all of the sites together]. And so that in itself drove some internal peer pressure because obviously you did not want to be viewed as a site with a score that said you weren't getting it done. And so again, they used measures and metrics in order to drive the behavior that the leadership was looking for."

In response to what helped sustain the lean transformation at Boeing, the interviewee indicated that the metrics were the key (lending further support to the 15th proposition). He elaborated by saying:

"The metrics and measures, and they have to be the right measures, but you definitely need to have a process in place that stays pretty consistent, because again at the end of the day, people do best what the boss checks. So that's very important. Also the leadership establishment of the expectation of a cultural change and not a flavor of the month. Because eventually what happened is the Lean Offices that were implemented at the various major sites were eventually reduced in size because again the expectation was not to have an infrastructure that drove the change. The expectation was to have a culture that drove the change. So again, there was a clear expectation upfront that this was not going to be something that some other organization was responsible for. The leadership and the businesses were responsible for implementing this change. That was certainly very clear.

And also there was an accountability piece to it. If there were areas or leadership pockets where the assessment scores showed that there was a consistent non-acceptance of the idea, then people were held accountable. And also something else that they did is they made a really big deal of publicizing the success stories – in the company newspaper, leadership talked about it in their staff meetings, at their monthly leadership meetings – so there were multiple venues that were used in order to share those success stories."

When asked how long it took to firmly establish the lean culture at Boeing, the interviewee indicated it was "probably about four to six years." When asked what some of the keys that created the culture were, he indicated:

"I go back to everything starts with the leadership commitment. To me, that's number one. You've got to have that because if you don't, again, you're going to get mixed results. That was the number one thing that Boeing did was make it clear that there was no wiggle room and that leadership was committed to it. And again, I go back to the training. It's important that you provide an appropriate level of training. It stretches out the time period if you aren't careful because you have to commit an appropriate level of dollars so you can do an appropriate level of training. If you try to scrimp on the training and say we're going to make it all online and do it on your own time or whatever it is, that potentially is going to give you a different result than if you make a commitment to a core Lean Office and then that Lean Office has experts that go out and help train people on the job or whatever. That will give you a different outcome than if you

just say we're going to train everyone online on their own time. You've got to have an appropriate commitment."

When asked if he had any other lessons learned with regards to implementing lean at Boeing, the interviewee indicated:

"We talked about them…number one: the leadership commitment. Number two: the appropriate infrastructure to support the cultural change. Number three: the accountability piece in terms of it wasn't a choice; you either got on the bus or we were ok with stopping the bus, opening the door, and letting you go somewhere else. And number four: really reinforcing the successes so people could see the benefits."

Overall Conclusions for the Case

Provided in figure 17 is an updated matrix that indicates which of the research propositions are supported for Boeing.

Propositions: D = supported by document analysis; I =supported by interviews

Case	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Boeing	D	D	D	D	D	D	I	D	I	D	D	I	D	D	D	D	D

Figure 17: Final List of Research Propositions Supported for Boeing

As indicated, support was found for all of the research propositions at Boeing. In addition to the actions mentioned in the propositions, an interview with a former member of Boeing's Quality Team and Lean Assessment Team indicated that setting up Lean Offices as resources for the various locations, having leadership make it clear that lean was not an option, making a commitment to training, and establishing measures to gage success were also keys to

implementing lean at Boeing. Metrics and measures, lean assessments, and publicizing lean success stories were identified as contributors to sustaining lean at Boeing.

Summary of Data across Cases

Based on the analysis of case study documents and interview responses, the following propositions are supported as indicated in figure 18 below:

Propositions: D = supported by document analysis; I =supported by interviews

Case	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Autoliv	D	D	I	D	D	D	D	D	D	I	D	D	I	D	D	D	D
Boeing	D	D	D	D	D	D	I	D	I	D	D	I	D	D	D	D	D
Danaher	D	D	D		D	I	D	D	D	D	I	D	D	D	D	D	D
UTC	D	D	D	D	D	D	D	D	D	D	D	D	I	D	D	D	D

Figure 18: Matrix of Research Propositions Supported Across Cases

Sixteen propositions were supported in all four of the case studies and one proposition was supported in three of the four case studies. Neither the case study document analysis nor the interviews revealed other items potentially missing from the model that were common to all four cases. Summarized in figure 19 below are the key factors for implementing and sustaining lean that were identified during the interviews for each of the case study companies.

Case Study Company	Keys to Implementing Lean	Keys to Sustaining Lean
Danaher	Leading from the top, making lean the strategy, transforming the people, getting people to think differently	Following up on kaizens, having a Kaizen Promotion Office, using standards and visual controls
Autoliv ASP	Using 5S to identify normal vs. abnormal, having a stable, capable process, teamwork, looking at all types of continuous improvement activities (not just big projects), leadership, and setting expectations	Following up, making sure expectations are driving the right behaviors, and leader standard work
UTC	Having a clear champion at the top, having a framework/operating system, commitment to training, using appropriate rewards/recognition, using root cause analysis for issues	Metrics, assessing achievement levels to drive accountability, the Passport Process for governance, and leveraging best practices and standard work
Boeing	Setting up Lean Offices as resources, leadership commitment and making it clear it's not an option, and commitment to training	Having the right metrics and measures, accountability via lean assessments

Figure 19: Keys to Implementing and Sustaining Lean from Case Study Interviews

Some other interesting facts were discovered looking across the cases, such as the fact that three of the four case studies of successful, sustained lean implementations utilized the same Japanese consulting firm, Shingijutsu Consulting, as senseis to guide their initial lean implementation. And though Autoliv did not utilize Shingijutsu, they too had the help of a former Toyota sensei, Takashi Harada. Therefore, all four case study companies had guidance from Toyota mentors that they engaged with for multiple years during their lean transformations.

Though all four case companies have their own version of the Toyota Production System, it seems that they place different emphasis on it. For example, the Danaher Business System is mentioned frequently on the corporation's website, has its own tab under "Our Culture" and is front and center on the home pages of each of the individual Danaher-owned companies. The DBS is clearly an important driver at Danaher. Autoliv's website also has its own tab for the Autoliv Production System under Products and Innovations. UTC mentions and provides an

overview of ACE under the Quality section of its webpage. Mention of the Boeing Production System was noticeably absent on its webpage, though lean did appear under the Culture and Values tab.

CHAPTER FIVE: CONCLUSIONS

Overall Summary of Findings

Overall, the document analysis and interviews provided support for nearly of all the propositions at all four case study companies. Factors that stood out as keys to success that were revealed in both the document analysis and subsequent interviews included driving lean from the top, being committed to providing sufficient and appropriate training, having an operating system similar to the Toyota Production System but adapted to the particular company, and utilizing a combination of metrics, visuals, and standard work to sustain the gains and continuously improve.

Model for Successful, Sustained Lean Implementation and Improvement

The final, tested model is shown in figure 20 below. Since sixteen of the seventeen propositions were supported by all four case study companies and the seventeenth was supported at three of the four case study companies, and no additional factors common to all four companies were discovered during the analysis, no changes were made to the initial conceptual model.

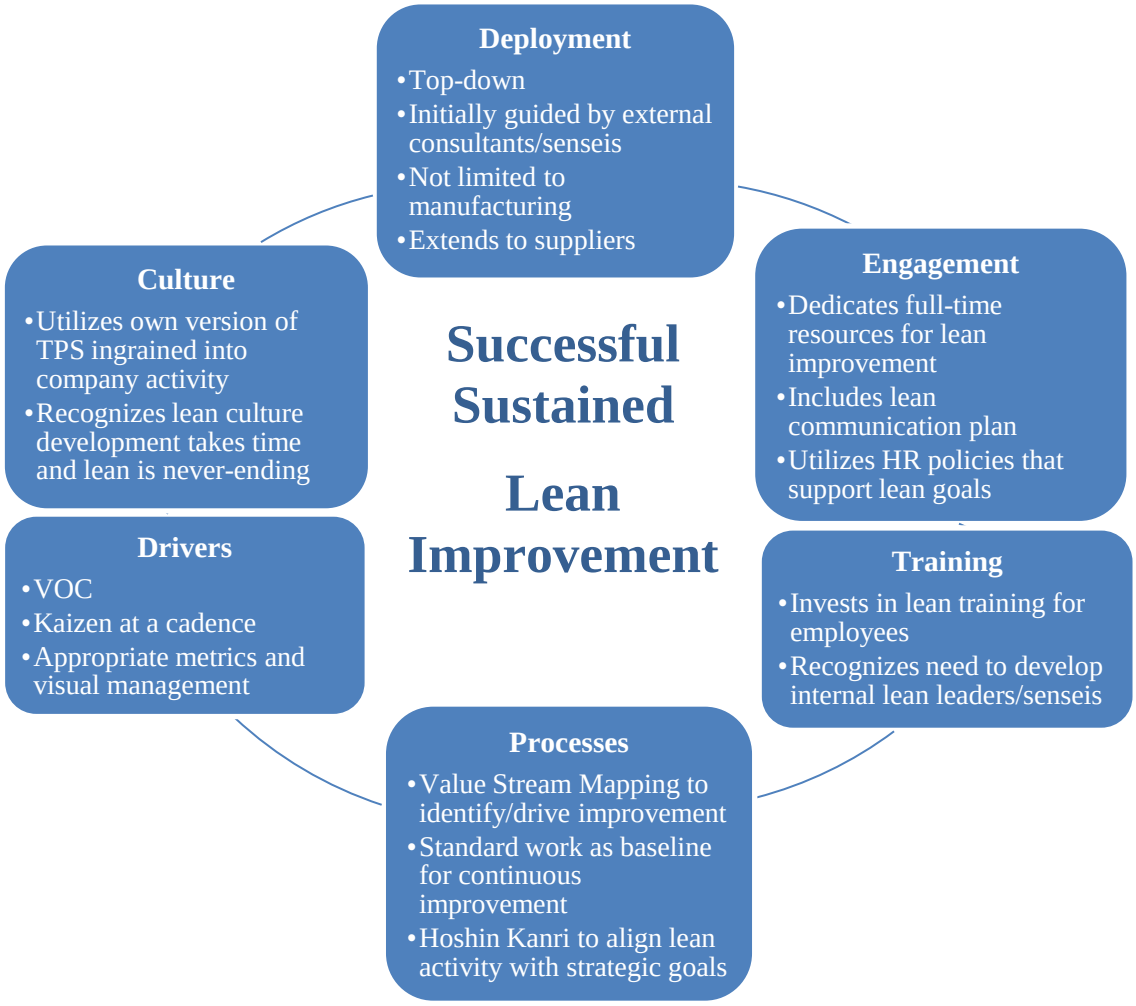


Figure 20: Final Model for Successful, Sustained Lean Implementation and Improvement

Recommendations

It is recommended that companies who wish to undertake a lean transformation apply the lessons learned from the very few U.S. companies who have successfully sustained lean

improvement. These key interrelated strategies are summarized in the conceptual model, which can act as a framework to guide lean transformations.

Lean implementation should be driven from the top of a company, by a strong leader who personally gets involved in the transformation. Senseis with experience at Toyota or other companies well along the lean journey should be utilized to provide initial guidance and mentoring during lean implementation. Lean should be applied to both manufacturing areas and non-manufacturing areas to reap the full benefits. Lean should also be extended to suppliers.

Full-time resources should be dedicated to making lean improvements. Communications on lean, particularly indicating what the benefits are and publicizing success stories, should occur frequently. Human Resource policies should be established to support the lean transformation and make it clear that lean will not result in any layoffs.

Companies undergoing lean transformations must be ready to commit to the level of training needed to support the development of a continuous improvement culture. Lean leaders and internal senseis should be developed as part of this process so that they can help with the ongoing deployment and sustainment of lean.

Value stream mapping should be utilized as a key tool to help identify where to focus improvement activities, particularly in the early phases of lean implementation. Standard work should be implemented to allow for consistent application of best practices and to act as a baseline for making further improvements. Hoshin kanri or policy deployment should be used to translate corporate goals and lean strategies into specific, actionable objectives.

The Voice of the Customer should be a key input into developing improvement activities. Kaizen should be a constant, ongoing activity, both in the traditional week-long format for bigger projects and in the day-to-day application of problem-solving and suggestions for continuous improvement. Appropriate metrics and measures that drive the desired lean behaviors should be utilized along with visual management for daily measurement and sustainment of lean progress.

An operating system similar to the Toyota Production System but customized to the particular company should be established to guide lean implementation and ingrained into the culture. Finally, there must be recognition that creating a lean culture is a lengthy but critical part of sustaining a lean transformation and achieving the desired results.

Contributions to the Body of Knowledge

Toyota is the company that is recognized for being the epitome of lean. There is much written about Toyota and their production system, philosophies, and tools. However, examples of lean success outside of Toyota are very limited. Though many companies attempt to implement lean, very few achieve the desired results.

This research helps to provide understanding into the key factors that can inhibit or hinder lean implementation and sustainment. It represents the first known in-depth analysis of how companies other than Toyota have achieved successful lean transformation. This is an important contribution given that successfully implementing lean can reduce costs, improve

quality, enable a culture of continuous improvement, and position a company for tremendous growth.

This research proposed and tested a model for successful, sustained lean implementation and improvement. The model consists of six different constructs with seventeen propositions that were derived from the literature review. A company wishing to achieve a successful lean transformation can focus on the propositions, which represent specific, tangible actions. The model also approaches lean implementation and sustainment from multiple perspectives and provides a set of inter-related strategies that contribute to lean success.

The model was tested on cases drawn from the very small number of companies in the U.S. that have achieved successful, sustained lean improvement. Therefore, the model has been verified using proven lean success stories. The case studies that the model was tested on represent a broad variety of manufacturing industries, increasing the likelihood of the research being able to be broadly generalized and applied. Finally, the model provides a framework of a set of related tangible actions that organizations that are planning to undertake a lean transformation can focus on in order to help insure successful implementation and sustainment.

Future Research

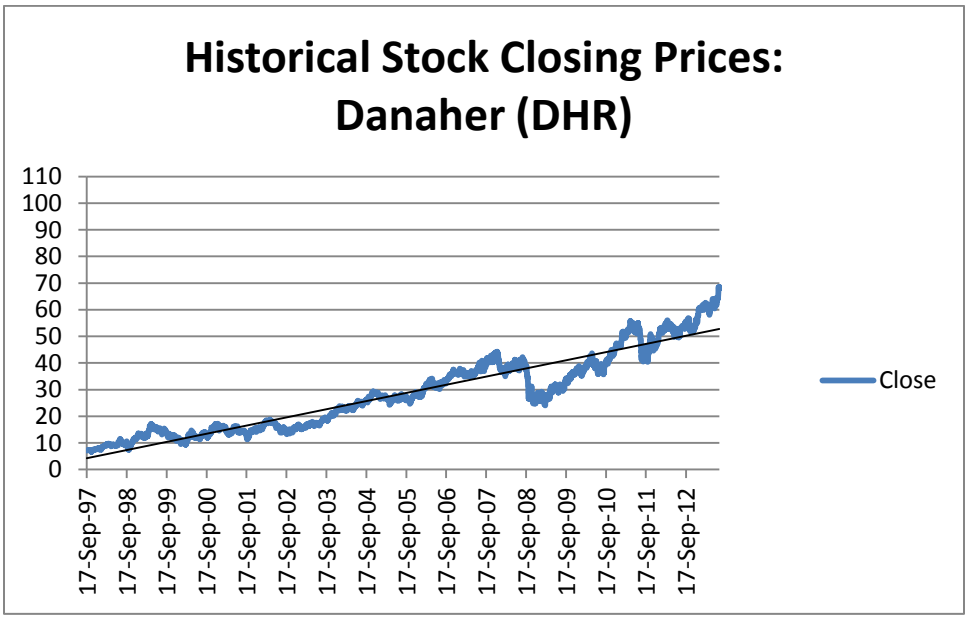
There are a number of opportunities for future research to expand on this work. In order to gain additional perspective on the key components of successful lean transformation, the interviews could be expanded to include employees at the production floor level at the case study

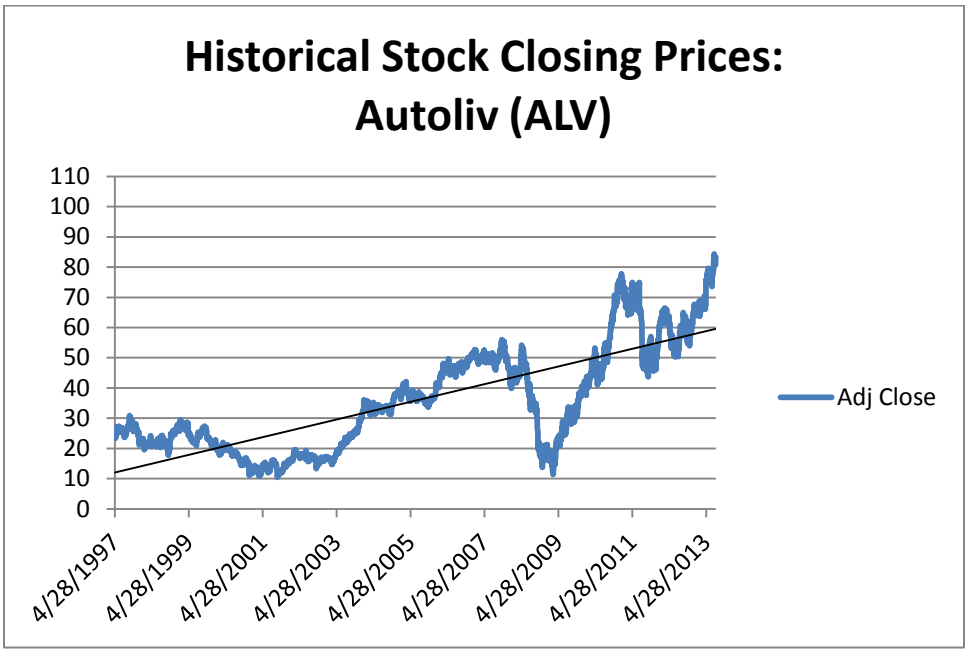
companies. The model could be tested on new implementations and followed for a number of years to see the results. This, of course, would require a lengthy engagement with a particular company in order to observe how lean is deployed and then sustained over time. Another opportunity would be to determine whether the model changes for companies wishing to "re-launch" or reinvigorate a lean implementation effort that has stalled or not reached the desired level of potential, or whether the proposed model can be used successfully as is. The model could also be tested on non-manufacturing companies (e.g. government, service industry, health care, etc.) to determine if it still applies or if modifications are needed. Additionally, one could examine cases of failed lean transformations to see if they are missing key aspects of the model.

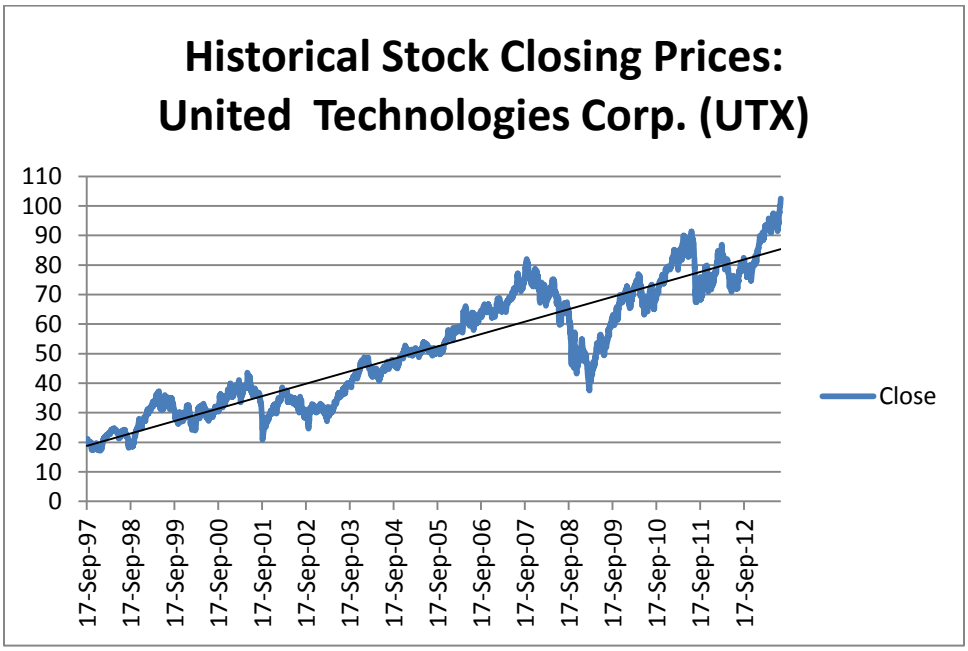
APPENDIX A:

HISTORICAL STOCK DATA FOR THE CASE STUDY COMPANIES

The following data is from Google Finance (http://www.google.com/finance) and Yahoo Finance (http://finance.yahoo.com/). Historical data was available from 1997 on.






Historical Stock Closing Prices:
United Technologies Corp. (UTX)
110
100
90
80
70
60
50
40
30
20
10
0
17-Sep-97
17-Sep-98
17-Sep-99
17-Sep-00
17-Sep-01
17-Sep-02
17-Sep-03
17-Sep-04
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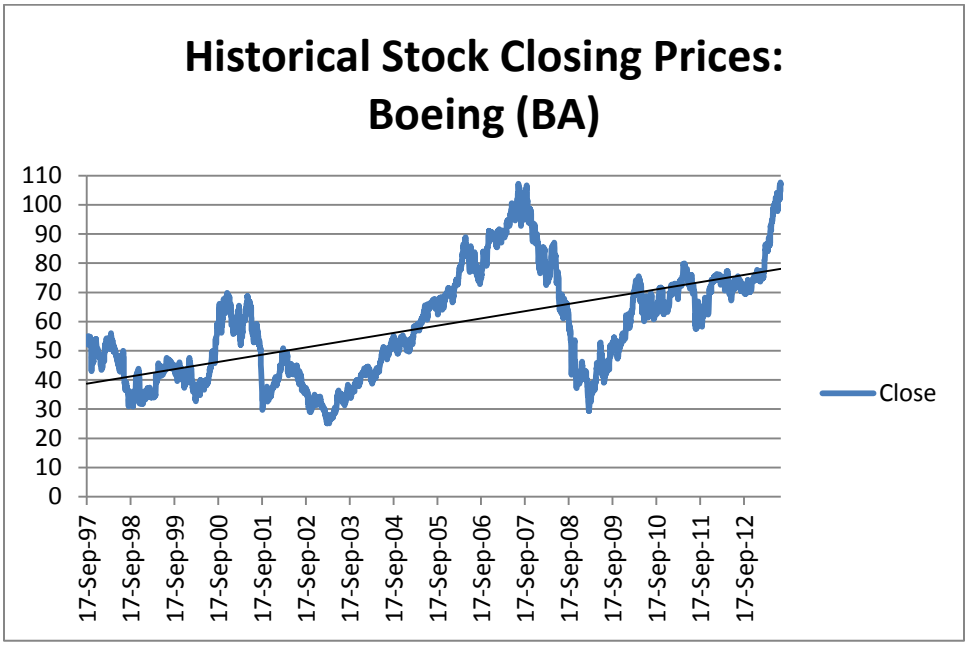
17-Sep-10
17-Sep-11
17-Sep-12
Close


Historical Stock Closing Prices:
Boeing (BA)
110
100
90
80
70
60
50
40
30
20
10
0
17-Sep-97
17-Sep-98
17-Sep-99
17-Sep-00
17-Sep-01
17-Sep-02
17-Sep-03
17-Sep-04
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17-Sep-06
17-Sep-07
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17-Sep-09
17-Sep-10
17-Sep-11
17-Sep-12
Close

APPENDIX B:

IRB APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Julie Sisson**

Date: **October 21, 2013**

Dear Researcher:

On 10/21/2013, the IRB approved the following activity as human participant research that is exempt from regulation:

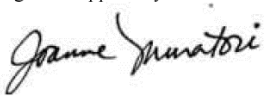
Type of Review:	Exempt Determination
Project Title:	FRAMEWORK FOR THE DEVELOPMENT OF A MODEL FOR SUCCESSFUL, SUSTAINEDLEAN IMPLEMENTATION AND IMPROVEMENT
Investigator:	Julie Sisson
IRB Number:	SBE-13-09674
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 10/21/2013 01:54:27 PM EDT



IRB Coordinator

APPENDIX C:

SUMMARY EXPLANATION FOR EXEMPT RESEARCH

EXPLANATION OF RESEARCH

Title of Project: Framework for the Development of a Model for Successful, Sustained Lean Implementation and Improvement

Principal Investigator: Julie Sisson

Other Investigators: n/a

Faculty Supervisor: Dr. Ahmad Elshennawy

You are being invited to take part in a research study. Whether you take part is up to you.

The purpose of this research is to test a conceptual model for successful, sustained lean improvement. The researcher is interested in understanding the key interrelated strategies that contribute to successful lean transformations, and is utilizing a multiple-case study approach.

One of the forms of data that is being analyzed for the case study companies is interviews with key individuals who are either employed there currently or have worked there in the past. The purpose of the interviews is to fill in some of the gaps in the document analysis and provide a richer context for the analysis.

Participants in the study will be asked to provide answers to interview questions on the research topic. Interviews are expected to take no more than one hour, and will be arranged at the participant's convenience.

The interviews will take place via Outlook MeetingPlace, Skype, or similar web-based meeting tool where possible, or by phone if the first option is not possible. Interviews will be recorded to assist with data capture and accuracy.

Transcripts of the interviews will be provided to participants to review. Once transcripts of the interviews have been reviewed, the recordings will be destroyed.

Selected interview responses may be used in the researcher's dissertation. Names of the interviewees will not be provided unless the participant desires. The case study company the interviewee works at or did work at will be indicated, along with the functional area that the interviewee works or worked in.

As a thank-you for participating in this study, you will be provided with a summary of the study findings.

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints, please contact Julie Sisson, PhD Candidate, Industrial Engineering and Management Systems program, College of Engineering and Computer Science, at (585)260-8771 or by email at sisson_julie_ucf@knights.ucf.edu or Dr. Ahmad Elshennawy, Graduate Advisor, Industrial Engineering and Management Systems, at (407)823-5742 or by email at Ahmad.Elshennawy@UCF.edu.

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901.

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