2007

Leveraging lean process improvement methodology to promote economic and environmental sustainability: Obstacles and opportunities

Jennifer Doman

Thesis:

Leveraging Lean Process Improvement Methodology to Promote Economic and Environmental Sustainability: Obstacles and Opportunities

Jennifer L. Doman

August 23, 2007

Department of Civil Engineering Technology

Environmental Management & Safety

Rochester Institute of Technology

Rochester, NY

Thesis or Project submitted in partial fulfillment of the requirements of the degree of

Masters of Science in Environmental, Health & Safety Management.

Approved by:

Maureen Valentine, P. E., Department Chair
Dr. John Morelli, Professor and Thesis Advisor

Thesis Committee:

- Dr. Jennifer Schneider
- Dr. John Morelli
- Dr. Sandra Rosenberg
- Mr. Joseph Rosenbeck

Table of Contents

Abstract 1
1. Introduction 1
Research Scope 2
Significance of the Topic 2
Timeliness of the Research 2
Target Audience 3
2. Literature Review 5
What is Lean? 5
Why Lean? 7
Obstacles and Opportunities 8
Opportunities 9
Obstacles 10
3. Research Methodology 13
Scope and Limitations 14
Case Studies 16
Availability of Data 16
Collection Matrix Design and Validation 16
Acceptance Criteria 17
Data Collection 17
Data Analysis and Interpretation 17
Descriptive Survey 17
Data Collection Method 1 – Workshop Questionnaire 17
Data Collection Method 2 – Broader Survey 19
Human Subject Protection 22
Data Analysis and Interpretation 22
4. Results and Findings 23
Analysis of Data 23
Findings 23
Published Case Studies 23
Workshop Pilot Survey 26
Broader Survey 28
Survey Case Studies 33
Summary 34
5. Conclusion 43
Conclusions and Implications 43
Recommendations for Further Research 44
Suggestions for Improvement 44
Opportunities for Additional Research 45
Bibliography 47
Appendix A 51
Appendix B 53

Abstract

We are on the verge of a paradigm shift in the regulatory community in the United States. The EPA is slowly moving away from command and control to a more collaborative structure, and Lean process improvement is one of the primary catalysts of change. A significant percentage of American enterprises have some experience with Lean methods, and the EPA and others believe that Lean can be leveraged to promote environmental benefits while still delivering valuable business benefits, such as increased productivity and reduced costs.

This research explores both the opportunities available for businesses today, and the current obstacles encountered when implementing Lean methods for activities that have environmental aspects. Drawing on published case studies and surveys of business professionals, a set of influencing factors was compiled, each categorized as an internal or external factor and as either a positive (opportunity) or negative (obstacle) influence. Although the case studies and survey results differed somewhat, both indicated that factors relating to costs and cost savings were perceived as the major influencing factors, while compliance and regulatory assistance were considered minor influences.

1. Introduction

We are on the verge of a paradigm shift in the regulatory community. The EPA is slowly moving away from command and control to a more collaborative structure, and Lean process improvement methodology is one of the primary catalysts of change. A significant percentage of American enterprises have some experience with Lean methods, and the EPA and others believe that Lean can be leveraged to promote environmental benefits while still delivering valuable business benefits, such as increased productivity and reduced costs.

Lean is a process improvement methodology widely used in industry that focuses on identifying and eliminating wastes to improve productivity and reduce costs. Lean wastes include delays caused by transportation or waiting for the next production step, defective products, excess inventory, and unnecessary movement or processing. If environmental wastes, such as wastes created during production, are considered, Lean methodology can be used to achieve environmental objectives as well.

This research explores both the opportunities available for businesses today, and the current obstacles encountered when implementing Lean methods for activities that have environmental aspects.

The Brundtland Report definition of sustainability as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” is widely accepted, but rather broad. (EPA, “Sustainability”) SustainAbility, Inc. reframed this concept in business terms, coining the phrase ‘triple bottom line’ which augments the traditional economic value with the addition of social and environmental value aspects. (1)

Research Scope

This research addresses two of the triple bottom line aspects; economic value and environmental value, and explore how business productivity improvements can be complementary to environmental improvements. The third aspect, social value or social responsibility, is beyond the scope of this research.

It is likely that many process improvement methodologies, such as Six Sigma, would produce similar environmental benefits, however Lean is the most widely studied, and has the most documented case studies suitable for research. For this reason, the scope of this research is primarily focused on addressing environmental improvements associated with Lean process improvement methods.

Significance of the Topic

In order to effectively influence business decisions, you must use business terms. (Rosenbeck) Lean is first and foremost a business tool that helps companies increase productivity, and that has the potential for environmental side-benefits. Pollution prevention, on the other hand, is an environmental tool that was promoted to have positive business advantages.

It is more likely that Lean, with its strong business linkages and immediate results, will be the mechanism by which business moves most readily toward sustainability. The EPA agrees. Studies done by the Environmental Protection Agency over the last few years indicate that "lean drivers for culture change...are consistently much stronger than the drivers that come through the 'green door', such as savings from pollution prevention activities..." ("LME", 2)

Identifying the obstacles and opportunities associated with Lean environmental implementations will facilitate development of strategies that can be used both to overcome hurdles and to promote organizational benefits that will encourage more organizations to adopt this methodology.

Timeliness of the Research

A full range of obstacles and opportunities must be considered in order to promote significant changes in how businesses evaluate and adopt environmental practices.

Jeb Emerson, in his Blended Values work, talks about practitioners and organizations pursuing objectives with many shared goals, but separately and in relative isolation from each other. He calls these separate approaches 'silos', and suggests that a 'blended value' approach is needed whereby issues of common concern are identified as challenges that could be addressed more effectively through cooperation, sharing information and setting common goals, rather than individually. (Bonini, 7)

Today, business, EPA, Lean practitioners and other organizations all use different approaches and methodologies to achieve environmental objectives, although in many

ways they may have similar goals. Much like Jed Emerson's blended value silos, each is focused on a particular problem or aspect, but there is still minimal interaction between groups, even though they may share similar objectives. (Emerson, 8)

EPA is currently promoting Lean as a means to achieve environmental objectives using commonly used business tools, however most EPA studies and programs are focused on regulatory aspects. Lean practitioners, on the other hand, are promoting Lean as a means for increasing business productivity and reducing the costs associated with waste, without considering environmental aspects. While still other organizations, such as the Executives for Energy Efficiency, are exploring why businesses reject or embrace opportunities to improve energy efficiency. Each has a piece of the pie but only by combining all of these approaches can we truly see the full picture.

We need to combine and integrate a number of approaches in order to form an effective business model for sustainability.

There is a natural synergy between many of these approaches, making a combination of methods even more effective. For example, Lean's 6S "fosters a culture of continual improvement and employee engagement that is essential for the successful implementation of Lean..." and may facilitate implementation of other Lean methods as well. (Toolkit, 50) Colorado State University's Industrial Assessment Center has found that pollution prevention strategies such as waste and energy reduction can help companies achieve Lean manufacturing objectives, increasing productivity and efficiency. (Edwards, 1) EPA studies and programs encourage companies to consider environmental aspects when implementing Lean programs.

The goal of this research, therefore, is to identify the current internal and external obstacles businesses face today when adopting a blended Lean/Environmental approach, and the internal and external benefits that can result from a successful implementation.

Target Audience

The primary audience for this research is Environmental, Health and Safety professionals. The results and recommendations will help ES&H professionals to achieve improved environmental performance in their organizations, by applying standard business tools, such as Lean process improvement methodology. Providing ES&H professionals with a better understanding of the business obstacles and opportunities associated with environmental process improvement will enable them to more effectively gain support from business leaders for environmental initiatives.

The secondary audience for this research is Lean practitioners. Placing environmental concerns in a familiar framework of Lean methodology will assist Lean practitioners in understanding and incorporating environmental improvements as part of their practice.

2. Literature Review

The Brundtland Report definition of sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" is widely accepted, but rather broad. (EPA, "Sustainability",pp2) SustainAbility, Inc. reframed this concept in business terms, coining the phrase 'triple bottom line' which augments the traditional economic value with the addition of social and environmental value aspects. (1)

This research addresses two of the triple bottom line aspects; economic value and environmental value, and explore how business productivity improvements can be complementary to environmental improvements. The third aspect, social value or social responsibility, is beyond the scope of this research.

What is Lean?

At the heart of Lean methodology is the elimination of *muda*, or waste, which is defined as "any human activity which absorbs resources but creates no *value*." (Womack, 15) Value is further defined as "a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer." (Womack, 353) This customer-centric philosophy has enabled companies to increase productivity, strengthen competitive advantages and reduce costs.

Taiichi Ohno initially identified seven causes of wastes: (Ohno, 19)

- Production of *defects*
- *Overproduction* ahead of demand
- Unnecessary *transport* of materials
- *Waiting* for the next process step
- *Inventories* (excess material and information)
- Unnecessary *movement* by employees
- Unnecessary *processing* due to poor design

Womack and Jones added an eighth waste: (Womack, 355)

- Goods and services that do not meet customer needs

To these traditional Lean wastes, the EPA suggests we add environmentally oriented wastes: ("Lean Waste Types")

- Non-product wastes
- Raw material wastes (excess or poor utilization of raw materials)

Each of the above wastes has a potential impact on the environment. For example, unnecessary transportation and waiting for items to reach the next process step can result in increased energy consumption. Defects and over-production can result in wasted raw materials, potentially depleting non-renewable resources. Disposal of wastes can impact air, water and soil.

Value Stream Mapping

Lean practitioners use a number of methods, alone or in combination, to achieve Lean results. Typically, a Lean implementation begins with a Value Stream Mapping (VSM) session to identify the current production flow and highlight inefficiencies in the form of waste. Part of this process requires an initial definition of value, against which activities are measured. The EPA Lean and Environment Toolkit suggests that identification of types of environmental wastes prior to a VSM session will help to ensure that all types of waste are identified. ("Toolkit", 12)

According to Womack and Jones, VSM activities are divided into three levels: (Womack, 38)

1. Activities which add value
2. Activities which do not add value but are currently part of the infrastructure, and
3. Activities which add no value and can be eliminated immediately

As a result of Value Stream Mapping, some waste can be removed immediately, while other wastes, such as those identified at the second VSM level, are targeted for removal via other Lean methods. The EPA suggests that VSM can be used to map natural resource flows, such as water and energy, in addition to the traditional production activities. ("Toolkit", 27)

Kaizen

Masaaki Imai introduced the concept of kaizen in his 1986 book, *Kaizen: The Key to Japan's Competitive Success*. (Pirimal, 3) He later refined the concept further in his 1997 book, *Gemba Kaizen: A Commonsense Low-Cost Approach to Management*. (Pirimal, 6) Kaizen focuses on incremental process changes to achieve results. ("Kaizen")

Kaizen is one of the primary methods used to implement Lean concepts. Short-term team-based events, often referred to as kaizen "blitzes", eliminate waste and implement workplace improvements. ("Kaizen", 3)

Interestingly, while the EPA includes Kaizen in its Lean and Environment Toolkit, it also acknowledges that many of the changes that typically result from a kaizen event can affect compliance. ("Toolkit", 37) Regulatory delays and complexity can negate some of the benefits of these rapid deployment events, making them less appealing. Fortunately, environmental agencies are responding to these challenges by implementing streamlined permitting for some pilot projects. ("Toolkit", 39)

6S (5S + Safety)

5S is a workplace organization tool that improves worker efficiency by organizing the contents of the work area and standardizing work procedures. The term "5S" comes from the starting letter "S" in each of the Japanese words characterizing each step. English

equivalents for each of these steps were developed to facilitate 5S implementations in the United States.

Pillar	Japanese	Activity
Sort	Seiri	Sort and remove/tag unnecessary items in workplace
Simplify	Seiton	Organize workplace once unneeded items are removed
Shine	Seiso	Clean
Standardize	Seiketsu	Make 6S practices consistent through inspection and procedures
Sustain	Shitsuke	Integrate 6S into normal business practices
Safety*		Create and maintain a safe workplace

* Safety was not one of the original 5 pillars and was added later

5S was made popular by Hiroyuki Hirano in his 1995 book, *5 Pillars of the Visual Workplace: The Sourcebook for 5S Implementation.* A sixth S for safety is included in the EPA Toolkit, although Hirano considers safety as a side benefit of the 5S process, rather than a separate contributor. ("5S for Operators", 15)

Why Lean?

In order to effectively influence business decisions, you must use business terms. (Rosenbeck) Lean is first and foremost a business tool that helps companies increase productivity, and that has the potential for environmental side-benefits. Pollution prevention, on the other hand, is an environmental tool that was promoted to have positive business advantages. It is more likely that Lean, with its strong business linkages and immediate results, will be the mechanism by which business moves most readily toward sustainability. The EPA agrees. Studies done by the Environmental Protection Agency over the last few years indicate that "lean drivers for culture change...are consistently much stronger than the drivers that come through the 'green door', such as savings from pollution prevention activities...". ("LME", 2)

Linking environmental goals to business values is an important step toward promoting sustainability in American industry. Because Lean is first and foremost a business system, Lean is more readily accepted by industry as a process improvement tool. Also, Lean produces tangible results that have a direct and immediate positive effect. The Mid-America Manufacturing Technology Center estimates that implementing Lean can achieve significant reductions in lead time and floor space, while increasing yield and productivity by up to 125 percent. ("Benefits") These types of benefits can improve a company's competitive advantage by lowering operating costs and increasing efficiency.

Not surprisingly, a recent EPA study on Lean and the environment reported that, "between 30 and 40 percent of all U.S. manufacturers claim to have begun implementing lean methods..." ("LME", 18) Although originally implemented in manufacturing production applications, Lean appears to be beneficial across a wide range of companies and industries, from banking to aerospace.

Even more appealing, environmental benefits can be obtained indirectly through Lean process improvement measures. Some examples of these benefits include:

- reducing the 'footprint' of a production floor can result in energy savings
- reducing defects means less raw materials are used, and less waste is generate
- eliminating unnecessary transportation reduces non-renewable resource requirements

Lean also may provide the necessary framework for companies to embrace sustainability, by creating an organizational culture that supports continuous improvement and promotes "eco-effectiveness". ("LME", 32)

A series of case studies ranging from 2000 through 2006 were funded by the EPA to study Lean manufacturing in a number of industries and how these strategies could be applied to pollution prevention and other environmental goals.

A number of other groups are also studying the interrelationship between Lean manufacturing and environmental objectives, including the Colorado State University Industrial Assessment Center, which performed almost 100 assessments between 1996 and 2000. (Edwards, 1) Focusing primarily on regional small and medium-sized manufacturers, the Colorado studies demonstrate that pollution prevention strategies such as waste and energy reduction can help companies achieve Lean manufacturing objectives, increasing productivity and efficiency. (Edwards, 1) Their focus is on identifying environmental improvements that will, in turn, provide the participating company with process efficiency improvements as well. Therefore, not only can implementing Lean provide environmental benefits, but providing environmental improvements can result in Lean improvements as well.

Obstacles and Opportunities

EPA studies have focused mainly on how Lean can be leveraged to achieve regulatory objectives, such as compliance and promoting sustainability. These studies identify a number of obstacles that businesses and regulatory agencies must overcome to effectively promote Lean in certain industries and applications.

Other studies, such as the Executives for Energy Efficiency project in New York, looked at what internal factors drive business decisions to implement environmental objectives. (Russell, 1)

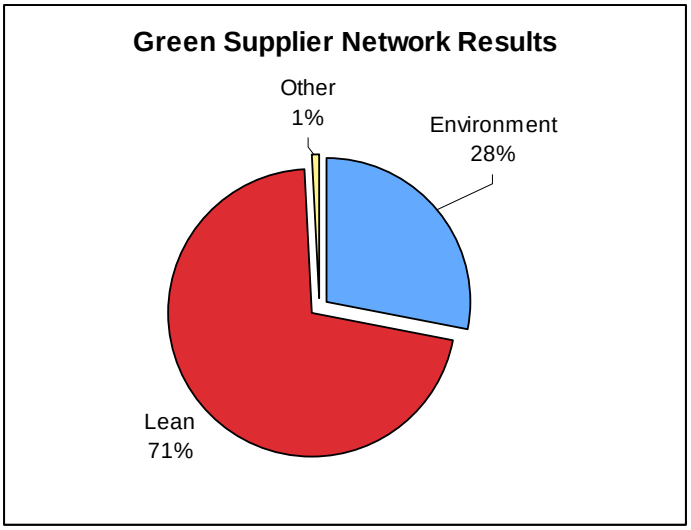
Opportunities

There are many opportunities for businesses that combine process improvement and environmental goals.

Regulatory Opportunities

EPA and the National Institute of Standards and Technology Manufacturing Extension Partnership (NIST MEP) are working with industry partners to provide their suppliers with low-cost "Lean and Clean" reviews, aimed at reducing waste and process improvement. (EPA, "Green Suppliers") This can expand Lean and environmental improvements throughout the supply chain, through combined efforts of waste reduction, increased quality and potentially decreased costs. ("Lean Benefits")

Currently, the Green Suppliers Network has performed over 49 reviews of businesses in the participating sectors of Automotive, Aerospace, Healthcare/Pharmaceutical and Office Furniture. (Green Suppliers Network)



Almost $27 million dollars in cost savings was identified as a result of these reviews, approximately three quarters of which was attributed to Lean and the remaining quarter attributed to environmental cost savings. ("Results")

Because Lean focuses on eliminating waste in all forms, it can assist companies in attaining or maintaining compliance. For example, reduced waste could include a reduction in hazardous waste, or in utilization of hazardous materials during production.

Business Opportunities

Process improvement methodologies such as Lean, can have a positive effect on corporate culture, underscoring the benefits of employee-involvement and continuous improvement. ("LME", 21) Frits Pil and Sandra Rothenberg agree, noting that process improvements such as Lean can provide a foundation of organizational expertise, that can make subsequent environmental implementations less costly. (Pil, 406)

In addition to leveraging improved environmental performance, organizations that improve their environmental practices may benefit from improved product quality as well. (Pil, 413)

A company can improve its competitive position by intelligent use of resources. Integrating process improvement and environmental goals into the business structure can increase the effectiveness of both, which company's can leverage to improve its competitive position. ("LME", 2)

One of main reasons that businesses implement Lean is to realize improved productivity. Although productivity may not appear at first glance to have environmental benefits, in fact it does; for example increased productivity may result in reduced shifts, which in turn reduces energy usage.

Because Lean promotes a waste elimination culture, the associated costs of excess materials, waste disposal, quality errors and so forth are eliminated. This reduces a company's overhead and contributes to profitability.

Obstacles

Although there are numerous environmental benefits to Lean and other process improvement methods, there are also a number of obstacles.

Regulatory Obstacles

Ross and Associates, who performed many of the studies for the EPA, posed the question "is the environmental regulatory system working at cross purposes with environmentally beneficial manufacturing strategies?" ("Perfection", 6) The answer appears to be yes. A slow regulatory process, manned by regulators still thinking in "batch and queue" mode, makes companies reluctant to press forward with innovative process improvements. ("Perfection", 5)

Lean promotes process flow, rather than a batch and queue approach. This means that production flows piece by piece from one process to the next. Regulatory permits generally expect equipment and processes to be stationary and unchanging, which may force companies to outsource processes or leave certain processes out of the Lean process flow. These "monument" processes cause the flow to be interrupted, and efficiency is lost. ("LME", 34)

The 2000 EPA study on Lean and the environment highlighted regulatory obstacles to implementing Lean for certain environmentally sensitive processes. Their 2003 follow-up study confirms and expands on why certain processes, especially those whose improvement potentially would be most desirable environmentally, are the most challenging to Lean. ("LME", 35)

Processes such as painting, metal finishing, and chemical treatment present challenges to Lean practitioners, primarily due to regulatory constraints. For example, the Federal Resource Conservation and Recovery Act (RCRA) can complicate waste reduction and chemical point-of-use implementations due to uncertainty around RCRA requirements and inconsistencies in regulatory agency interpretations. ("LME", 36) RCRA's definition

of solid waste also may complicate recycling efforts, especially in the transition between waste and reuse. (“LME”, 37)

Time constraints may also play a role in discouraging companies to Lean certain types of processes. Relocation or substitution of equipment to facilitate Lean process flow may be inhibited by cumbersome and time-consuming permitting requirements, such as air emissions, causing the improvement effort to be abandoned. (“LME”, 38) This would tend to deter companies in heavily regulated industries, such as painting and printing, from Lean implementations that could otherwise benefit both the company and the environment.

Industry Obstacles

Although many diverse industries from aerospace to healthcare to banks and universities have successfully applied Lean techniques with some success, other industries remain a challenge. Industry that relies on heavy fixed capital investments such as foundries or petroleum refineries do not appear to embrace Lean, according to recent EPA study. (“LME”, 20)

The reasons for this were not apparent from the published study, and would require additional research into Lean case studies and industry data.

Business Obstacles

Business decisions are frequently affected by the economics of the marketplace, and resources may not always be available for some improvement activities. In addition, some Lean improvements may require capital equipment expenditures which a company might be reluctant to fund in difficult economic times. However in this case, often other less costly Lean improvements can be made, gleaning sufficient cost savings to fund other more expensive improvement projects.

New York State, in conjunction with the U. S. Department of Energy and the Alliance to Save Energy initiated an *Executives for Energy Efficiency* (E4EE) project in 2003, with the goal of identifying factors that would inspire business leaders to implement energy efficiency measures. (Russell, 1) They identified a number of what were termed “hurdles to business energy efficiency” that ultimately related to how comfortable corporate executives were with assuming risk. (Russell, 6)

The E4EE report says that environmental objectives must be presented in a form compatible with business leader’s risk perception in order to facilitate adoption. They discuss a hierarchy of risk scenarios, the critical factors of each, and how environmental objectives must be packaged in order to effectively reach that audience.

The sophistication of a company also has a bearing on whether executives will choose to pursue environmental initiatives, such as energy efficiency, even if there are clear benefits. For example, a company that is disorganized or unfocused is concentrating mainly on survival, and has little interest in optimization. (Russell, 12)

A 2004 Stanford University survey-based study looked at the motivating factors for business leaders to incorporate sustainability methods during construction. (Castillo, 1) The results reported that 25% of respondents were unaware of sustainability. (Castillo,6) Although this was a small study, it does indicate that some potential environmental gains may be lost simply because business leaders are unaware of sustainability options. The study recommendations are in line with current consensus that sustainability needs to be marketed as a sound business strategy. (Castillo, 18)

A 2003 EPA study agrees that awareness may cause companies to miss opportunities for realizing environmental improvements. ("LME", 41) As companies embrace Lean, conversion processes may be made solely based on productivity considerations, without taking into account environmental improvements that could be implemented at little or no additional cost. The EPA study goes on to point out that the initial investment stage is critical to realizing cost benefits associated with environmental improvements such as pollution prevention and waste reduction. ("LME", 41) If this investment point is missed due to lack of awareness, companies may find it uneconomical to implement at a later time.

3. Research Methodology

This study explored the obstacles and opportunities associated with utilization of Lean methods to promote sustainability in American industry. Four dimensions, shown below, were identified and sufficient examples in each of the four quadrants were found during the Literature Review to give merit to this categorization method.

Quadrant I – Obstacles External/Regulatory	Quadrant II – Opportunities External/Regulatory
Quadrant III – Obstacles Internal/Business	Quadrant IV – Opportunities Internal/Business

The following diagram was developed as a research tool to assist in the characterization of the internal and external forces that may encourage or discourage organizations from pursuing environmentally beneficial business practices. As illustrated below, these forces can both provide business benefits and present hurdles which businesses must overcome.

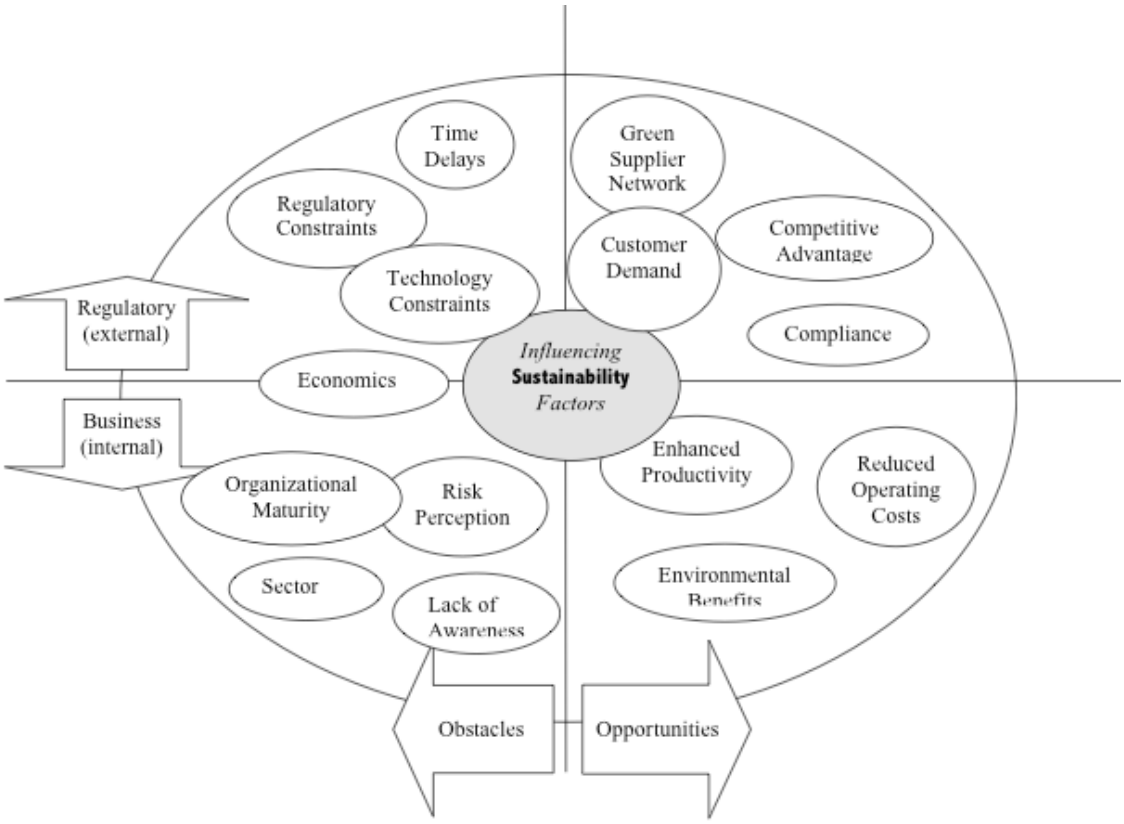


Figure 1 Business Influences

Two primary research methods were employed for this study. The first method was quantitative and entailed an in-depth analysis of secondary data (existing case studies) and development of a collection matrix to determine the degree of correlation between case study activities and reported results, and to facilitate comparisons between studies.

All four dimensions of this research were represented in the initial collection matrix, although it was originally anticipated that very little data would be available in quadrant three (internal/business obstacles). This is because most case studies do not advance to completion (or publication) if the initial internal business hurdles are not overcome. An iterative process was taken during the case study review, as the first pass through the available data resulted in adjustment and refinement of the initial collection format.

The second method was qualitative, and used descriptive survey methods to attempt to complete the collection matrix, confirming case study results and providing additional data for quadrant three. Influencing factors were noted on the matrix diagram by quadrant, to facilitate development of survey questionnaires.

The qualitative results were collected to support and augment the data collected through case study analysis and a review of the relevant literature, providing data triangulation in support of research findings.

Scope and Limitations

The scope of this study is limited to identifying the factors that influence organizations to implement environmental process improvements through surveys and reviews of case studies. Even with a limited number of case studies and a reasonably small survey population, it is anticipated that the major influencing factors can be identified, categorized by dimension (internal, external, obstacle, opportunity) and placed into one of the four quadrants of the research matrix.

Selection of the appropriate matrix quadrant within which to place influencing factors gleaned from this study could be somewhat subjective. For example, one could argue that all regulatory related influencing factors are external drivers, and should be placed in either quadrant 1 (external obstacle) or quadrant 3 (external opportunity). However, and equally valid allocation, and the one utilized for this study, would consider regulatory costs and constraints as external drivers, but cost savings associated with reduced regulatory demands as an internal driver, with placement in quadrant 4 (internal opportunity). Throughout this study, a standard allocation scheme was used for consistent placement of each type of influencing factor. Generally, direct cost-driven factors (such as cost savings, or expenditures) were considered internal drivers.

The study does not address the long-term effectiveness of any environmental process improvements undertaken, nor does it provide a comprehensive, in-depth analysis of the underlying reasons why the identified factors influence organizational decisions.

The study was also limited by the accessibility of a survey target population and the number of respondents. There were no incentives, other than goodwill, to encourage respondents to complete and return the survey.

Regulatory changes, programs, economic climate and other elements may affect obstacles and opportunities. Because of this temporal aspect, a similar study performed at a later date may produce different results.

There are inherent limitations in using any type of survey document. Some bias can be inadvertently introduced by a number of factors, such as order or wording of questions, choices presented and target population selected. In this study, the target population selected for the broader survey was based on accessibility of a reasonably large subject pool available to the researcher. The typical subject in this target population is a small to medium sized company in the printing industry. The bias introduced by selecting an industry-specific target population for the survey is balanced somewhat by the use of published case studies, which contained a wider distribution of organizational size and industry.

Economic data, in the form of actual (dollar value) cost savings or expenditures related to implementation of environmental process improvements was not consistently reported in the case studies available. The economic benefits associated with environmental process improvements has proven difficult to ascertain since many companies do not track the savings associated with an improvement projects, or track only productivity or other traditional operations markers. The Goodrich Aerostructures case study explains:

> "... environmental benefits were not calculated in making the business case. Improving... the production process and reducing the capital and time intensity of production, overshadowed other benefits. Savings in operational costs [due to environmental improvements] may be significant, but they are significantly smaller than business benefits achieved from reduced capital and time intensity of production. In other words, the business case for change did not enter through the 'green door'." ("LME, 62)

Case Studies

Availability of Data

There are a number of published case studies available for analysis. Case study data resulting from recent EPA studies on Lean and the Environment was available with considerable detail. These studies include a variety of industries and applications, from aerospace to ship repair. The following table lists the published case studies originally identified for use in this study. A final list of the case studies that were included in this research is presented in the following chapter.

Reported By	**Company**	**Industry**
GSN	Harr-Conn Chrome Co.	Metal Finishing
EPA	Lockheed Martin	Defense
CSU IAC	Alcoa Spanish Fork Plant	Aluminum Extrusion
EPA	Boeing Auburn	Machine Fabrication
EPA	Boeing Everett	Aerospace
EPA	Apollo Hardwoods	Wood Products
EPA	General Motors	Automotive
EPA	Goodrich Corp. Aerostructures Group	Aerospace
EPA	Warner Robins U.S. AFB	Government
GSN	Medegen Medicine Manufacturing Services	Healthcare
EPA	Various Shipbuilding and Ship Repair Companies	Shipbuilding
GSN	H&L Advantage	Injection Molding
Baxter	Baxter International, Inc.	Healthcare

Collection Matrix Design and Validation

Available case studies were reviewed and a collection matrix was defined in Excel spreadsheet format to facilitate data collection and later analysis. A ‘test matrix’ was completed with a representative selection of studies to ensure that the collection framework was adequate and all parameters of interest were included. The matrix was refined to finalize matrix design prior to formal data collection.

Each case study described one or more projects that were undertaken by the organization. When there was more than one project described in the case study, each separate project was entered into the collection study.

Minimum elements collected:

- Industry (coded by SIC code)
- Company/Organization name
- Case study date

- Case study type (published or via survey/questionnaire/interview)
- Reporting organization
- Obstacle/Opportunity data (one or more data sets containing the following:)
  - Quadrant (I, II, III, IV)
  - Obstacle or opportunity sub-code (e.g. energy savings, permitting problem)

  Additional elements to be collected (if available)
  - Lean method employed (e.g. Value Stream Mapping, 5S)
  - Value <Loss> expressed in dollars
  - Strategies used to overcome obstacles encountered, and their effectiveness

Acceptance Criteria

In order for a published case study to be accepted into this research, it had to contain sufficient reliable data in quantitative form. Regulatory changes, programs, economic climate and other elements may affect obstacles and opportunities. Because of this temporal aspect, only recent (2000 or later) case studies were considered.
For a published case study to be accepted, it had to meet the following requirements:

- provide data for all required elements of the pre-defined criteria
- have been performed, overseen, or reported by government, accredited universities or non-profit organizations
- be recent (2000 or later)

Data Collection

Case studies that were reviewed and rejected for inclusion were documented, along with rejection criteria.
Case studies accepted into this research were coded into the collection matrix in such a way as to ensure that each element could be linked back to the parent study.

Data Analysis and Interpretation

The data collected was interpreted in graphical (charts and graphs) format to identify trends and highlight commonality across multiple dimensions. Opportunity and obstacle data was quantified, to the extent possible, and prioritized by rank.

Descriptive Survey

The purpose of the descriptive survey in this research was to augment and validate findings from the comparative case study and supported by the literature review.

Data Collection Method 1 – Workshop Questionnaire

A questionnaire was developed for distribution at a business workshop to solicit information from participants on topics related to all four of the research quadrants, and to serve as a pilot for a larger survey. Survey respondents were workshop attendees, including business owners and other industry professionals.

The survey questionnaire included an optional contact information section, for follow-up. This workshop survey was constrained by the space limitations associated with the Green Printing Workshop questionnaire. The workshop coordinator could accept only two research questions for inclusion in the workshop questionnaire, in order to keep the total length of the questionnaire to fewer than two pages.

All responses were kept confidential and secure, and will be destroyed once the study is complete. The full workshop questionnaire is included in Appendix A.

The first workshop survey question (question 8 in the workshop questionnaire) was designed to capture the relative importance of a number of negative influencing factors that present obstacles to organizations considering environmental process improvement projects.

Potential obstacles for this question were compiled from the literature review and selected to include representative obstacles from both quadrant 1 (external obstacles) and quadrant 3 (internal obstacles). Quadrant 3 selections were emphasized in this question, because the published case studies provided limited data on internal obstacles.

Final selections were then narrowed down to those that were best considered as unambiguous and easily interpreted by the respondents. An additional category of "Other" was included to allow respondents to enter in obstacles of importance that were not in the printed list.

Respondents were asked to rank each of the influencing factors from 1 (most influence) to 5 (least influence).

Workshop Survey – Question 8

Quadrant	Influencing Factor - Obstacles
1	Regulatory demands make changes difficult
3	Unfamiliar with environmental process improvement methods
3	Cost factors
3	Other business priorities

The second workshop survey question (question 9 in the workshop questionnaire) was designed to capture the relative importance of a number of positive influencing factors that present opportunities to organizations considering environmental process improvement projects.

Potential opportunities for this question were compiled from the literature review and selected to include representative opportunities from both quadrant 2 (external opportunities) and quadrant 4 (internal opportunities).

Final selections were then narrowed down to those that were best considered as unambiguous and easily interpreted by the respondents. An additional category of

"Other" was included to allow respondents to enter in obstacles of importance that were not in the printed list.

Respondents were asked to rank each of the influencing factors from 1 (most influence) to 5 (least influence).

Workshop Survey – Question 9

Quadrant	Influencing Factor - Opportunities
2	Competitive advantage / Customer demand
2	Environmental, Health and Safety benefits
2	Green Supplier Network assistance
4	Reduced compliance costs
4	Increased efficiency and reduced production costs

Data Collection Method 2 – Broader Survey

A second survey questionnaire was developed to collect additional data, augmenting both the workshop survey data on influencing factors, and to collect additional case study data. The full text of the survey questionnaire is included as Appendix B.

Learning from the initial workshop study, the influencing factors ranking questions were refined, and additional questions were added.

Survey Question 1

The first survey question was designed to capture basic background information on the respondent's organization, such as primary industry, SIC code, number of employees and whether or not the organization had an onsite Environmental, Health and Safety staff. Prior to the study, it was unclear if company size or ES&H staffing could have a bearing on which influencing factors were considered most important, so it was decided to include these additional elements.

Survey Question 2

The second survey question was designed to capture information relating to an organization's experience with other quality methodologies, such as ISO, Lean or Six Sigma. Some of the literature suggests that prior experience with quality systems allows organizations to "transfer learning and insight from existing quality programs to their environmental improvement efforts". (Pil, 406)

Survey Question 3

The third survey question is a refinement of the first workshop question (question 8 in the workshop questionnaire), which was designed to capture the relative importance of a number of negative influencing factors that present obstacles to organizations considering environmental process improvement projects.

As with the workshop question, potential obstacles for this question were compiled from the literature review and selected to include representative obstacles from both quadrant 1 (external obstacles) and quadrant 3 (internal obstacles). Additional selections were identified based on the results of the published case studies and the workshop responses. For example, in two of the Boeing Everett case study projects, technological issues, such as lack of availability of acceptable less hazardous chemical substitutes ("Horizontal Stabilizer"), or product characteristics such as paint curing time, limited productivity improvements. ("Wing Seal")

Final selections were then narrowed down to those that were best considered as unambiguous and easily interpreted by the respondents. An additional category of "Other" was included to allow respondents to enter in obstacles of importance that were not in the printed list.

Respondents were asked to rank each of the influencing factors from 1 (most influence) to 5 (least influence).

Quadrant	Influencing Factor - Obstacles
1	Regulatory constraints (e.g. permitting, time delays)
1	Technological issues (e.g. suitable environmentally friendly products unavailable)
3	Lack of experience with environmental process improvement methods
3	Cost or economic factors
3	Risks or uncertainty associated with chances to product or process
3	Other business priorities take precedence over environmental improvements

Survey Question 4

The fourth survey question is a refinement of the second workshop survey question (question 9 in the workshop questionnaire), which was designed to capture the relative importance of a number of positive influencing factors that present opportunities to organizations considering environmental process improvement projects.

As with the workshop question, potential opportunities for this question were compiled from the literature review and selected to include representative opportunities from both quadrant 2 (external opportunities) and quadrant 4 (internal opportunities).

Final selections were then narrowed down to those that were best considered as unambiguous and easily interpreted by the respondents. An additional category of "Other" was included to allow respondents to enter in obstacles of importance that were not in the printed list.

Respondents were asked to rank each of the influencing factors from 1 (most influence) to 5 (least influence).

Quadrant	Influencing Factor - Opportunities
2	Improved competitive advantage by having sustainable products / processes
2	Increased customer demand for environmentally friendly products / processes
2	Improved compliance or other environmental, health and safety benefits
2	Green Supplier Network or EPA assistance
4	Reduce production costs by reducing or eliminating excess materials or waste
4	Previous successful process improvement project

Survey Question 5

The first additional influencing factor question was added to allow respondents to share their thoughts and suggestions on what methods they considered would be most successful in encouraging organizations to implement environmental process improvement projects. This question was added as another avenue to capture potential positive influencing factors not already listed as predefined selections in question 4.

Survey Question 6

The second additional influencing factor question was added to allow respondents to share their thoughts and suggestions on what they considered to be the biggest hurdle for organizations to overcome when considering implementation of environmental process improvement projects. This question was added as another avenue to capture potential negative influencing factors not already listed as predefined selections in question 3.

Survey Question 7

The case study portion of the questionnaire was designed to capture the same type of information as defined in the published case study collection matrix, described above.

Identifying Respondents

Respondents were identified through the literature review, case studies, referrals and conference attendees as persons in industry that have implemented Lean in their businesses, had an interest in improving environmental, health or safety aspects of their organizations, or were associated with organizations that have performed Lean assessments with environmental objectives.

Soliciting Participation

An email with attached survey document was sent to potential respondents, along with a cover letter. The cover letter introduced the researcher as a graduate student, gave a brief overview of the purpose of the study, briefly described the article, website or other source that led the researcher to the potential respondent, and asked the respondent if he or she would participate in a short thesis research survey.

When a completed survey was received back from a respondent, a follow up email was sent to the participant, thanking them for their participation and reconfirming that all responses would be kept confidential.

Human Subject Protection

The following procedure was used to ensure that information obtained from human subjects is obtained via informed consent and is used appropriately and exclusively for the purposes for which that consent is obtained.

Prior to the Interview/Survey

- Provided each participant with a written statement including background information on the researcher, purpose and goal of the research, and the survey process to be used
- Confirmed that email survey results will be kept confidential and secure

After the Interview/Survey

- Data collected (via email) was kept secure and inaccessible to others
- Electronic correspondence will be deleted after the research is complete

Data Analysis and Interpretation

Information obtained via email survey was entered into the collection matrix similar to the one developed for the case study analysis. Data were reviewed to identify any conflicting or unexplained results and additional clarification from the source was obtained.

4. Results and Findings

Analysis of Data

Findings

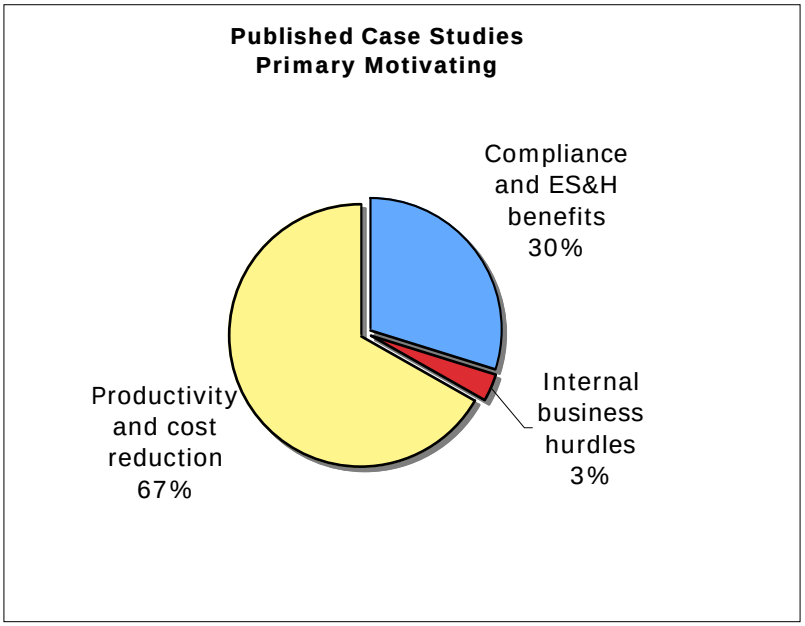
Published Case Studies

The following table lists the published case studies reviewed in this study. The case studies were reported by the U.S. Environmental Protection Agency (EPA) as part of their Lean Manufacturing initiatives, or through the Green Supplier Network (GSN).

Reported By	**Company**	**Industry**	**# Projects**
EPA	Apollo Hardwoods	Wood Products	1
EPA	Baxter International, Inc.	Healthcare	1
EPA	Boeing Everett	Aerospace	7
EPA	Goodrich Corp. Aerostructures Group	Aerospace	6
EPA	Rejuvenation		1
EPA	Warner Robins U.S. AFB	Government	5
EPA / WA Dept. of Ecology	Canyon Creek	Wood Products	2
GSN	3M		1
GSN	H&L Advantage	Injection Molding	1
GSN	Harr-Conn Chrome Co.	Metal Finishing	1
GSN, Primex	Lehigh Press Puerto Rico	Printing	1
GSN	Medegen Medicine Manufacturing Services	Healthcare	1
GSN	Metalworks	Manufacturing	1
GSN	Sermatech Connecticut	Aerospace	1

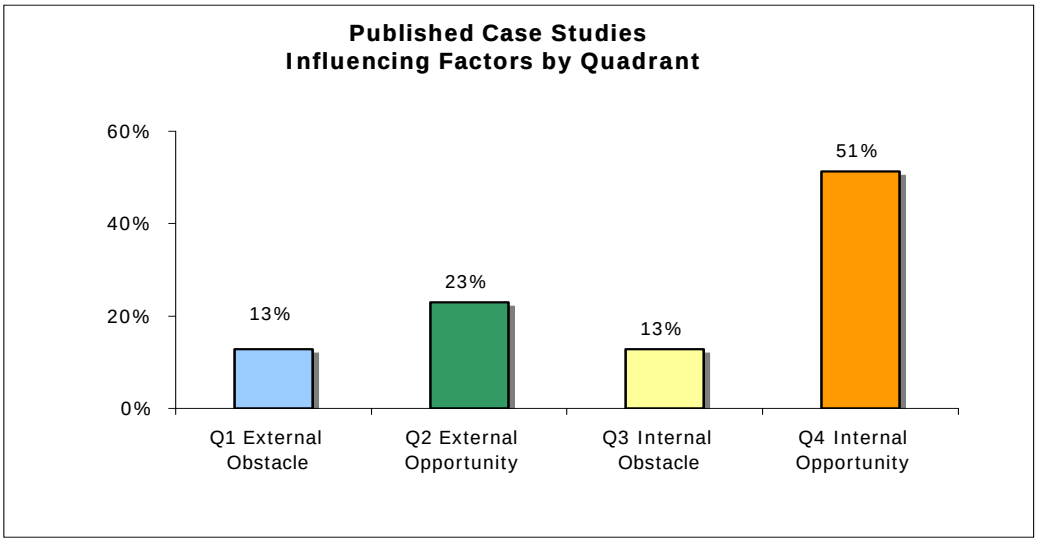
The EPA case studies for Lockheed Martin, General Motors and Boeing Auburn, originally proposed for inclusion in this research, were eliminated because the reported projects were completed prior to the stated research study cutoff date of 2000. The EPA Shipbuilding and Repair Sector case study originally proposed for inclusion, was eliminated from consideration because it did not meet minimum case study reporting requirements.

A total of thirty projects in fourteen published case studies were reviewed and analyzed to determine the major factors influencing the organization to implement a Lean project while considering environmental benefits.



Opportunities, such as productivity improvements and cost savings, generally were considered the major drivers for organizations to consider Lean methodologies. Attempting to Lean environmental areas posed obstacles such as permitting issues or other regulatory constraints.

In the published case studies evaluated, 20 of the projects were initiated with the promise of increased productivity or cost savings. Environmental compliance and other environmental, health and safety benefits were stated as the primary motivating factors in nine of the case study projects. An internal business obstacle, a potential plant closure, was reported as the primary motivating factor in one project.



Looking at both motivating factors and obstacles encountered by quadrant, case study projects were largely motivated by internal opportunities, such as potential cost savings. External influences, both positive and negative, were not as significant.

Obstacles Encountered

Although most of the published case studies cited only positive results, some did address obstacles encountered during the project implementation, and the strategies used to overcome them.

Two of the Green Supplier Network case studies centered on organizations whose lack of experience had prevented them from successfully implementing environmental process improvements. H&L Advantage had two disadvantages; first, they had been unsuccessful in implementing Lean on their own, and secondly, they had minimal knowledge of pollution prevention techniques, both of which made it difficult for them to initiate successful environmental process improvement projects. ("H&L") Metalworks, on the other hand, had some experience in Lean and environmental improvements, however they did not feel they had adequate expertise or resources to implement a successful environmental process improvement project. In both cases, these organizations benefited from expertise and resources provided through the Green Suppliers Network and were able to implement successful projects with dual environmental and economic benefits. ("Metalworks") Rothenberg's 2004 research on Lean manufacturing in the printing industry confirms the experience and resource challenges that smaller companies face when attempting to implement Lean. ("Medium-Sized Printers", 9)

Although survey results indicated that availability of assistance from the Green Suppliers Network and EPA was not ranked as influential as other opportunities such as cost savings that have a more direct contribution to the bottom line, case studies indicate that this method can be quite effective in producing positive results.

Regulatory and technical constraints plagued the Boeing 767 & 747 Wing Seal Moving Lines project, reports the EPA. Flow time of the exterior sealing process was limited by the cure time of the paints and sealants, causing Boeing to investigate alternative products. Unfortunately, many faster drying products have a higher VOC content and can contribute to increased air emissions. ("Perfection", A-5) Rothenberg et al explored this connection between Lean and higher VOC emissions in a 2001 study, and concluded that a compromise in Lean practices is sometimes needed in order to achieve emissions control. ("Quest", 240) This is borne out by the Boeing study, where a lower production flow rate was adopted in order to accommodate use of existing paints and sealants. ("Perfection", A-5)

The Boeing project wing seal project also faced regulatory constraints. Building reconfigurations suggested to make most effective use of the facility would have required changes to existing construction and environmental permits or new permit applications. Time constraints forced Boeing to scale back the facility re-design. ("Perfection", A-5)

Another Boeing project was not so successful when faced with regulatory challenges related to spray painting and coating operations on the 747 Horizontal Stabilizer project. In this case, the combined regulatory requirements associated with construction, OSHA and air emissions proved to be insurmountable in terms of time and resources, and the

project was placed on hold. (“Perfection”,A-7) The EPA, in their 2003 Lean manufacturing study, identified permitting time delays as one of the primary challenges faced when trying to Lean painting operations. (“LME”, 38)

Another aerospace company, Goodrich Aerostructures, cited organizational culture as a major obstacle when implementing and sustaining Lean improvements at their Riverside facility. Both management and employees were faced with the twin challenges of changing both thinking and behaviors. One strategy used to improve real time problem resolution required a physical change as well. Manager and engineer’s offices were relocated to the shop floor with the expectation that proximity and accessibility would reduce resolution time. (“Goodrich”)

Production interruption posed an obstacle to Goodrich’s San Marcos facility reconfiguration efforts. In order to minimize production downtime while reconfiguring the manufacturing layout, they used a cross-functional team approach during a week-long kaizen event. (“LME”, 62)

Workshop Pilot Survey

A pilot survey was conducted during a one-day CARE Green Printing Workshop, held on April 26, 2007 in Rochester, New York. The workshop was sponsored by the Center for Environmental Information (CEI) as part of a U.S. EPA Community Action for a Renewed Environment (CARE) Grant and was hosted by the Rochester Institute of Technology’s E. Phillip Saunders College of Business. There were 38 attendees, including business people, students and workshop facilitators. Two research survey questions (questions 8 and 9 on the workshop questionnaire) were included in the workshop evaluations, which were collected at the close of the workshop.

Workshop attendees completed six surveys that included responses to the research survey questions. A blank workshop questionnaire is attached as Appendix A.

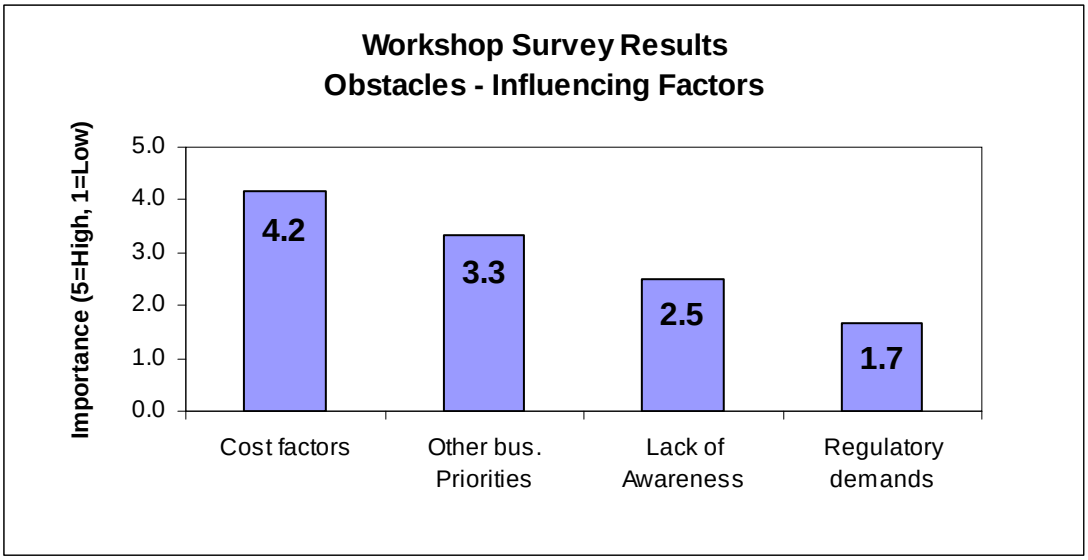
Influencing Factors: Obstacles

The first workshop survey question (question 8 in the workshop questionnaire) was intended to identify the importance that respondents associated with perceived internal and external obstacles. Awareness, cost factors and other business priorities were considered to be internal obstacles. Regulatory demands were considered to be external obstacles.

Results from the workshop participants were compiled into two tables, one for each question. Respondents ranked selections from 1 (highest importance) to 5 (lowest importance). No respondents ranked “Other” in either question, so this selection was eliminated from the results tables in both cases.

Respondent rankings were inverted as the results were transposed to the tables so that the higher value (5) reflected high importance and the lowest value (1) indicated lowest importance. This was done to facilitate evaluation of the perceived importance of each factor. A straight transformation was performed (1=5, 2=4, 3=3, 4=2, 5=1) to ensure correct translation of results. Any blank entries were allocated a 1 (lowest priority).

Relative importance of each of the four factors was determined by summing each of the responses for each factor and dividing by the total to obtain an average.

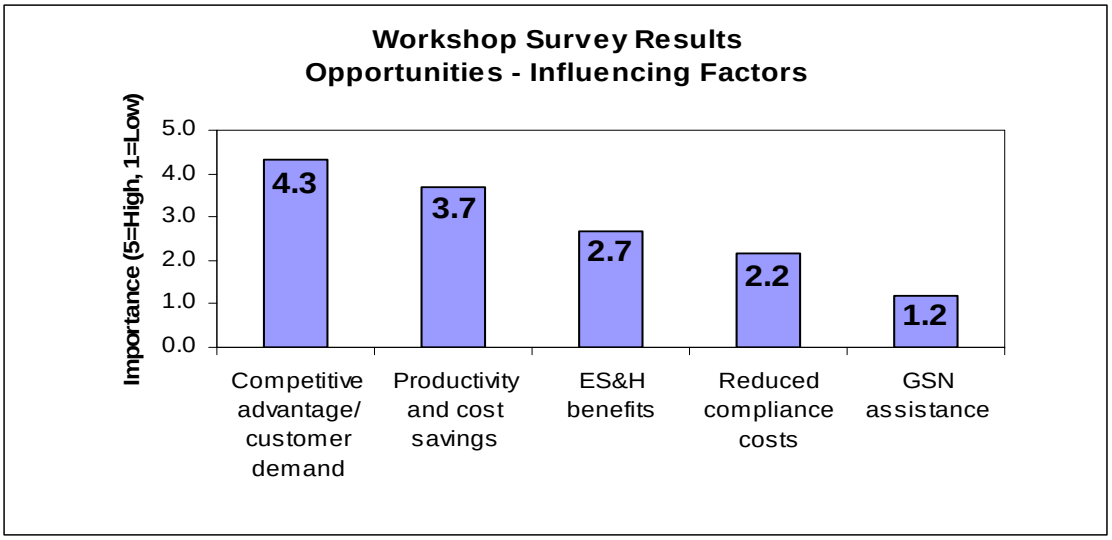


As shown in the graph, cost was considered, on average, to be the primary obstacle to implementing Lean process improvement initiatives, closely followed by other business priorities. Regulatory demands scored lowest in importance according to workshop survey respondents.

Influencing Factors: Opportunities

Question 9 was intended to identify which opportunities respondents considered to be most important in motivating their organizations to implement Lean process improvement initiatives. Competitive advantage, customer demand, ES&H benefits, and GSN assistance were considered external opportunities. Increased efficiency, reduced costs and reduced compliance costs were considered internal opportunities.

Relative importance of each of the five factors in Question 9 was determined by summing the responses for each factor and dividing by the total to obtain a percentage.



As shown in the chart, above, competitive advantage and customer demand were, on average, perceived as the most important positive influencing factors for implementing Lean process improvement initiatives, closely followed by the benefits associated with increased efficiency and reduced production costs. Reduced regulatory compliance costs and other environmental, health and safety benefits were considered less important influencing factors, and the availability of Green Supplier Network assistance scored lowest in importance according to survey respondents.

Broader Survey

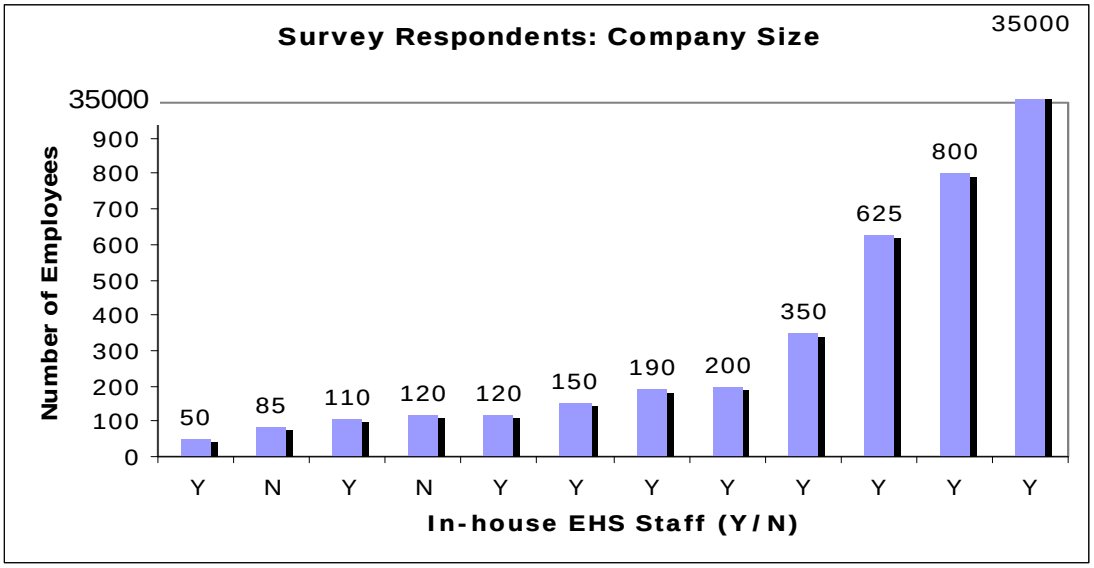
An enhanced survey document, based on lessons learned from the pilot workshop study, was sent via email to a larger group of potential respondents. This survey was sent to 130 individuals that attended the National Environmental, Health and Safety Conference ’07 for the Graphic Communications Industries. The researcher presented a paper on International Environmental Regulations at the conference, and co-chaired a conference workshop on Lean environmental process improvements.

Ten of the email surveys were rejected with errors indicating that the email address was not valid, or that an SMTP error had occurred on the receiving server. Email addresses were rechecked and resent, but the resend failed in all cases. Three individuals responded but declined to participate, citing that their organization or function was not applicable to the study.

A total of twelve individuals returned completed surveys. In addition, eight responses included one or more case study entries, for a total of eleven case studies. A blank survey questionnaire is included as Appendix B.

Survey Respondent Profile

Survey respondents generally were in the commercial printing industry and ranged in size from 50 to 800 employees, with a typical size of approximately 150 employees.



In addition, one respondent was from a very large newspaper publishing company, with a total of 35,000 employees. Only two companies did not have in-house ES&H staff.

Four organizations were ISO 9000 certified and three were ISO 14000 certified. All except three organizations had prior experience with Lean and seven also had experience with Six Sigma.

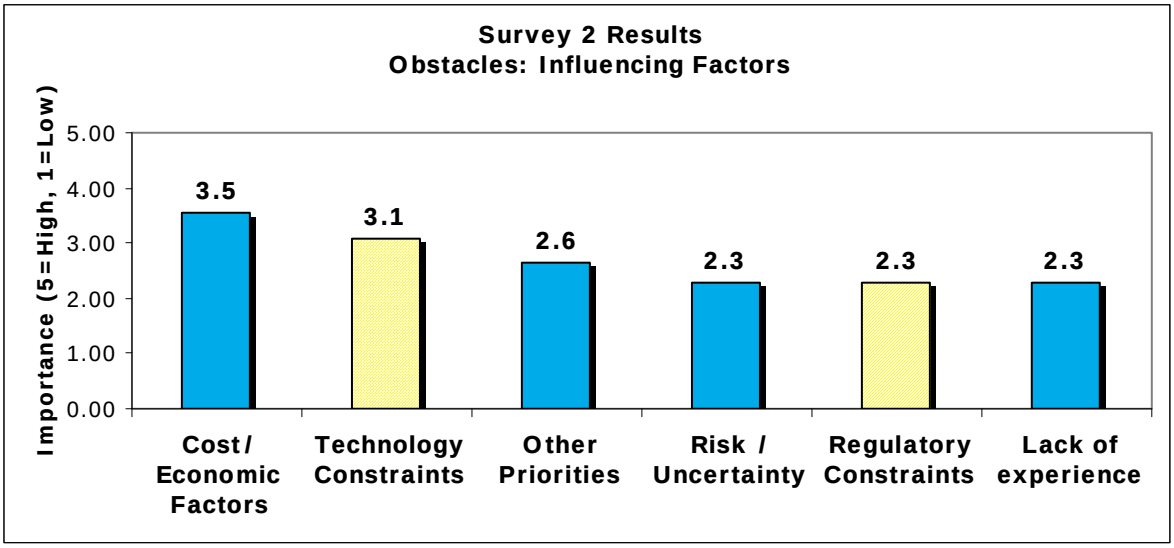
Influencing Factors: Obstacles

The first influencing factor survey question (survey question 3) was intended to identify the importance that respondents associated with perceived internal and external obstacles. Lack of process improvement experience, cost factors, risk/uncertainty concerns and other business priorities were considered to be internal obstacles. Regulatory demands and technological constraints were considered to be external obstacles.

Responses to this survey question were entered into an Excel spreadsheet table. Respondent rankings were inverted as the results were transposed to the table so that the higher value (5) reflected high influence and the lowest value (1) indicated lowest influence. This was done to facilitate evaluation of the perceived importance of each factor. A straight transformation was performed (1=5, 2=4, 3=3, 4=2, 5=1) to ensure correct translation of results. Any blank entries were allocated a 1 (lowest priority).

No respondents ranked “Other” for this question, so this selection was eliminated from the results table.

Relative importance of each of the influencing factors was determined by summing each of the responses for each factor and dividing by the total to obtain an average.



As shown in the chart, above, cost and technological constraints were, on average, considered to have the greatest influence on organization's decisions to implement environmental process improvements. Regulatory constraints and lack of experience with environmental process improvements were considered factors with the least influence. External influences are shown as blue bars and internal influences are shown as yellow striped bars on the chart.

In addition to ranking a set of predefined potential obstacles, respondents were asked to comment on what they considered to be the main reason why organizations did not pursue environmental process improvement projects (survey question 6).

Six respondents reiterated that costs and budgets were what they considered to be the main reasons why organizations do not implement environmental process improvements. One respondent had this to say regarding costs and profits:

> "While we all know that environmental programs are important, there is too much hype and too little credible information. Businesses are in the business of using natural resources for profit, so when regulation or process prevents profits, there is no incentive to change. In many cases, companies avoid change (cost) to survive. In cases where there would be no additional direct cost, there is opportunity cost (time and effort to research and implement at no return). Therefore, to ensure effective conversion to environmentally-sound practices, incentives must be induced, whether through subsidy such as tax breaks, direct cash, or credits, or the marketplace must create a profitable demand."

Other respondents cited other business priorities and lack of knowledge, which were also already reflected in the predefined obstacles stated in survey question 3. As one respondent stated “It is not on their radar screen. Senior management doesn’t make this a priority.”

Time and resource constraints were mentioned, reflecting influencing factors identified through the published case studies.

The responses did, however, uncover some additional influencing factors that were not captured in the published case studies. Fear of change was mentioned, as was uncertainty, which may relate to an organization’s executive risk taking comfort level. New York State’s Executives for Energy Efficiency (E4EE) project in 2003 explored this correlation between risk perception and project adoption. (Russell, 6)

One respondent suggested that lack of customer demand presented a negative incentive for implementing environmental process improvements. Another respondent believed that the regulatory climate does not support process improvement and cited an example:

> “Case in point – we are CESQG, [Conditionally Exempt Small Quantity Generator] during a recent state hazwaste inspection the inspector argued that we should not be, and that we should still be paying hazwaste fees and filing reports!”

Influencing Factors: Opportunities

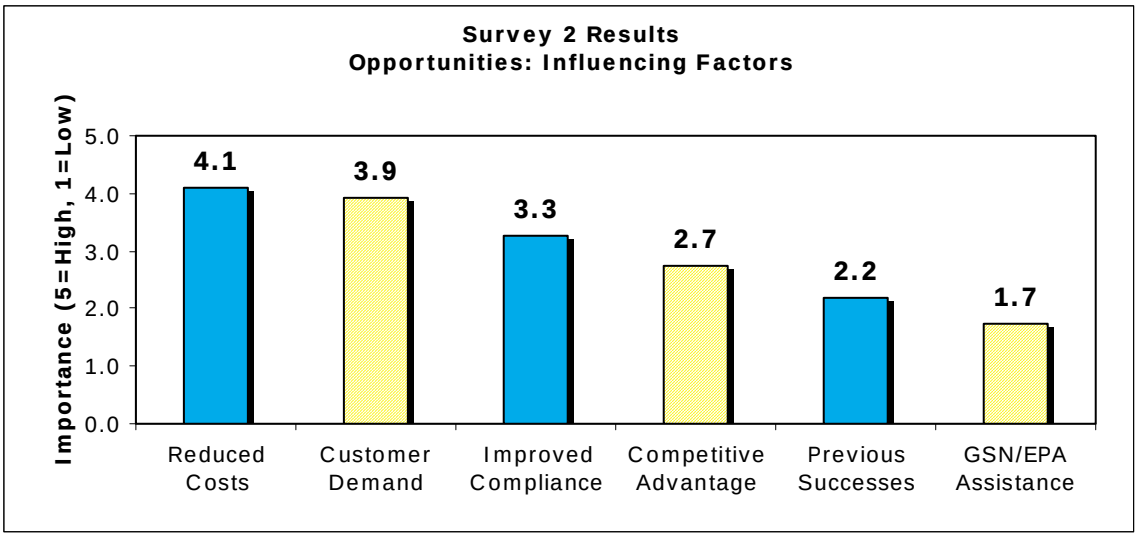
The second influencing factor question (survey question 4) was intended to identify which opportunities respondents considered to be most important in motivating their organizations to implement Lean process improvement initiatives.

Responses to this survey question were entered into an Excel spreadsheet table. Respondent rankings were inverted as the results were transposed to the table so that the higher value (5) reflected high influence and the lowest value (1) indicated lowest influence. This was done to facilitate evaluation of the perceived importance of each factor. A straight transformation was performed (1=5, 2=4, 3=3, 4=2, 5=1) to ensure correct translation of results. Any blank entries were allocated a 1 (lowest priority).

No respondents ranked “Other” for this question, so this selection was eliminated from the results table.

Relative importance of each of the influencing factors was determined by summing each of the responses for each factor and dividing by the total to obtain an average.

Competitive advantage, customer demand, reduced compliance costs and GSN/EPA assistance was considered external opportunities. Reduced production costs, improved compliance and previous successes were considered internal opportunities.



As shown in the chart, above, reduced costs and customer demand were, on average, considered to be the most influential factors motivating organizations to implement environmental process improvements. Regulatory assistance through the Green Suppliers Network or the EPA ranked lowest in influence. External influences are shown as blue bars and internal influences are shown as yellow striped bars on the chart.

In addition to ranking a set of predefined positive influencing factors (opportunities), respondents were asked to provide suggestions on how organizations might be encouraged to pursue environmental process improvement projects (survey question 5).

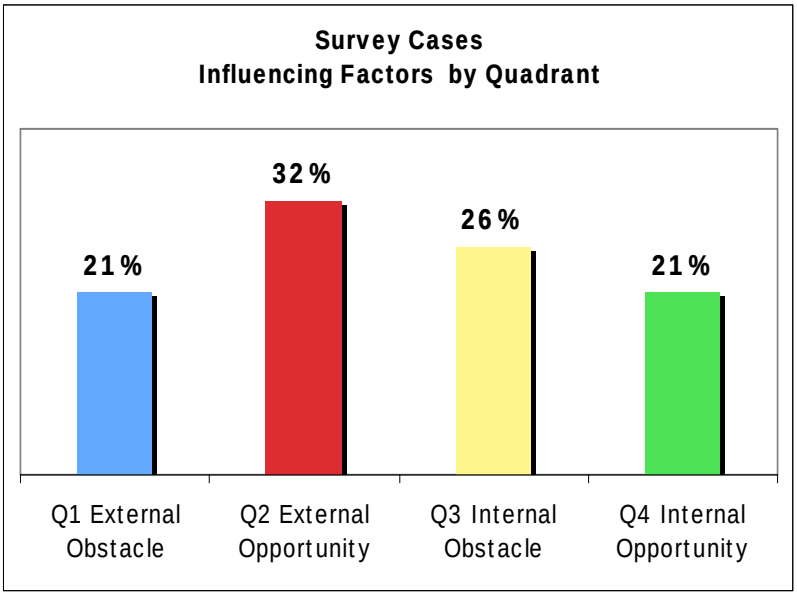
As with the previous set of negative influencing factors, costs (in this case, cost savings) were a main focus of many of the suggestions. Increasing awareness of the cost savings of environmental process improvements, including the cost savings resulting from increased customer satisfaction, looking at Net Present Value (NPV) rather than just payback periods, and performing a complete cost analysis for each aspect of the project were mentioned.

Other suggestions included enhanced networking with other industry and ES&H professionals, and encouraging suppliers of environmentally friendly products to increase awareness of their alternative products through education and other promotional efforts. One respondent suggested that, rather than encouraging organizations, the regulatory community needed more information on the value of process improvements so that they would “jump on board rather than get in the way”.

Survey Case Studies

Survey respondents were asked if they had implemented any environmental process improvement projects, and if so, to provide project information on up to two projects. Eight respondents indicated that they had implemented environmental process improvements, and reported a total of eleven projects. Respondents reported that obstacles were encountered in eight of the projects, however in all cases the obstacles did not prevent the projects from being completed.

Respondents were asked to specify the primary process improvement method used for each of the reported projects. Value Stream Mapping was the Lean method specified for four of the projects. Partnering with a manufacturer was the method of choice for two projects, both reported by the same organization. Respondents did not specify a process improvement method for the remaining five projects.



In contrast to the published case study data, survey respondents considered external factors (53%) such as environmental compliance and technological constraints to be almost equal in influence to internal factors (47%) such as cost savings.

Environmental concerns, such as environmental compliance or reducing hazardous chemical usage and waste, were primary motivating factors in six of the projects. Cost savings was the primary motivating factor in the remaining five projects.

The difference in focus between the two case study groups may be due to the fact that survey respondents, having recently attended an Environmental, Health and Safety conference, had a greater interest in environmental improvements than the organizations that participated in the published case studies. Since the objective of this research is to identify all of the factors that may influence an organization to implement an environmental process improvement project, this disparity between the two groups is considered to be positive indicator that a broad range of factors was collected.

Survey respondents reported an interesting array of obstacles. Physical building constraints, installation issues and regulatory and technical constraints were obstacles common to both the survey case studies and the published case studies. However, the survey case studies also revealed some additional internal obstacles; management and employee perceptions, divided support for the project, competing projects, and difficulty maintaining improvements over time.

A variety of solutions were suggested to overcome the obstacles encountered. Use of a cross-functional team was successful in efficiently redesigning a building layout that posed a technical difficulty. This same strategy was also documented in the Goodrich Aerostructures case study, in order to reduce redesign time for their San Marcos production facility. (“LME”, 62)

Providing management and employees with factual information on the effectiveness of environmentally friendly cleaners helped to overcome negative perceptions, and persistence was suggested as a mechanism to help organizations maintain improvements over time. One survey respondent reported that their project portfolio management system effectively conveyed resources and investments, expected benefits and project alignment with corporate goals, which helped gain executive team buy-in and provided data for project prioritization.

Summary

The following research deliverables were proposed:

- A completed matrix diagram, identifying the internal and external obstacles and opportunities that organizations in the study have considered when evaluating implementation of environmental process improvements.
- A list of strategies (both successful and unsuccessful) that the research subject organizations (both case studies and interviewees), have tried in their attempts to overcome internal and/or external obstacles.
- A list of the economic benefits (or costs) associated with environmental process improvements implemented by study participants.

Research Matrix Diagram

The research matrix diagram contents, originally based on influencing factors obtained from the literature review, have been updated to reflect the additional factors gleaned from the published case studies and descriptive survey. The completed matrix diagram, shown below, identifies the internal and external obstacles and opportunities that influence organizations considering implementation of environmental process improvement projects.

I External Obstacles	**II External Opportunities**
• Regulatory constraints (L, C, S) • Technological constraints (C, S) • Lack of customer demand (S)	• Partnerships, Green Supplier Network or EPA assistance (L, C, S) • Competitive advantage (L, S) • Customer demand (C, S) • Compliance (C, S) • Environmental benefits (L, C)
III Internal Obstacles	**IV Internal Opportunities**
• Risk perception or uncertainty (L, C, S) • Lack of awareness or experience (L, C, S) • Lack of resources (L, C, S) • Organizational culture(L, C, S) • Other business priorities (L, S) • Production time constraints (C) • Sector or industry (L) • Cost (S)	• Reduced production costs (L, C, S) • Improved product quality (L, C) • Organizational culture (L, S) • Improved productivity (L, C) • Reduced production time (C) • Reduced compliance costs • Reduced energy costs (C) • Reduced waste disposal costs (C) • Labor savings (C)

Source key: L – Literature review
C – Published case studies
S – Research Survey

Quadrant I – External Obstacles

Regulatory constraints were considered to be the most significant obstacles to organizations considering implementation of environmental process improvements. This was consistently reported in the literature review, published case studies and by survey respondents. The EPA recognizes that the current mechanisms for ensuring regulatory compliance may dissuade organizations from implementing process improvements that

would otherwise benefit both the company and the environment, and has funded a number of studies to understand and address these limitations.

For example, air emissions regulations, because many permits are tied to physical equipment locations, present problems for organizations wanting to reconfigure manufacturing layouts to optimize flow or for cellular manufacturing. Other companies have been forced to accept less than optimal layouts in order to minimize changes to existing permits, which often result in unacceptable time delays. The time factor associated with regulatory permits alone was enough to discourage many organizations from pursuing environmental process improvements.

Technological constraints, such as availability of suitable, less toxic, alternatives have also posed obstacles to organizations improvement efforts. Performance of environmentally-friendly products has also been a concern, although this may often be more of an obstacle related to perception, as discussed later in the Quadrant II discussion, below.

Lack of customer demand was an obstacle reported by one survey respondent, and is probably a more prevalent influence than this study would suggest. Both the workshop and the broader survey respondents ranked customer demand as having a high level of positive influence on their decision to implement environmental process improvements. Other business priorities also ranked high on both surveys. It is likely that lack of customer demand has an influence on which projects are undertaken, and which are not.

Quadrant II – External Opportunities

Partnerships and cooperative ventures between customer and supplier, or with regulatory agencies or their advocates, have proven very successful in helping organizations achieve environmental process improvements. The EPA has funded programs such as the CARE grants mentioned in the workshop pilot survey, above, to partner with small and medium sized companies in improving environmental performance. These partnerships, such as assistance from the Green Suppliers Network, can also provide the expertise and resources that would otherwise hold organizations back from implementing environmental process improvements. In addition to the published case studies touting the benefits of GSN assistance, survey respondents also reported using partnering in two successful environmental process improvement projects.

Customer demand and competitive advantage ranked as the highest positive influencing factor in the workshop survey, and second and fourth in importance, respectively, in the broader survey. Both of these influences are directly associated with the potential for improved profits, which is a major business driver. This could be extrapolated to predict that as customer demand for ‘green’ products and production processes increases, companies are likely to respond and focus on more environmental improvements.

Improved compliance and other environmental, health and safety benefits were ranked as relatively important positive influencing factors in the two surveys. Thirty percent of the published case studies also cited compliance and other ES&H benefits has the primary motivating factors for projects undertaken. Compliance, specifically compliance relating to air emissions regulations, was one of the reasons that Canyon Creek Cabinet Company chose to partner with the Washington State Department of Ecology and Washington Manufacturing Services in a lean and environment pilot project. Improvements to their finishing department resulted in a reduction of VOC emissions, which may allow production capacity to increase without the need for further regulatory compliance measures. ("Canyon Creek", 9)

Quadrant III – Internal Obstacles

Survey respondents ranked cost as the number one obstacle to implementing environmental process improvements. In addition to the direct costs of labor and resources to implement these types of projects, one survey respondent also points out that opportunity costs must also be considered. Evaluating opportunity costs involves weighing the investment return potential of projects and selecting the one that best meets the organization's current objectives.

The opportunity cost of that selection is the value, or return, that would have been obtained had the next best alternative project been selected. This is a significant concept, and may be the single most important reason why environmental process improvements, even with clear, positive benefits, are passed over for other projects perceived as more lucrative. Not coincidentally, other business priorities were ranked high in influence in both the workshop and the broader survey. As pointed out in the Goodrich case study, although there may be considerable savings associated with reduced waste or chemical usage, it is not as significant as the benefits associated with other business improvements. ("LME", 62)

Lack of resources was mentioned in surveys and published case studies as a significant deterrent to implementing environmental process improvement projects. This also speaks to the relative lack of importance organizations attach to environmental benefits, as compared to the more traditional business metrics, such as productivity enhancements. As Schalltegger and Muller point out, environmental costs are considered overhead in most organization's accounting systems, therefore management is not aware of, or able to accurately track, potential savings associated with environmental improvements. (Bennett, 86)

In addition to the lack of awareness of the true cost of their environmental choices, management and Lean practitioners alike are unaware of the potential opportunities for environmental improvements to be implemented as part of any process improvement effort. As one survey respondent pointed out, environmental concerns are not "on their radar screen".

Although executives may not be aware of the environmental benefits, they are certainly cognizant of the inherent risks associated with environmental projects. Regulatory constraints and the uncertainties associated with changes to regulated processes make organizations reluctant to implement significant environmental improvements, especially when regulatory permits are involved.

Organizational culture also plays a part in determining if an organization's projects are successful. An organization's resistance to change may be due to the risk comfort level of management, as explored in the Executives for Energy Efficiency project. (Russell, 6) Perceptions can also be a barrier to change as one survey respondent pointed out, explaining that his project had to overcome both management and employee perceptions that environmentally friendly products were less effective. Another survey respondent mentioned that it was difficult to maintain improvements after they were implemented, although she did point out that over time, with persistence, the improvements were sustained.

Obstacles related to a particular sector or industry were mentioned briefly in the EPA studies on the effectiveness of Lean implementations, however these industries were principally foundries and refineries. ("LME", 20) No published case studies were available for this sector, nor were potential survey respondents.

Quadrant IV – Internal Opportunities

Improved productivity and cost reductions were the primary motivating factors in 67 percent of the published case studies. These factors also ranked high in influence in both the workshop and the broader survey. This is not surprising, as productivity and cost savings are primary motivating factors for most Lean process improvements, regardless of any associated environmental benefits. They also are likely to result in improvements that are trackable using typical business accounting methods, which, as discussed earlier, places this type of project ahead of many environmental projects where the benefits may not be immediately recognized.

Related to cost savings, are the savings associated with energy reductions. Energy savings were obtained by reducing the space requirements for production or storage, thus reducing the energy costs associated with maintaining the space. Other energy savings were associated with a reduction in water use, which resulted in less energy being expended to power water pumps. Similarly, cost savings associated with reduced waste disposal were reported in the case studies.

Positive changes in the culture of organizations that have implemented environmental process improvements were also noted in the literature and echoed in the survey responses. One EPA report notes that process improvement methodologies such as Lean, can have a positive effect on corporate culture, by promoting employee involvement and a focus on continuous improvement. ("LME", 21) Pil and Rothenberg agree, suggesting that process improvement methods such as Lean provide a foundation of organizational

expertise that can be leveraged in future projects, reducing overall implementation costs. (Pil, 406) Although not considered as influential as costs, customer demand and improved compliance, successes with prior projects was ranked higher than external assistance as a positive influencing factor by survey respondents.

Improved product quality was also linked to environmental process improvements. Consistent quality was one of Rejuvenation's goals for implementing Lean through flow manufacturing. ("Rejuvenation") 3M also believes that Lean can improve quality, as well as support the company's environmental and sustainability goals, and has implemented Lean Six Sigma practices throughout the corporation. ("3M")

Lean Methods Used

Value Stream Mapping (VSM) was the most widely used environmental process improvement method reported by survey respondents and in published case studies. A total of 14 projects incorporated VSM. This is not surprising, since most Lean process improvement projects start with a VSM to map out the current process and identify the wastes and other inefficiencies. ("Toolkit", 12) VSM can also be used to map out the desired 'future state' of a process, as an implementation objective.

5S and 6S (5S plus Safety) methods were also widely used in the published case studies. Eight of the case studies applied 5S or 6S during a project. One survey respondent also reported use of 5S in a project to reduce operating costs and response times.

Kaizen, or rapid improvement events, were used in eight of the published case studies. None of the survey respondents reported use of kaizen.

External assistance was used in six projects. Two projects reported by a survey respondent utilized partnering with a manufacturer or supplier to achieve their environmental process improvement objectives. One project focused on auto-wash reformulation, and the other involved implementing a solvent waste recovery system.

Green Supplier Network assistance was used in four of the case study projects to provide expertise and resources needed to implement their environmental process improvement projects.

Cellular flow, also known as cell-based production, was used in six published case study projects to reduce production time. Because changing to cell-based production often requires redesign of the production floor, obstacles related to regulatory permitting and associated time delays were reported in case studies where this Lean method was used.

Use of other Lean methods, such as 3P, kanban, point-of-use and Lean Six Sigma were less prevalent, each used in only one or two implementations.

Environmental Issues Addressed

A variety of environmental issues were addressed in the case studies and by survey respondents. These may represent the 'low hanging fruit' opportunities that could provide an initial focus for organizations seeking to implement environmental process improvements, or to incorporate environmental considerations into other planned process improvement initiatives.

- Waste reduction – both hazardous and non-hazardous -
- Reduced use and storage of hazardous materials.
- Reduced air emissions.
- Water savings.
- Energy savings associated with reduced transportation, inventory storage, or water use
- Cost savings associated with reduced material use (raw materials, packaging, natural resources)
- Compliance
- Improved health and safety / reduced ES&H risks (spill risk, trip and fall hazards)

Strategies and Outcomes

The following table lists the strategies (both successful and unsuccessful) that the research subject organizations (both case studies and survey respondents) have tried in their attempts to overcome internal and/or external obstacles.

Obstacle	**Suggested Strategies**
Physical building layout posed obstacles to equipment installation or redesign (C, S)	Cross-functional teams consisting of tradesmen and manufacturing personnel (C,S)
Negative management and employee perceptions of the effectiveness of environmentally friendly products (S)	Providing tangible proof of efficacy of environmentally friendly products (S)
Compliance (C, S)	Partner or discussions with regulatory agency (S), consider less hazardous alternatives (C)
Lack of resources or experience (C, S)	Partnering with Green Supplier Network , supplier or customer (C, S)
Other business priorities (S)	Develop a full cost accounting of all project facets (S)
Technological constraints (C)	Investigate alternative processes and products(C)
Cellular flow design constrained by regulatory requirements (C)	Accept less than ideal configuration if time constraints do not allow permit changes (C)

Economic Benefits and Costs

A list of the economic (actual dollar value) benefits (or costs) associated with environmental process improvements implemented by study participants was anticipated, however the published case studies that were reviewed did not provide sufficient detail to support including this type of information as a requirement for the study. Many of the documented case studies indicated that the original intent of the improvement project did not consider environmental benefits, and so these aspects were not consistently measured.

The following table shows the environmental benefits and associated savings (or costs) associated with the implemented environmental process improvement project. All of this information comes from the published case studies. As illustrated in the table, environmental process improvement projects have a wide range of reported results. Variances in accounting practices, as discussed later in this study, may account for some of this variation.

Case Study Project	**Environmental Benefit(s)**	**Savings**
Canyon Creek – Millennia Production Line	Reduced materials use	$110,000
Canyon Creek – Finishing Department	Reduced air emissions, reduced hazardous waste, reduced energy	$980,947*
Warner Robins AFB C130	Improved worker safety, reduced VOC emissions, reduced chemical use	$373,000
Baxter Healthcare	Reduced energy use resulting from reduced water use	$17,000
Harr-Conn Chrome	Reduced energy use, reduced water use	$51,962
Metalworks	Reduced energy use, reduced hazardous waste, reduced air emissions, reduced water use	$50,000
Sermatech Connecticutt	Reduced hazardous waste, reduced air emissions	$81,000
Lehigh Press Puerto Rico	Reduced waste	$47,000

* includes $624,000 labor costs

5. Conclusion

Conclusions and Implications

This study set out to identify the obstacles and opportunities that influenced organizations considering implementation of Lean process improvements with environmental benefits. The basic premise was that Lean, with its strong business linkages and immediate results, would be the mechanism by which sustainability could be introduced and embraced by business.

Although this research was limited in scope, it does confirm that Lean is widely used by businesses, and that Lean methods can also result in environmental improvements. What is also revealed, however, is that adding an environmental focus to Lean may not be sufficient to persuade organizations to fund environmental process improvements.

When organizations evaluate environmental process improvement projects, they weigh the potential return associated with each potential investment of capital. The results of this study reflect the importance placed on factors such as cost versus potential savings, either in the form of reduced expenses or improved productivity.

Regulatory compliance, and the inherent financial risks associated with non-compliance force organizations to invest in environmental improvements, at least at a minimal level. Additional environmental improvements, however, are often passed over for other business priorities that will provide a greater potential return on investment. Even with the offer of assistance from external sources, such as the Green Suppliers Network, companies are reluctant to spend time and resources on environmental improvements. Both the workshop and the broader survey indicated that respondents considered assistance by GSN or regulatory agencies to be the least influential factor in their decisions to implement environmental process improvements. This is especially interesting to note since workshop respondents had just attended a presentation on the benefits of Green Supplier Network assistance. It is clear that promoting environmental improvements through the regulatory framework is not sufficiently appealing to business to encourage investments in environmental improvements beyond basic compliance.

Probably the most significant conclusion that can be drawn from this study is that organizations may not be sufficiently aware of, or able to accurately measure, the true costs of their environmental choices. Traditional accounting methods focus on tracking and measuring direct costs, such as labor and materials. These methods are not as effective in measuring environmental costs.

Shawn Adams points out that ES&H staff must promote environmental projects using the ‘common language of business’, and suggests that ES&H practitioners will be more effective in furthering environmental goals by presenting them in terms of financial benefits, using financial terms. (Adams, 24)

However, even if ES&H staff can provide financial data to support environmental projects, these projects may still not be funded by the organization when the potential returns are compared to other investments. As discussed earlier, the Goodrich case study noted that cost savings associated with environmentally beneficial outcomes could not compete in significance with benefits associated with productivity and other traditional business improvements.

The survey responses also tend to support this view. As one survey respondent suggests, opportunity cost evaluations may be one of the reasons why more organizations do not implement environmental process improvements. Other survey respondent suggestions for encouraging organizations to implement environmental process improvements included promoting "more awareness relative to cost savings as a result of sustainable practices" and performing a "complete cost analysis for every aspect of the project".

It is interesting to note that while cost savings appears to be the primary motive for initiating environmental process improvements, published case studies often were not able to report (or did not capture or report) cost data -- many case studies stated that while environmental benefits were realized through the project, they were not the primary reason for doing the project and were not tracked before or after. ("LME", 62) This may be because most firms have not adopted environmental cost accounting or activity-based accounting practices that might better represent the true cost benefits associated with environmental improvements.

Recommendations for Further Research

Suggestions for Improvement

The study had a number of flaws and limitations which could be addressed in future similar studies. Some suggested improvements are listed below.

The case study portion of the broader survey questionnaire could be enhanced. First, the question regarding obstacles encountered during the project was posed as a closed ended question, which could be responded to by a simple yes or no. This resulted in some lost information on the types of obstacles encountered. Also, the case study section could have included a question on the cost savings (or loss) associated with the project. This would give more information on the accounting practices of the organization and whether or not environmental costs were tracked, in addition to a general picture of the dollar-values associated with implemented projects.

In the general portion of the broader survey questionnaire, the background information solicited in Question 1 and 2 could have been enhanced to include familiarity with environmental or activity-based accounting practices. The role that ISO played in an organization's decision to implement environmental process improvements also was not explored.

Identifying a sufficiently large target population for further study also presented a challenge in this study. Only about 10 percent of survey questionnaires were returned, which some say is a typical, but meager, return rate for a non-incentivized survey. Responses were generally received within a day or two of the initial email, and a reminder email gleaned a few additional responses, however it is assumed that the remaining subjects either chose not to participate, or more likely, the email simply got lost in the volume of daily mail. Sending out the survey Sunday evening resulted in the highest response rate, whereas an email sent on Thursday evening had minimal response. Future surveys of this type could include a timing consideration to optimize results.

The target population selected could have a bearing on what type of influencing factors that population considered most important. In this study, the broader survey population was selected from attendees of a recent Environmental, Health and Safety conference. Their responses indicated that external environmental factors were perceived as having the most influence on whether or not organizations implemented environmental process improvement projects. The published case studies, in contrast, indicated that in general, internal cost and productivity factors had the most influence on project decisions. This view may reflect the opinions of the organization's executive leaders, and their reasons for participating in the case study.

Opportunities for Additional Research

This study provides only a small glimpse into the business reasons why some environmental process improvement projects are implemented and others are not.

One of the opportunities for additional research that could build from the results of this study could be to explore in more depth the disparity between the factors considered to be most influential by the ES&H community, and those factors considered to be most influential by business leaders. This discontinuity may reflect the values of the two groups, and provide additional insight into why environmental process improvement projects are not undertaken.

Evaluating which Lean methods were most (or least) successful in obtaining environmental benefits could be an interesting offshoot of this study as well. For example, as noted in the case study findings, obstacles related to regulatory permitting are often encountered when converting production lines to cellular flow.

Other studies could include a more in-depth look at the obstacles and opportunities associated with implementing environmental cost accounting methods. If organizations do not have the appropriate tools to measure the costs and benefits associated with environmental decisions, they are not likely to be inclined to change.

Also, understanding the influencing factors associated with encouraging Lean and Six Sigma process improvement practitioners to incorporate environmental considerations into their projects could be another avenue of pursuit.

Bibliography

Adams, Shawn. “Financial Management Concepts”, Professional Safety. (August 2002)

Baxter International Inc., “Baxter Integrates ‘Lean and Clean’ into Environmental Program”, Baxter, <http://www.baxter.com/about_baxter/sustainability/sust_stories/environment/env_lean_clean.html> (accessed 17 Sep 2006)

Bennett, Martin and Peter James, ed. The Green Bottom Line: Environmental Accounting for Management: Current Practice and Future Trends, Sheffield, United Kingdom: Greenleaf Publishing Limited (2000)

Bonini, Sheila and Jed Emerson. “Maximizing Blended Value– Building Beyond the Blended Value Map to Sustainable Investing, Philanthropy and Organizations”, 2005, <http://www. www.blendedvalue.org/media/pdf-max-blendedvalue.pdf> (accessed 23 March 2007)

Castillo, Rachel and Ngai Chi Chung, “The Value of Sustainability”, Stanford University Center for Integrated Facility Engineering (2004)

Colorado State University Industrial Assessment Center (IAC), <http://www.engr.colostate.edu/IAC/>, Colorado State University (accessed 11 Oct 2006)

Day, Robert “Beyond Eco-Efficiency: Sustainability as a Driver for Innovation”, Sustainable Enterprise Perspectives. (March 1998)

Edwards, Harry W. and Jason M. Jonkman, “Pollution Prevention and Lean Manufacturing”, Colorado State University

Emerson, Jed, “The Blended Value Map: Tracking the Intersects and Opportunities of Economic, Social and Environmental Value Creation”, 2003, <http://www.BlendedValue.org> (accessed 20 Oct 2006)

EPA, “3M Lean Six Sigma and Sustainability Case Study”, EPA Case Studies and Best Practices webpage, <http://www.epa.gov/lean/studies/3m.htm> (accessed 4 Aug 2007)

EPA, “Apollo Hardwoods Case Study”, EPA Case Studies and Best Practices webpage, <http://www.epa.gov/lean/studies/apollo.htm> (accessed 10 Oct 2006)

EPA, “Baxter Healthcare Corporation Case Study”, EPA Case Studies and Best Practices webpage, <http://www.epa.gov/lean/studies/baxter.htm> (accessed 10 Oct 2006)

EPA, “Boeing Everett Case Study”, EPA Case Studies and Best Practices webpage, <http://www.epa.gov/lean/studies/everett.htm> (accessed 10 Oct 2006)

EPA, “Findings and Recommendations on Lean Production and Environmental Management Systems in the Shipbuilding and Ship Repair Sector”, EPA (2004)

EPA, “Goodrich Corporation Case Study”, EPA Case Studies and Best Practices webpage, <http://www.epa.gov/lean/studies/goodrich.htm> (accessed 10 Oct 2006)

EPA, “Green Suppliers Network”, EPA, <http://www.epa.gov/greensuppliers> (accessed 5 Oct 2006)

EPA, “Kaizen”, EPA Webpage, <http://www.epa.gov/lean/thinking/kaizen.htm> (accessed 5 Oct 06)

EPA, “Lean and the Environment Toolkit”, Kaizen Events <http://www.epa.gov/lean/thinking/kaizen.htm> (accessed 5 Oct 2006)

EPA, “Lean Benefits”, EPA Webpage, <http://www.epa.gov/lean/thinking/summary.htm> (accessed 5 Oct 2006)

EPA, “Lean Manufacturing and the Environment: Research on Advanced Manufacturing Systems and the Environment and Recommendations for Leveraging Better Environmental Performance ” (LME), EPA (2003)

EPA, “Lockheed Martin Case Study”, EPA Case Studies and Best Practices webpage, <http://www.epa.gov/lean/studies/lockheed.htm> (accessed 5 Oct 2006)

EPA, “Pursuing Perfection: Case Studies Examining Lean Manufacturing Strategies, Pollution Prevention, and Environmental Regulatory Management Implications”, EPA (2000)

EPA, “Rejuvenation Case Study”, EPA Case Studies and Best Practices webpage, <http://www.epa.gov/lean/studies/rejuvenation.htm> (accessed 4 Aug 2007)

EPA, “Robins U.S. Air Force Base Case Study”, EPA Case Studies and Best Practices webpage, <http://www.epa.gov/lean/studies/robins.htm> (accessed 11 Oct 06)

EPA, “Robins U.S. Air Force Base Point of Use Distribution of Hazardous Materials Case Study”, EPA Case Studies and Best Practices webpage, <http://www.epa.gov/lean/studies/robins3.htm> (accessed 11 Oct 06)

EPA, “Robins U.S. Air Force Base Waste Collection Process Case Study”, EPA Case Studies and Best Practices webpage, <http://www.epa.gov/lean/studies/robins2.htm> (accessed 11 Oct 06)

EPA, “Sustainability”, EPA Webpage, <http://www.epa.gov/sustainability/>, (accessed 8 Oct 2006)

Green Suppliers Network, “Case Studies” <http://www.greensuppliers.gov/gsn/page.gsn?id=case_studies> (accessed 11 Oct 2006)

Green Suppliers Network, “Green Suppliers Network”, Green Suppliers Network, <http://www.greensuppliers.gov/gsn/home.gsn> (accessed 5 Oct 2006)

Green Suppliers Network, “Results”, Green Suppliers Network, <http://www.greensuppliers.gov/gsn/page.gsn?id=program_results> (accessed 05-Aug-07)

Green Suppliers Network, “Success Story - H&L Advantage”, <http://www.greensuppliers.gov/gsn/page.gsn?id=hl_adv> (accessed 11 Oct 2006)

Green Suppliers Network, “Success Story - Har-Con Chrome Company”, <http://www.greensuppliers.gov/gsn/page.gsn?id=harconn> (accessed 11 Oct 2006)

Green Suppliers Network, “Success Story – Medegen Medical Manufacturing Services”, < http://www.greensuppliers.gov/gsn/page.gsn?id=medegen> (accessed 11 Oct 2006)

Green Suppliers Network, “Success Story – Sermatech”, <http://www.greensuppliers.gov/gsn/page.gsn?id=sermatech> (accessed 3 Aug 2007)

Green Suppliers Network, ”Success Story – Metalworks”, <http://www.greensuppliers.gov/gsn/page.gsn?id=metalworks> (accessed 3 Aug 2007)

Hirano, Hiroyuki, 5 Pillars of the Visual Workplace: The Sourcebook for 5S Implementation, (Portland, Oregon: Productivity Press, 1995)

Hirano, Hiroyuki, 5S for Operators: 5 Pillars of the Visual Workplace (for Your Organization), (Portland, Oregon: Productivity Press, 1996)

Leedy, Paul D., Practical Research: Planning and Design, New York: Macmillan Publishing Company (1993)

Mid-Atlantic Manufacturing Technology Center, "Benefits of Lean", MAMTC Webpage, <http://www.mamtc.com/lean/intro_benefits.asp> (accessed 21 Oct 2006)

Pil, Frits K and Sandra Rothenberg, "Environmental Performance as a Driver of Superior Quality", Production and Operations Management. (Fall 2003)

Pirimal, Gita, "The Father of Kaizen Speaks", The Smart Manager, <http://rediff.com/money/2005/jan/28spec2.htm> (accessed 21 Oct 2006)

Primex Puerto Rico Manufacturing Extension, "Success Story – Lehigh Press Puerto Rico", <http://www.primexpr.org/lehigh.html> (accesed 3 Aug 2007)

Rosenbeck, Joseph ,"Themes in EHS and Business Integration", Rochester Institute of Technology, Video Lecture Topic 2.

Rothenberg, Sandra, "Lean Manufacturing in Small- and Medium-Sized Printers", RIT Printing Industry Center (December 2004)

Rothenberg, Sandra, Frits K. Pil and James Maxwell, "Lean, Green, and the Quest for Superior Environmental Performance", Production and Operations Management (Fall 2001)

Russell, Christopher, "Motivating Business Leaders to Improve Profitability Through Energy Efficiency", Alliance to Save Energy, Executive Summary, http://www.ase.org/content/article/detail/940, (accessed 2 Oct 2006)

Smith, Joyce Cooper and Jeff McDaniel , "Enhancing Supply Chain. Performance with Environmental Cost Information: Examples from Commonwealth Edison, Anderson Corporation and Ashland Chemical", EPA (2000)

SustainAbility,"What is the Triple Bottom Line?", SustainAbility, http://www.sustainability.com/news-media/news-resource.asp?id=209, (accessed 20 Oct 2006)

Washington State Department of Ecology, "Lean & Environment Case Study: Canyon Creek Cabinet Company", EPA Case Studies and Best Practices webpage, <http://www.ecy.wa.gov/pubs/0604024.pdf>, (accessed 4 Aug 2007)

Womack, James P. and Daniel T. Jones, Lean Thinking: Banish Waste and Create Wealth in Your Corporation, (New York:Free Press, 2003)

Appendix A

CARE Green Printing Workshop – Thursday, April 26, 2007 – at RIT
Workshop Survey

Thank you for attending today's workshop and for helping us to assess its effectiveness.

1. Select all that apply:
☐ I work at a printing operation ☐ I consult with printing operations ☐ Other

2. I attended: ☐ Track 1: Green Printing ☐ Track 2: Energy Savings

3. Because of attending this workshop, my knowledge and understanding has increased on the topic of:

	Circle one:
... reducing air toxics*	No / A little / A lot
... preventing pollution	No / A little / A lot
... saving energy	No / A little / A lot
... implementing other green practices	No / A little / A lot
... current environmental regulations	No / A little / A lot
... environmental assistance available	No / A little / A lot
... how to increase profit by being green	No / A little / A lot

* Examples of air toxics: volatile organic compounds (VOCs), certain glycol ethers, toluene, perchloroethylene and methylene chloride, particulate matter, etc.

4. The most helpful things I learned today are:

5. Please answer this question if you work at or with a printing operation:
Because of attending this workshop, I am more likely to recommend or implement changes:

	Circle one:
... to reduce air toxics*	Yes / No / Already done
... preventing pollution	Yes / No / Already done
... saving energy	Yes / No / Already done
... implementing other green practices	Yes / No / Already done
... current environmental regulations	Yes / No / Already done
... environmental assistance available	Yes / No / Already done
... how to increase profit by being green	Yes / No / Already done

6. With or without this workshop, I am likely to recommend or implement these changes in 2007 through my company: Check all that apply:

☐ reduce air toxics* ☐ save energy ☐ Lean practices
☐ environmental planning/management ☐ reduce discharges to wastewater
☐ prevent pollution ☐ reduce materials used ☐ other green/sustainable practices
☐ other (please specify) _____
Example changes I am considering:

(over)

CARE Green Printing Workshop – Thursday, April 26, 2007 – at RIT
Workshop Survey, *continued...*

7. My main motivation for making "green" changes through my company is:

Data from questions 8 and 9 will be included in a research project for Jennifer Doman's Master's thesis. The project is titled: "Leveraging Lean Process Improvement to Achieve Economic and Environmental Sustainability in Industry." Thank you for your responses.

8. What has prevented your company from implementing environmental process improvements in the past?

☐ Unfamiliar with methods for environmental process improvement
☐ Cost factors associated with environmental process improvement
☐ Regulatory demands make implementing changes difficult
☐ Other business priorities take precedence
☐ Other (please specify) _____

9. What opportunities would encourage your organization to implement environmental process improvement?

☐ Competitive advantage / customer demand
☐ Reduced compliance costs
☐ Increased efficiency and/or reduced production costs
☐ Environmental, health and safety benefits
☐ Green Supplier Network assistance
☐ Other (please specify) _____

10. Other comments or ideas about the workshop:

11. Optional:
Name: _____ Organization: _____
Email: _____ Phone: _____

Thank you!

Appendix B

Survey on Environmental Process Improvement

Survey responses will be treated as confidential information and used solely for thesis research. All surveys will be destroyed at the end of the research period. The research report will not contain any identifying information about survey respondents or their organizations. Thank you for your participation!

1. What is your primary industry:
   SIC Code:
   Approximate number of employees at your location:
   Do you have an in-house ES&H staff?

2. Is your organization: (check all that apply)
_____ ISO 9000 certified _____ Pursuing ISO 9000 certification
_____ ISO 14000 certified _____ Pursuing ISO 14000 certification
_____ Familiar with Lean _____ Familiar with Six Sigma

3. Which influencing factors present the greatest obstacles to implementing an environmental process improvement project in your organization?
Please rank each from 1(most influence) to 5 (least influence)
_____Lack of experience with environmental process improvement methods
_____Cost or economic factors
_____Regulatory constraints (e.g. permitting, time delays)
_____Technological issues (e.g .suitable environmentally friendly products unavailable)
_____Risk or uncertainty associated with changes to product or process
_____Other business priorities take precedence over environmental improvements
_____Other (please specify)

4. What opportunities might influence your organization to consider implementing an environmental process improvement project?
Please rank each from 1 (most important) to 5 (least important)
_____Improved competitive advantage by having sustainable products/processes
_____Increased customer demand for environmentally friendly products/processes
_____Reduce production costs by reducing or eliminating excess materials or waste
_____Improved compliance or other environmental, health and safety benefits
_____Green Supplier Network or EPA assistance
_____Previous successful process improvement project
_____Other (please specify)

5. What suggestions do you have that would help to encourage organizations to implement environmental process improvement projects?

6. What do you think is the main reason why more organizations do not implement environmental process improvement projects?

7. Has your organization implemented any environmental process improvement projects (such as Lean and Green)?

If yes, **for each project** please provide the following:

Project #1:
1a. What was the name or primary focus of the project?

1b. What was the primary factor influencing your organization to do the project? (e.g. cost savings, productivity, environmental compliance, customer demand, etc)

1c. What was the primary process improvement method used for this project (e.g. Lean, Value Stream Mapping, 5S, etc)

1c. Were there any obstacles encountered during the project? (e.g. regulatory permits, technological difficulties, etc) Yes or No

If yes, what strategies were most effective in overcoming those obstacles?

1d. Was the project successfully completed?

If not, why not?

Project #2:
1a. What was the name or primary focus of the project?

1b. What was the primary factor influencing your organization to do the project? (e.g. cost savings, productivity, environmental compliance, customer demand, etc)

1c. What was the primary process improvement method used for this project (e.g. Lean, Value Stream Mapping, 5S, Kanban, etc)

1c. Were there any obstacles encountered during the project? (e.g. regulatory permits, technological difficulties, etc) Yes or No

If yes, what strategies were most effective in overcoming those obstacles?

1d. Was the project successfully completed?

If not, why not?
