The Environmental Professional's Guide to Lean & Six Sigma

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How to Use This Toolkit

This guide uses icons in the page margins to help you find and follow important information.

Key Point

Identifies an *important point* to remember

Key Term

Defines an *important term* or concept

New Tool

Presents a *technique* or *resource* that helps capture, communicate, or apply new knowledge

How-To Steps

Describes *sequenced actions*

Caution

Highlights a *potential problem* that could arise without close attention

This is one of a series of Lean and Environment publications from the U.S. Environmental Protection Agency. For more information, visit the EPA Lean and Environment website at www.epa.gov/lean.

Acknowledgments

The U.S. Environmental Protection Agency (EPA) is grateful for the valuable assistance of the individuals who helped develop this guide and shared experiences and techniques for integrating Lean, Six Sigma, and environmental improvement efforts. EPA's National Center for Environmental Innovation and Green Suppliers Network Program participated in the development of this guide.

This guide has benefited from the collective expertise and ideas of many individuals. In particular, EPA would like to thank the following individuals for their thoughtful contributions:

- Jenni Cawein, Corporate Environmental Health and Safety (EHS) Engineering Manager, Baxter International
- Chris D. Chapman, Senior Program Manager, Rochester Institute of Technology
- Michelle Gaither, Environmental Engineer, Pacific Northwest Pollution Prevention Resource Center
- Newton Green, Business Manager, New York State Pollution Prevention Institute
- Gretchen Hancock, Project Manager, General Electric
- Judy Kennedy, Environmental Engineer, Washington State Department of Ecology
- Scott Lakari, Vice President of Operations, Metalworks
- Kurt Middelkoop, Field Specialist, Texas Manufacturing Assistance Center
- Jeff Monaghan, Manufacturing Engineer and Lean Practitioner, Climax Portable Machine Tools, Inc.
- Hugh O'Neill, Lean and Environment Project Supervisor, Washington State Department of Ecology
- Joanna Pierce, Pollution Prevention Coordinator, Idaho Department of Environmental Quality
- Laura Rauwerda, Senior Environmental Analyst, Michigan Department of Environmental Quality
- Judy Wlodarczyk, Environment and Energy Director, CONNSTEP, Inc.

This guide was prepared for the U.S. Environmental Protection Agency by Ross & Associates Environmental Consulting, Ltd. (www.ross-assoc.com) in association with Industrial Economics, Inc. (EPA Contract # EP-W-04-023).

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Executive Summary

Lean and Six Sigma are two powerful business improvement systems that are rapidly being deployed across multiple manufacturing and service sectors. This *Environmental Professional's Guide to Lean and Six Sigma* is designed to introduce environmental professionals—including environmental health and safety managers, environmental agency personnel, and non-governmental environmental technical assistance providers—to these methods. The guide describes how Lean and Six Sigma relate to the environment and provides guidance on how environmental professionals can connect with Lean and Six Sigma activities to generate better environmental and operational results.

Lean and Six Sigma Definitions

Lean—historically referred to as Lean manufacturing—refers to the principles and methods of the Toyota Production System. Lean methods focus on the systematic identification and elimination of non-value added activity (called "waste"). Box ES-1 introduces Lean's "Deadly Wastes."

Lean "Deadly Wastes" (Box ES-1)

1. **Overproduction** (manufacturing items ahead of demand)
2. **Inventory** (excess material and information)
3. **Defects** (production of off-specification products)
4. **Transport** (excess transport of work-in-process or products)
5. **Motion** (human movements that are unnecessary or straining)
6. **Over-processing** (process steps that are not required)
7. **Waiting** (idle time and delays)

Six Sigma—developed by Motorola and popularized by General Electric—refers to a method and set of tools that utilize statistical analysis to measure and improve an organization's performance, practices, and systems with a prime goal of identifying and eliminating variation to improve quality.

Why Connect Lean, Six Sigma, and Environmental Efforts

Lean and Six Sigma both rely on a continuous improvement culture that is very conducive to pollution prevention and sustainability. Compelling reasons for linking Lean, Six Sigma, and environmental improvement efforts include:

- **Fast and Dramatic Results:** Lean produces compelling results quickly. Lean events typically last 2–5 days, during which teams dramatically reduce production lead times and costs, while improving product quality and customer responsiveness. Leveraging Lean efforts to include environmental issues can yield impressive environmental results as well.
- **Continual Improvement Culture:** Lean and Six Sigma tools engage employees throughout an organization in identifying and eliminating production wastes. When environmental wastes are included, Lean and Six Sigma become powerful vehicles for engaging employees in identifying and implementing environmental improvement opportunities.
- **Avoided Pitfalls:** Integrated "Lean and environment" efforts can minimize environmental impacts and navigate regulatory and permitting issues that may arise in operational changes from Lean and Six Sigma.
- **New Market for Environmental Improvement Ideas:** By connecting with Lean and Six Sigma practitioners, environmental professionals can connect the wealth of environmental resources with those who are driving strategic and fundamental operational changes.

How Lean and Six Sigma Relate to the Environment

On their own, Lean and Six Sigma efforts can result in significant environmental performance gains. However, since these approaches are not environmentally driven, they can miss opportunities to achieve even better environmental results. By adding environmental wastes to Lean's deadly wastes, organizations can harness the powerful drivers behind Lean and Six Sigma to make businesses more competitive while reducing environmental impacts and wastes (see Box ES-2).

While Lean and Six Sigma have many similarities with environmental initiatives, they also have important differences, including the following.

- **Similarities:** Lean, Six Sigma, and environmental improvement initiatives incorporate a philosophy of continual improvement, "waste" elimination, and employee engagement.
- **Differences:** The drivers for Lean and Six Sigma are fundamentally about competitiveness. Lean and Six Sigma practitioners also use different languages (including Japanese terms such as kaizen, kanban, and muda) and employ different tools (including value stream mapping, kaizen events, and 5S) than those used by environmental professionals.

Results from "Lean and Environment" Efforts (Box ES-2)

- ✓ **3M** reduced volatile air emissions by 61% and toxic inventory releases by 64% from 2000 to 2005 using Lean and Six Sigma techniques in coordination with pollution prevention.
- ✓ **Columbia Paint & Coatings** recovered 49,200 lbs per year of paint solids from wash water and reduced wastewater by 36,900 gallons per year based on a few Lean and environment events.
- ✓ **Woodfold Manufacturing** reduced volatile organic compound (VOC) emissions by nearly 1,000 lbs per year and diverted 6 tons per year of solid PVC waste from the landfill through opportunities identified in a value stream mapping event.

It is important for environmental professionals to understand how to talk to Lean and Six Sigma practitioners in a way that maximizes the likelihood of successful partnerships. Attempts to shift Lean and Six Sigma efforts away from their competitiveness drivers are likely to be less effective than efforts to integrate environmental considerations into the Lean and Six Sigma methodologies.

Integrating Lean and Environmental Improvement Efforts

There are a range of ways environmental professionals can improve results by leveraging Lean and Six Sigma efforts. "Lean and environment" approaches refer to strategies for integrating environmental considerations and tools into Lean and Six Sigma implementation. Examples of Lean and environment efforts include:

- **Connect Lean, Six Sigma, and Environmental Efforts at Facilities.** Environmental health and safety personnel can support operations-driven Lean and Six Sigma efforts, expanding their traditional scope, revealing hidden wastes, and improving environmental and operational results.
- **Deliver Lean and Environment Technical Assistance.** Environmental technical assistance providers can partner with Lean and Six Sigma service providers to jointly deliver Lean and environment services.
- **Use Lean to Enhance Environmental Programs and Processes.** Visual controls and other Lean concepts can improve the effectiveness of compliance-assistance efforts, and environmental agencies can use Lean to reduce waste in administrative processes such as permitting processes.

The ultimate goal of Lean and environment efforts is to seamlessly integrate environmental considerations into Lean and Six Sigma so that eliminating environmental wastes becomes just another part of doing Lean.

Getting Started with Lean and Environment

There's no single "right" way to do Lean and environment, and the best way to learn is to try it out. A few steps for getting started are as follows:

1. **Learn about Lean.** Learning about Lean and Six Sigma is a good first step for understanding how these efforts can advance environmental goals.

2. **Get Involved with Lean Efforts.** If you work at an organization using Lean or Six Sigma, set up time to meet with Lean managers at your organization and volunteer to participate in Lean events or trainings.

3. **Frame "Environment" in Lean Terms.** When advancing Lean and environment ideas, it's important to speak the language of Lean and Six Sigma and explain how including environmental considerations in Lean efforts will address core business needs and priorities.

4. **Bring a "Problem Solving" Orientation to Lean and Six Sigma Teams.** The bias of Lean toward rapid improvement may require environmental professionals to operate in different ways, focusing on identifying opportunities to reduce wastes in Lean events, thinking creatively about solutions to potential issues, and anticipating potential regulatory issues.

With the expansion of Lean and Six Sigma implementation, as well as the growing recognition of the importance of environmental issues, environmental professionals have an exciting opportunity to leverage Lean and Six Sigma to reduce wastes and significantly improve environmental outcomes.

CHAPTER 1
Why Lean and Six Sigma Are Important to the Environment

Over the past few years, many environmental professionals have watched the rapid expansion of Lean and Six Sigma activities sweeping across diverse commercial and manufacturing sectors. A growing number of environmental professionals see an exciting opportunity to leverage this trend to achieve better environmental results more quickly.

This chapter discusses this trend and explores why environmental professionals might want to learn more about and connect with Lean and Six Sigma initiatives. The chapter explores how connecting Lean and Six Sigma process improvement efforts with environmental initiatives can advance both efforts, delivering environmental and sustainability results faster. The challenge, and opportunity, for environmental professionals is to productively engage with Lean and Six Sigma practitioners—meeting them where they are; to translate environmental opportunities and concepts into the Lean and Six Sigma lexicon; and to make environmental improvement a seamless, integrated aspect of delivering value to meet customers' needs.

Lean & Environment Business Case (Box 1.1)

- ✓ Fast and Dramatic Results
- ✓ Employee-Engaged Culture
- ✓ Avoided Lean Pitfalls
- ✓ New Market for Environmental Improvement Ideas

Much Progress but More Opportunity

Dramatic progress has been made during the past twenty years in commercial and industrial sector environmental management. Focus on end-of-pipe clean-up and regulatory compliance has expanded to preventing pollution at its source and considering broader environmental sustainability objectives in organizational decisions. Environmental professionals have enabled this transition. The results attributed to environmental management, pollution prevention (P2), and environmental sustainability initiatives are impressive. Advances in four key areas are helping organizations across diverse sectors realize compelling environmental and economic results:

- **Environmental tools and expertise** help businesses and other organizations minimize waste, prevent pollution, and move towards more environmentally sustainable processes and products.
- **Environmental management systems** (EMS) institutionalize environmental management activities and foster continual improvement.

- The **business case for environmental activities** influences an increasing number of business decisions, as case studies and analysis demonstrate the benefits proactive environmental management can have on bottom line performance.
- Businesses are increasingly experimenting with **"paths to sustainability"** incorporating corporate social responsibility and "triple bottom line" thinking into the core fabric of business strategy and operations.

Despite the progress, there is still significant opportunity to improve environmental performance—further reducing the environmental footprint of production processes, products and services.

If environmental initiatives pay, why don't they compete as well as we would expect?

- ✓ Lack of awareness of environmental opportunities and tools only tells part of the story.
- ✓ Internal competition for capital and management attention may be a more powerful barrier.

Given the numerous environmental and economic benefits of environmental initiatives—such as EMS, pollution prevention, design for environment, and other environmental and sustainability initiatives—one might expect that it would be easy to get companies to implement more environmental efforts. Typically, however, these initiatives have a difficult time competing in the corporate culture.

One misconception that environmental professionals sometimes have is that if more people knew about the benefits of environmental opportunities, organizations would do more. An obvious implication of this argument is to invest in more information diffusion and technical assistance. If we could only get the wealth of environmental management tools that exist into the right hands, more would be done. While this thinking is clearly important, there is reason to suspect there is more to the story.

A well known and documented study of pollution prevention activities at Dow's Midland, Michigan chemical manufacturing plant found that the most common barrier to environmental and P2 project implementation is the internal competition for capital and management time and attention. A positive return on investment is not always sufficient—capital projects must clear internal hurdles that weigh the value of each alternative when using limited capital. Even small projects that require limited or no capital investment must compete for limited organizational time and attention. As a result, many promising ideas—environmental and other—end up on the cutting room floor because they are not viewed as central to business success.

This challenge has spurred many environmental professionals to seek creative ways to attract attention and organizational investment for environmental improvement opportunities. It is in this context that Lean manufacturing and Six Sigma have emerged as powerful vehicles for delivering

environmental results. While it is not necessarily easy, initial results from leveraging Lean and Six Sigma business improvement methods to advance environmental goals are promising. Box 1.2 provides examples of how companies have obtained environmental results and saved costs by integrating environmental considerations into Lean projects.

Results from Lean and Environment Efforts (Box 1.2)

- ✓ **Baxter Healthcare:** A Baxter Healthcare facility in the U.S. Southeast conducted a three-day value stream mapping event focused on water use, and developed an action plan to save 170,000 gallons of water per day and $17,000 within 3 months, with little or no capital investment. With this project, the facility no longer needed to expand its wastewater treatment plant.
- ✓ **Canyon Creek Cabinet Company:** Through a combination of value stream mapping and weeklong kaizen events, Canyon Creek saved almost $1.2 million per year, reduced volatile organic compound (VOC) emissions by 55,100 lbs per year, and decreased hazardous wastes by 84,400 lbs per year.
- ✓ **General Electric:** GE conducted over 200 energy "treasure hunts"—a Lean strategy of identifying wastes—at facilities worldwide in 2005–07. This effort cut greenhouse gas emissions by 250,000 metric tons and saved $70 million in energy costs.

Leveraging Operational Process Improvement Efforts


Key Term

Lean manufacturing refers to a collection of business improvement principles and methods—originally developed by Toyota—that focus on the systematic identification and elimination of non-value added activity or "waste" involved in producing a product or delivering a service to customers. *Six Sigma*—developed by Motorola and popularized by General Electric—refers to a method and set of quantitatively rigorous tools that utilize information and statistical analysis to measure and improve an organization's performance, practices, and systems, with a primary goal of identifying and eliminating sources of variation. Lean and Six Sigma both incorporate a continuous improvement culture that is conducive to waste minimization and pollution prevention. Some companies place more emphasis on Lean, while others emphasize Six Sigma as an organizing framework. Increasingly, organizations merge the methods as "Lean Six Sigma."


Key Term

Lean and Six Sigma process improvement methodologies work well together. Lean's focus on eliminating waste and improving speed of processes is complemented with Six Sigma's focus on eliminating variation and improving product quality. Box 1.3 provides a comparison of Lean and Six Sigma.

Characteristics of Lean and Six Sigma (Box 1.3)

Lean	Six Sigma
✓ Focuses on maximizing product flow and velocity	✓ Emphasizes the need to recognize opportunities and eliminate defects
✓ Provides tools for analyzing process flow and delays at each process step	✓ Recognizes that variation hinders the ability to reliably deliver high-quality services
✓ Centers on the separation of "value-added" from "non-value added" work with tools to eliminate root causes of non-value added activities	✓ Requires data-driven decisions and incorporates a comprehensive set of quality tools under a systematic framework for problem solving
✓ Provides a means for quantifying and eliminating the cost of complexity	✓ Provides a highly prescriptive cultural infrastructure effective in obtaining sustainable results

Source: Michael George, *Lean Six Sigma for Service: How to Use Lean Speed & Six Sigma Quality to Improve Services and Transactions*, (New York: McGraw Hill, 2003).


Key Point

Lean and Six Sigma have legs. Businesses, organizations, and government agencies are aggressively expanding the use of Lean and Six Sigma as core strategies for addressing competitive market pressures affecting cost, quality, and customer demands. Lean is driving change in numerous commercial and industrial sectors, ranging from automotive, aerospace, and metal finishing to health care, construction, and wood products. Lean's bias towards action and rapid improvement creates staying power which helps Lean avoid a reputation as a flavor of the month. Even while commitment to Lean and Six Sigma varies significantly across organizations, many view implementation as a long-term journey that will require sustained leadership and organizational commitment.


Key Point

Lean and Six Sigma can effectively complement environmental initiatives. Environmental professionals have long contended that to make sustained environmental improvement that moves beyond "low-hanging fruit," an organization must create a continual improvement-focused waste elimination culture. Common elements of this organizational culture, as identified in many environmental initiatives, include:

- A systematic approach to *continual improvement*
- A systematic and on-going effort to identify, evaluate, and *eliminate waste* and environmental impacts that is *embraced and implemented by operations personnel*
- Environmental *metrics* that provide performance feedback
- Engagement with the *supply chain* to improve enterprise-wide performance

Lean and Six Sigma seek to create a very similar, and highly complementary, organizational culture focused on continual improvement. In doing so, they use tools that are similar to many used by environmental professionals, such as visual mapping of processes and root cause analysis.


Key Point

By connecting environmental initiatives with Lean and Six Sigma deployment efforts, environmental professionals can help environmental improvement ideas compete more effectively and embed them in culture-changing process improvement practices. *When the plant floor is being reconfigured and operations are being changed through Lean Six Sigma, the marginal cost of incorporating environmental improvement ideas is low*. Box 1.4 lists some labels that have been used to describe efforts that integrate environmental considerations into Lean and Six Sigma activities.

Many Names for Lean and Environment (Box 1.4)

Efforts to integrate environmental considerations into Lean and Six Sigma have sometimes used labels such as "Lean and Clean," "Lean and Green," "Lean and Sustainability," "Lean Ecology," or "Green Six Sigma."

These terms can be useful in drawing attention to efforts to integrate the parallel universes of Lean and environment. At the same time, these terms can imply that environmental considerations are an add-on, something distinct and separate from Lean and Six Sigma, deterring full integration.

The considerations involved in choosing whether to explicitly label an initiative "green" are discussed further in Chapter 5.

The key is to get environmental improvement ideas and knowledge into the hands of Lean teams at the point where operational change decisions are being made. Environmental improvement ideas do not need to compete independently; they can ride the coattails of Lean and Six Sigma implementation, Box 1.5 talks about one company's experience. Real world experience demonstrates that this "Lean and environment" collaboration benefits both operational and environmental outcomes.

Learning How to See Environmental Waste at TRUMPF, Inc. (Box 1.5)

TRUMPF, Inc., located in Connecticut, is the leading manufacturer of sheet metal fabricating machinery in the United States. TRUMPF had been using Lean methods for many years, but with the global recession, it decided to look beyond the traditional Lean wastes for cost reduction opportunities that might be hidden in environmental wastes.

After hearing a presentation by CONNSTEP, Connecticut's Manufacturing Resource Center (a NIST MEP affiliate), on opportunities for savings in materials, energy, water, and utility consumption, TRUMPF hired CONNSTEP to conduct a 3-day project that included a half-day training on how to identify environmental waste opportunities within the company's existing Lean initiatives.

This project focused on reducing paper usage, white paper recycling, and trash haulage. The improvement areas identified by the TRUMPF team will save the company approximately $46,000. This project helped to increase "green" awareness at TRUMPF. The company has established a goal to reduce office supplies in the future by 50%. Specific environmental and cost savings include:

- Reduced black plastic bin liner usage from 600 daily to 90, saving $6,500
- Decreased trash hauling charges by $8,000 per year through the reduction of visits to compactors and dumpsters which were only partially full
- Recycling of job traveler plastic sleeves, saving $4,000 per year


Key Point

Lean and Six Sigma are not replacements for environmental management approaches and tools, but powerful delivery mechanisms. As organizational improvement tools, they have the potential to connect environmental management concepts with a rapid implementation setting where critical business decisions are being made. Lean and Six Sigma do not focus on process improvement alone. In addition to process improvement, Lean and Six Sigma can be applied to product design by using methods such as Production Preparation Process (3P) and Design for Lean Six Sigma. The challenge, and opportunity, is to harness the collection of Lean and Six Sigma methods to drive environmental improvement and sustainability ideas deep into core business strategy and operations. Lean and Six Sigma are means, while zero waste and sustainability are goals. These goals fit well with Lean's focus on identifying and eliminating non-value added activity.

The Lean and Environment Business Case

For environmental professionals, the fundamental value of integrating Lean and environment efforts is to get more environmental results faster. Four compelling reasons support the business case for Lean and environment.

- **Fast and Dramatic Results:** Lean produces change and results fast. Kaizen rapid improvement events identify waste and implement solutions in less than a week. When environmental issues are integrated into Lean activities, companies have seen quick and compelling environmental results. Without proper attention, however, Lean's focus on immediate implementation can sometimes conflict with permitting requirements for environmentally sensitive processes (see Chapter 4 for more information). This is an important reason for environmental professionals to be involved.

- **Continual Improvement Culture:** Lean and Six Sigma tools—such as value stream mapping (VSM), kaizen events, 5S, standard work, visual controls, and total productive maintenance—engage personnel throughout an organization in identifying and eliminating Lean wastes. Leveraging these tools can make environmental professionals' jobs easier, reinforcing roles and responsibilities and breathing life into EMS implementation. The more eyes and ears there are seeing environmental wastes and improvement opportunities, the more progress can be made.

- **Avoided Lean Pitfalls:** While Lean and Six Sigma (without intervention by environmental professionals) can produce powerful environmental improvement results on its coattails, the rapid changes can also create environmental and regulatory compliance headaches. Lean and environment integration can help ensure adverse environmental impacts are avoided and navigate regulatory and permitting issues that may arise during Lean and Six Sigma driven changes.

- **New Market for Environmental Improvement Ideas:** Lean and Six Sigma practitioners are an important new audience for environmental improvement ideas and tools. By connecting with Lean and Six Sigma practitioners, environmental professionals can connect the wealth of environmental improvement ideas and tools with those who are driving strategic and operational change within many organizations.

The challenge, and opportunity, for environmental professionals is to figure out how to connect with Lean Six Sigma improvement efforts in a seamless way that embeds environmental considerations and sustainability concepts into the normal way of doing business. This guide is designed to assist

environmental professionals in meeting Lean and Six Sigma practitioners where they are; help them translate environmental concepts into the Lean lexicon; and make environmental improvement efforts a seamless, integrated aspect of delivering waste-free value to meet customers' needs.

The next two chapters provide more thorough descriptions of Lean and Six Sigma and subsequent chapters will describe the relationship between Lean, Six Sigma, and environmental initiatives.

CHAPTER 2
What Is Lean?

This chapter describes Lean manufacturing principles and methods. The sections in this chapter include:

- What is Lean Manufacturing?
- Creating a Lean Culture
- History of Lean Activity
- Lean Tools
- Where to Find More Information on Lean

What is Lean Manufacturing?


Key Term

The term "Lean," coined by James Womack, et al. in the 1990 book, *The Machine that Changed the World* describes the manufacturing paradigm established by Toyota. *Lean manufacturing* or *Lean production* refers to a collection of principles and methods that focus on the identification and elimination of non-value added activity (waste) involved in producing a product or delivering a service to customers. In the Lean context, waste is any activity that does not lead directly to creating the product or service a customer wants when they want it.

Seven "Deadly" Wastes (Box 2.1)

1. **Overproduction** (manufacturing items ahead of demand)
2. **Inventory** (excess material and information)
3. **Defects** (production of off-specification products)
4. **Transport** (excess transport of work-in-process or products)
5. **Motion** (human movements that are unnecessary or straining)
6. **Over-processing** (process steps that are not required)
7. **Waiting** (idle time and delays)

Box 2.1 lists seven "deadly" wastes that Lean commonly targets. With the rise of environmental and social consciousness, some companies are expanding the definition of Lean (see Box 2.2).

Expanding the Definition of Lean (Box 2.2)

Some companies have expanded the definition of Lean to incorporate concepts of environmental, economic, and social sustainability.

New Lean Definition:

"Develop the highest quality products, at the lowest cost, with the shortest lead time by systematically and continuously eliminating waste, ***while respecting people and the environment.***"

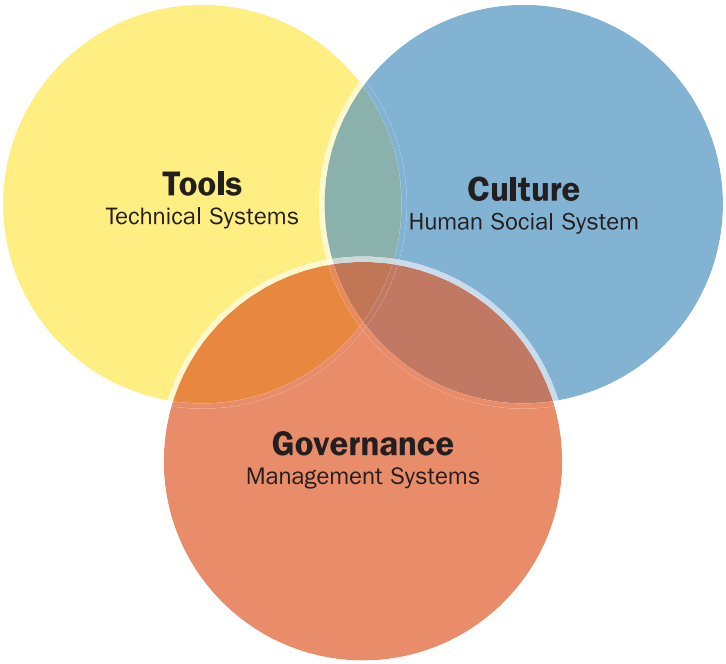
Creating a Lean Culture

Lean manufacturing embodies several important principles as well as a collection of tactical methods for achieving them. These principles and methods effectively engage employees in a continuous improvement culture that naturally encourages waste minimization and pollution prevention. Key Lean principles include:

- *Let customers pull* value through the enterprise by understanding what the customer wants and producing to meet real demand.
- *Pursue perfection* by working to continually identify and *eliminate non-value added activity* (waste) from all processes.
- *Involve employees* in continual improvement and problem-solving activities.
- Implement a *rapid plan-do-check-act* improvement framework to achieve results fast and to build momentum (e.g., "try-storming" in kaizen events).
- Use *metrics and rapid performance feedback* to improve real-time decision-making and problem-solving.
- Approach improvement activities from a *whole enterprise or system perspective*.
- *Emphasize learning at an organizational level* through sharing of best practices from one project to another. In Japanese, this is called yokoten.

Lean can be considered a combination of management system (governance), organizational culture, and continual improvement tools (see Figure 2.1).

Figure 2.1: Model of a Lean Learning Organization



Source: This "Model of a Lean Learning Organization" is a variation of the "Basic Lean Model" used by the Texas Manufacturing Assistance Center.

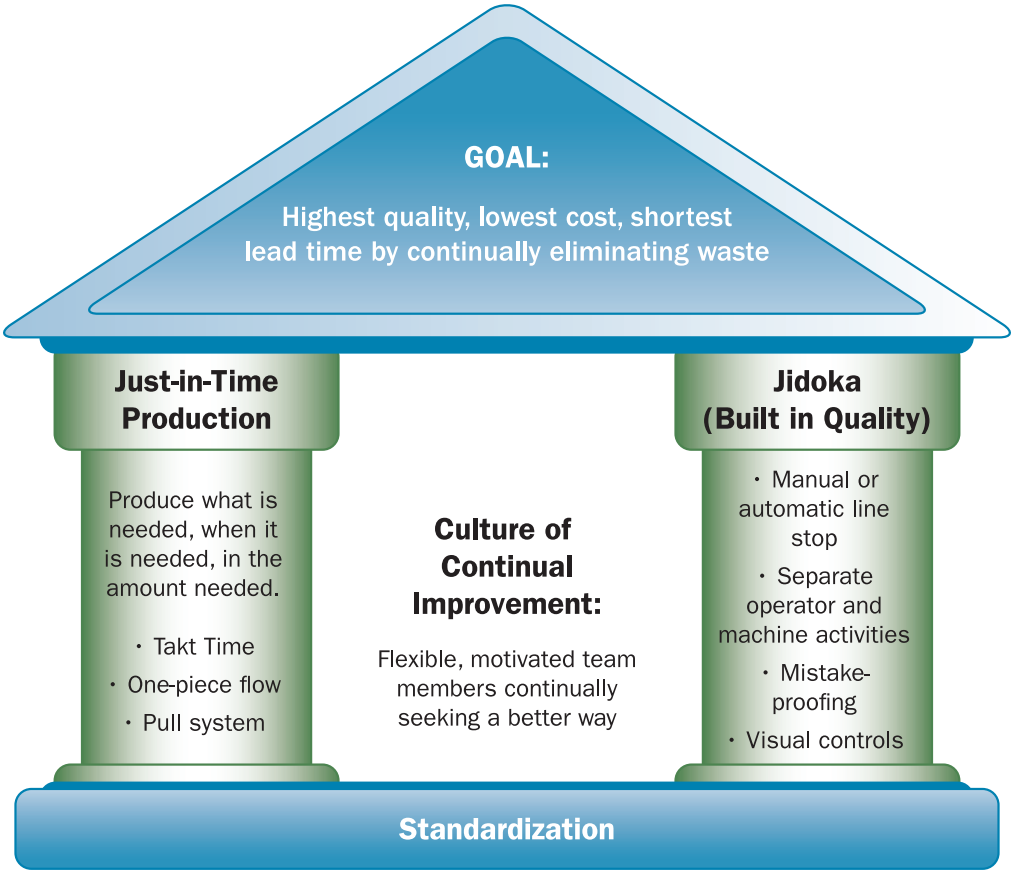
History of Lean Activity

After World War II, the Toyota Motor Company, with the help of Japanese engineers Taiichi Ohno and Shigeo Shingo, pioneered a collection of advanced manufacturing methods that aimed to minimize the resources it takes for a single product to flow through the entire production process. Inspired by concepts developed by Henry Ford in the early 1900s, Toyota created an organizational culture focused on the systematic identification and elimination of all waste from the production process, called the Toyota Production System (TPS).

The TPS "house" (Figure 2.2) has become a common symbol of Lean. The roof represents the customer-oriented goal of Lean: to provide the highest quality products and services, at the lowest cost, with the shortest lead time. At the core of the "house" is the involvement of all employees in a culture of continual improvement. The pillars are just-in-time production and jidoka (built in quality), while the foundation is standardization. The individual tools and terms listed in the TPS house are defined below and in Appendix C.

Toyota's success has led thousands of other companies across numerous industry sectors to tailor these advanced production methods to address their operations.

Figure 2.2: Toyota Production System House



Source: Adapted from multiple sources, including Dennis Pascal, *Lean Production Simplified*, Productivity Press, 2002 and TBM Consulting Group, "House of Toyota," available at www.tbmcg.com/about/ourroots/house_toyota.php.

Status of Lean Activity in the United States

In the U.S., Lean implementation began in the 1980s in the automotive and aerospace sectors. Today, numerous companies of all sizes and across multiple sectors are implementing Lean production. *According to the 2007* IndustryWeek/Manufacturing Process Improvement Census of Manufacturers*, nearly 70 percent of all U.S. plants have adopted Lean manufacturing as an improvement methodology*.[1]

Key Point

[1] Blanchard, David. "Census of U.S. Manufacturers–Lean Green and Low Cost," *IndustryWeek* (October 2007).

U.S. Sectors Implementing Lean

Examples of U.S. manufacturing sectors where there is significant Lean activity include the following. (Implementation of Lean is not limited to these industries, however.)

- Aerospace
- Appliances
- Automotive
- Banking
- Construction
- Electronics
- Furniture
- Government
- Medical devices
- Shipbuilding & Repair

Although it originated in manufacturing, Lean production has been rapidly expanding to service industries, including healthcare, banking, insurance, and even government agencies. Over the past five years, about 20 state environmental agencies have used Lean methods to improve permitting and other agency processes.[2]

Lean Tools

There are a variety of common methods in the Lean toolbox, many of which are defined in Table 2.1 and displayed in the "Lean Tactical Tools" diagram in Figure 2.3. Each of these tactical methods has clearly defined process steps, techniques, and desired outcomes. Most Lean tools are implemented in short bursts of activity that include focused and intensive planning and implementation phases. In this context, there is a strong bias toward implementation, as opposed to prolonged planning. This fits within the continual improvement philosophy that emphasizes making changes to address problems and eliminate waste, tracking performance, and making additional changes to further increase performance.

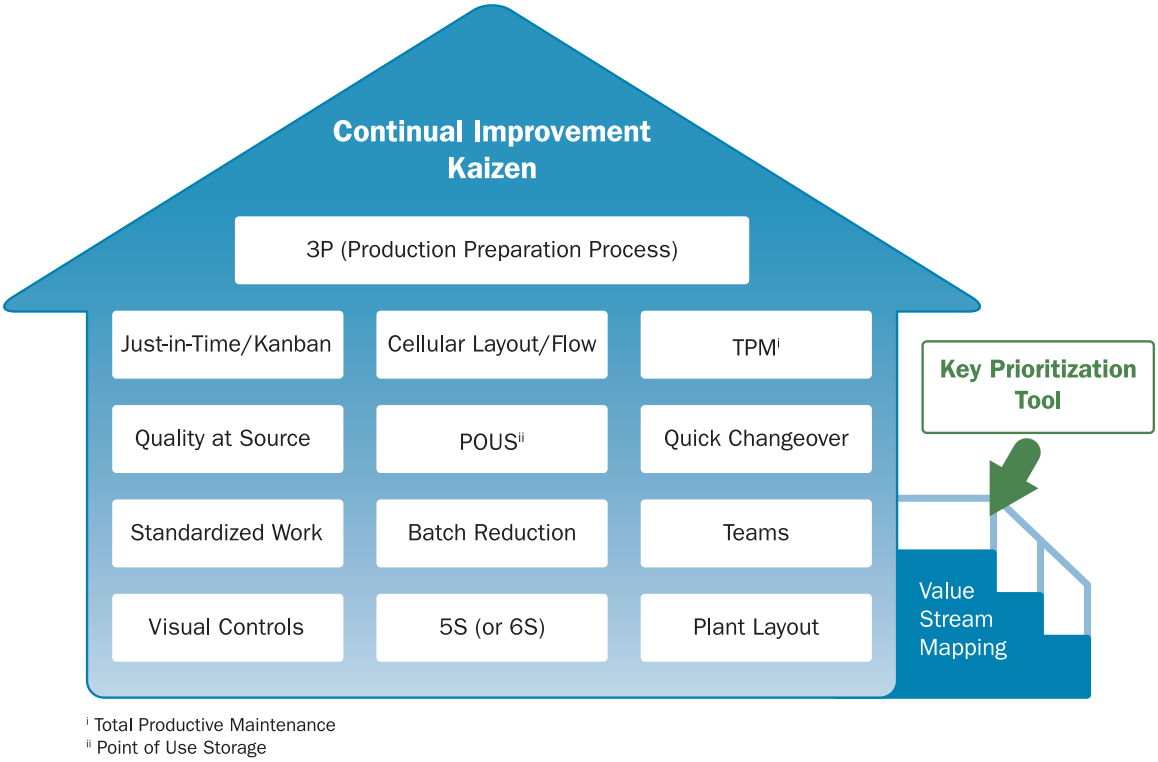
[2] For more information on federal and state agency Lean efforts, see EPA's Lean Government website, www.epa.gov/lean/leangovernment.htm.

Table 2.1: Selected Lean Tools	
Tool	**Description**
5S (or 6S)	5S is a systematic, five-step process for developing and maintaining a clean and orderly workspace. 6S refers to 5S plus safety considerations.
Cellular Manufacturing	An approach in where manufacturing work centers (cells) have the total capabilities needed to produce an item or group of similar items; contrasts to setting up work centers on the basis of similar equipment or capabilities, in which case items must move among multiple work centers before they are completed.
Just-in-Time Production	Just in time is a production scheduling concept that calls for any item needed at a production operation—whether raw material, finished product, or anything in between—to be produced and available precisely when needed.
Kaizen	The kaizen philosophy implies that small, incremental changes routinely applied and sustained over a long period result in significant improvements. Lean is typically implemented through kaizen events, which are 2-5 day rapid process improvement events.
Kanban	Kanban (signals) are used to control levels of inventory and work in process.
Point of Use Storage	In point of use storage, raw material in right-sized quantities is stored at the workstation where it is used.
Production Preparation Process (3P)	3P is the Lean method for process and/or product design. 3P designs and implements production processes, tools, and equipment that support one-piece flow, are designed for ease of manufacturing, and achieve appropriate cost, quality, and lead time. Also known as Pre-Production Planning.
Standard Work	Standard work represents the sequence of activities needed to perform a given operation. Improvements made during kaizen events are immediately documented as standard work to ensure that all employees understand and consistently implement the new process.

Table 2.1: Selected Lean Tools	
Tool	**Description**
Total Productive Maintenance (TPM)	TPM is an approach to enlist operators in the design, selection, correction, and maintenance of equipment to ensure that every machine or process is always able to perform its required tasks without interrupting or slowing down defect free production.
Value Stream Mapping	A process mapping method used to document the current and future states of the information and material flows in a value stream from customer to supplier.
Visual Controls	Visual controls are used to reinforce standardized procedures and to display the status of an activity so every employee can see it and take appropriate action. Visual controls are frequently implemented during kaizen events to simplify the workplace and provide visual feedback on process performance.
Lean Enterprise Supplier Networks	A set of buyer-supplier relationships where organizations apply Lean concepts across the supply chain to reduce costs, delays, and other wastes.

For a longer list of Lean manufacturing terms and definitions, see Appendix C.

Figure 2.3: Lean Tactical Tools



[i] Total Productive Maintenance
[ii] Point of Use Storage

Source: This diagram is a variation of the "Lean Building Blocks" diagram used by the National Institute of Standards and Technology Manufacturing Extension Partnership.

Because of their importance to understanding Lean, three methods—VSM, kaizen events, and 5S—are described in more detail below.

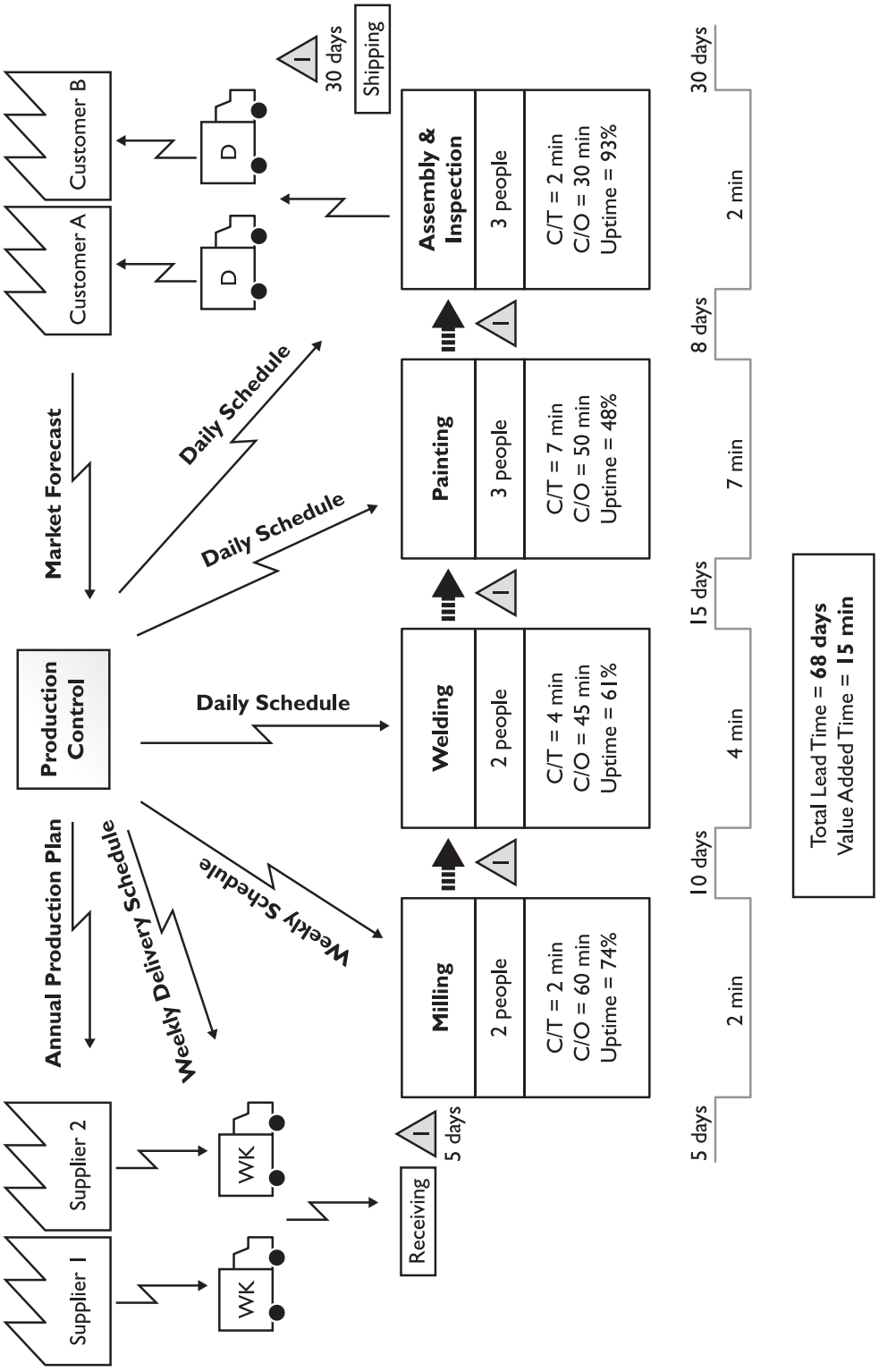
Value Stream Mapping

Key Term

Value stream mapping (VSM) refers to the process of developing a high-level visual representation of the activities involved in delivering a product or service (a "value stream") to customers (see example in Figure 2.4). Value stream mapping is shown as the "staircase" in the house of Lean toolbox above because Lean practitioners use value stream mapping to prioritize and select Lean implementation projects. Lean practitioners use value stream mapping to:

- Identify major sources of non-value added time in a value stream
- Envision a less wasteful future state
- Develop an implementation plan for future Lean activities

Figure 2.4: Value Stream Map



The typical results of a 2 to 5 day value stream mapping event are two maps—a "current state" map of the targeted process (see Figure 2.5) and a "future state" map of the desired process flow (i.e., what you want the process to look like). An implementation plan for how you are going to get from the current state to the future state is also developed. Because value stream maps help highlight the sources of waste, they enable an organization to target future kaizen improvement events on specific processes or process steps in the value stream to help move toward the desired "future state" value stream map. *Value stream mapping is the most foundational tool in the Lean toolset*. As the map is developed, the team as a whole is able to recognize and validate what is actually happening in a process.

Key Point

Figure 2.5: Current State Map

The power of value stream mapping lies in walking the plant floor, talking to workers, and closely observing how a product is actually made from start to finish. This is an excellent way to identify waste and non-value added activity in the value stream, including excess work in process, which can represent the majority of lead time.

Key Point

Kaizen Events

Lean production is founded on the idea of kaizen, or continual improvement. Kaizen is a combination of two Japanese words that mean "to take apart" and "to make good." The kaizen philosophy implies that small, incremental changes routinely applied and sustained over a long period result in significant improvements. Lean is typically implemented through kaizen events, which are 2-5 day rapid process improvement events. Kaizen events are a key method used to foster a culture of continual improvement and waste elimination and are often used to implement other Lean methods. Box 2.3 provides an overview of kaizen event. Preparation of a value stream map is an important component of kaizen pre-event planning.

Kaizen Event Overview (Box 2.3)

Day 1: Training	**Day 2:** Discovery	**Day 3:** Do	**Day 4:** Do, Re-Do, Document	**Day 5:** Celebrate Results
Lean training; begin mapping and measuring current work process	Measure and analyze current work process	Create and map new process	Evaluate improvements, operate using new process, finalize	Present results and celebrate

The kaizen strategy aims to involve workers from multiple functions and levels in the organization in working together to address a problem or improve a particular process. The team uses analytical techniques, such as process maps, to quickly identify opportunities to eliminate waste in a targeted process. The team works to rapidly implement chosen improvements (often within 72 hours of initiating the kaizen event), typically focusing on solutions that do not involve large capital outlays. Periodic follow-up events aim to ensure that the improvements from the kaizen "blitz" are sustained.

5S

5S is a systematic, five-step process for developing and maintaining a clean and orderly workspace. 5S derives from the belief that, in the daily work of a company, routines that maintain organization and orderliness are essential to a smooth and efficient flow of activities. The 5S pillars help create a productive work environment and create the foundation for implementing more advanced Lean methods such as cellular manufacturing and just-in-time production.

The 5S's are:

- *Sort (Get rid of it):* Separate what is needed in the work area from what is not; eliminate the latter.
- *Set in order (Organize):* Organize what remains in the work area.
- *Shine (Clean and solve):* Clean and inspect the work area.
- *Standardize (Make consistent):* Standardize cleaning, inspection, and safety practices.
- *Sustain (Keep it up):* Make 5S a way of life.

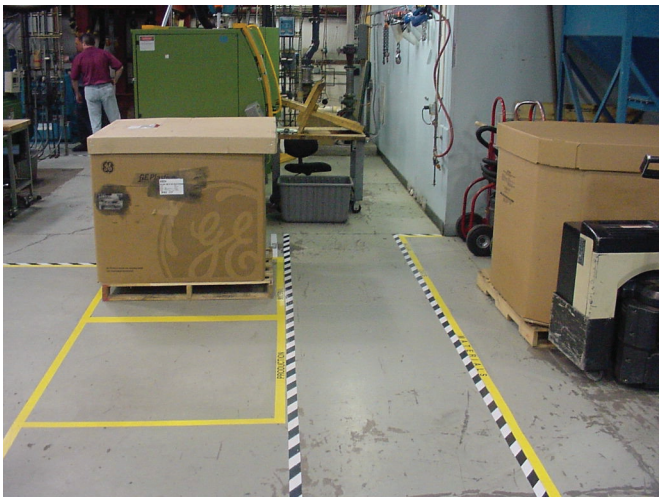
Implementation of this method "cleans up" and organizes the workplace, and it is typically the starting point for shop-floor transformation. A typical 5S project would result in significant reductions in the square footage of space needed for existing operations. It also would result in the organization of tools and materials into labeled and color coded storage locations, as well as "kits" that contain just what is needed to perform a task. Sometimes companies add a 6th "S" for safety (see Figure 2.6). Figures 2.7 and 2.8 are before and after 5S photos.

Figure 2.6: 5S + Safety Diagram

Source: Adapted from Productivity Press Development Team, *5S for Operators: 5 Pillars of the Visual Workplace*, (Productivity Press 1996).

Figure 2.7: Photo Taken Before 5S

Figure 2.8: Photo Taken After 5S



How Lean Factories Differ from Traditional Manufacturing Environments

Traditional U.S. manufacturing facility layouts are set up in what is called a "batch and queue" production systems (see Figure 2.9). Batch and queue production entails the use of large machines, large production volumes, and long production runs. Each department is designed for one specific purpose and completed products cannot move on to the next functional department until the entire "batch" has been processed. In contrast, cellular manufacturing is a workplace-design approach in which manufacturing work centers (or cells) have the total capabilities needed to produce an item or group of similar items. Figure 2.10 displays the product-aligned, one-piece flow, "pull" production system that cellular manufacturing systems are based on.

Figure 2.9: Example Plant Layout for Traditional "Batch and Queue" Production

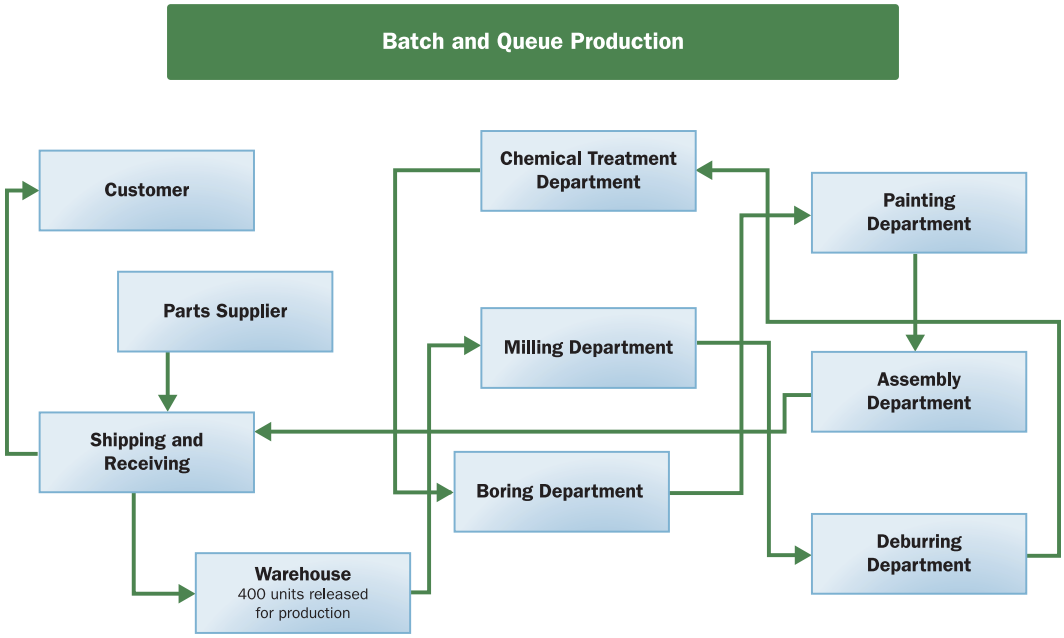
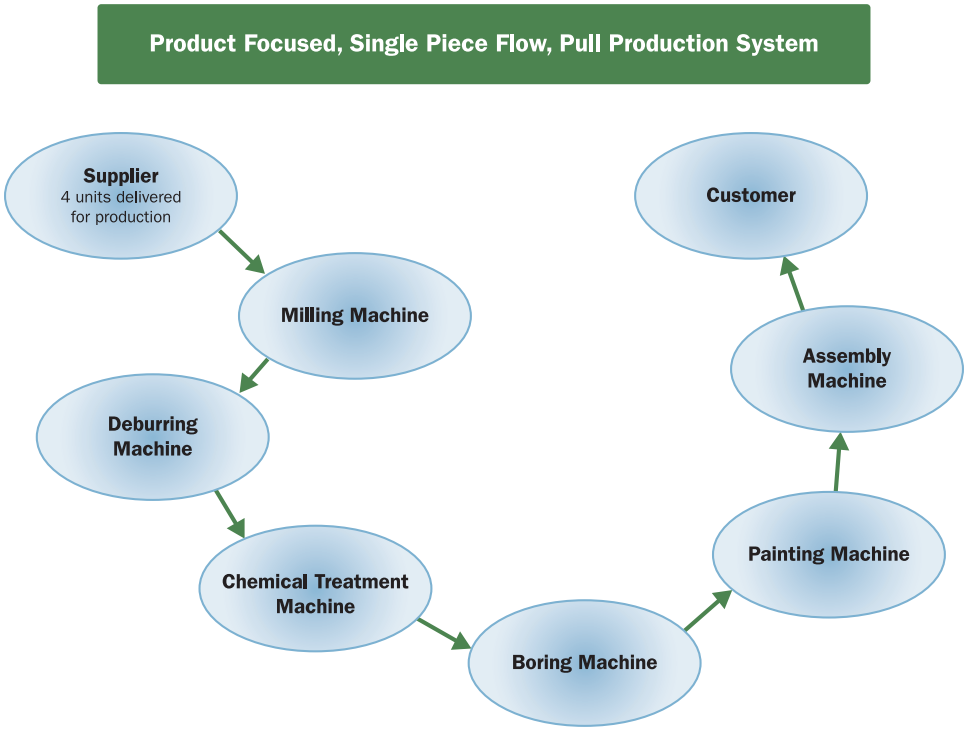


Figure 2.10: Example Structure of a Lean Manufacturing Cell for a Single Product



In cellular manufacturing systems, properly trained, semi-independent work cells are flexible and responsive. Defects and other manufacturing issues can be managed more efficiently than work centers set up on the basis of similar equipment or capabilities, where items must move among multiple work centers before they are completed. Table 2.2 compares Lean manufacturing and traditional manufacturing characteristics.

Table 2.2: Comparing Lean and Traditional Manufacturing

Lean	Traditional Manufacturing
People: • Clusters of employees working in teams • Extensive, continuing training	**People:** • Employees contribute minimally to total product • Training for limited skills • Management makes decisions
Products: • Focused on internal/external customer	**Products:** • Standardized, focused on volume not quality
Work Environment: • Some discretion, group effectiveness, empowerment, team accountability, and work cells	**Work Environment:** • Limited skills and knowledge • Repetitive, mind-numbing work • Little discretion, simplified tasks

Source: Adapted from National Institute of Standards and Technology Manufacturing Extension Partnership "History of Manufacturing" Table.

Lean production typically represents a paradigm shift from conventional "batch and queue," functionally-aligned mass production to "one-piece flow," product-aligned pull production. This shift requires highly controlled processes operated in a well maintained, ordered, and clean operational setting that incorporates principles of just-in-time production and employee-involved, system-wide, continual improvement.

Where to Find More Information on Lean

There are numerous publications, training programs, and websites that provide information on Lean principles and Lean methods. For a list of resources, please see Appendix A, Lean and Six Sigma Resources.

CHAPTER 3
What Is Six Sigma?

This chapter describes Six Sigma principles and methods. The sections in this chapter include:

- Six Sigma Definition
- History of Six Sigma
- Method and Implementation Approach
- Six Sigma Statistical Tools
- Where to Find More Information on Six Sigma

Six Sigma Definition

6σ

Six Sigma refers to a set of well-established statistical quality control techniques and data analysis methods used to identify and reduce variation in products and processes. Sigma is a letter in the Greek alphabet that represents the standard deviation from a statistical population, so "six sigma" denotes a target level of quality that is six times the standard deviation. This means that defects only occur approximately 3.4 times per million opportunities, representing high quality and minimal process variability. Six Sigma methods are used to support and guide organizational continual improvement activities. By using Six Sigma statistical tools, companies are able to diagnose the root causes of performance gaps and variability, thereby improving productivity and product quality. Six Sigma borrows martial arts ranking terminology to define practitioner roles.


Key Term

History of Six Sigma

The use of Six Sigma as a tool for improving manufacturing processes and eliminating defects can be traced back to the 1920s; however, it was not widely used as a quality control technique until the late 1980s. Motorola engineers, interested in more closely measuring defects in products and eliminating them, developed the Six Sigma continual improvement philosophy and many of the statistical tools used to implement this philosophy. At that time, Motorola was under the direction of Chairman Bob Galvin. Since Motorola's development of Six Sigma, the techniques have been widely adopted by companies in a variety of industrial sectors. General Electric's CEO Jack Welch adopted Six Sigma's techniques for his business strategy in 1995, which helped to expand the use of the Six Sigma philosophy even further.

Method and Implementation Approach

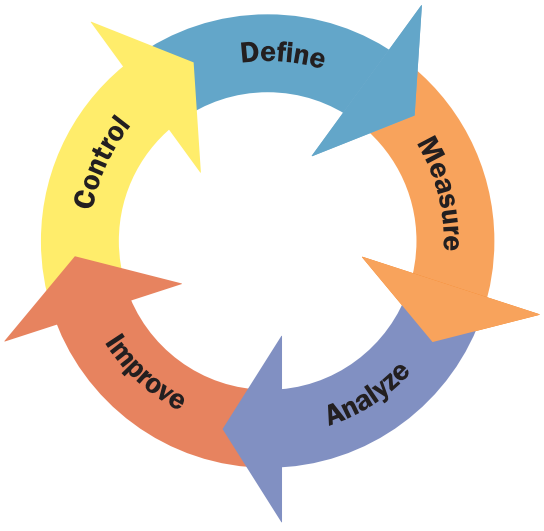
Key Term

Six Sigma typically involves implementing a five-step process called the *DMAIC (Define, Measure, Analyze, Improve, and Control)* process. This process is used to guide implementation of Six Sigma statistical tools and to identify process wastes and variation. It is similar to the Plan-Do-Check-Act business process improvement method.

The steps in the Six Sigma DMAIC process are as follows.

- **Define:** In this phase, Six Sigma teams focus on defining the problem statement—including project improvement activity goals and identifying the issues that need to be addressed to achieve a higher sigma level.
- **Measure:** In the Measure phase, the aim is to gather information about the targeted process. Metrics are established and used to obtain baseline data on process performance and to help identify problem areas.
- **Analyze:** This phase is concerned with identifying the root cause(s) of quality problems, and confirming those causes using appropriate statistical tools.
- **Improve:** During the Improve phase, teams work on implementing creative solutions to the problems identified. Sometimes Lean methods, such as cellular manufacturing, 5S, mistake-proofing, and total productive maintenance, are identified as potential solutions. Teams conduct statistical assessments of improvement in this stage as well.
- **Control:** In the final phase, teams work to institutionalize the improved system by modifying policies, procedures, and other management systems. Process performance results are again periodically monitored to ensure productivity improvements are sustained.

Figure 3.1: The Six Sigma DMAIC Process



Six Sigma projects are led by trained "green belt" and "black belt" practitioners. Green belts are employees who take up Six Sigma implementation along with their other job responsibilities. They lead less complex projects and operate under the guidance of black belts, who have more training and lead more complex projects. Participants in Six Sigma projects typically include five to ten team members from both within and outside the process that is the subject of the Six Sigma project. It can take several months or up to a year or more to go through the steps of the DMAIC process on a Six Sigma project as compared to week-long lean kaizen events. Specific technical tools are used throughout the DMAIC process and are explained in the next section.

Six Sigma Statistical Tools

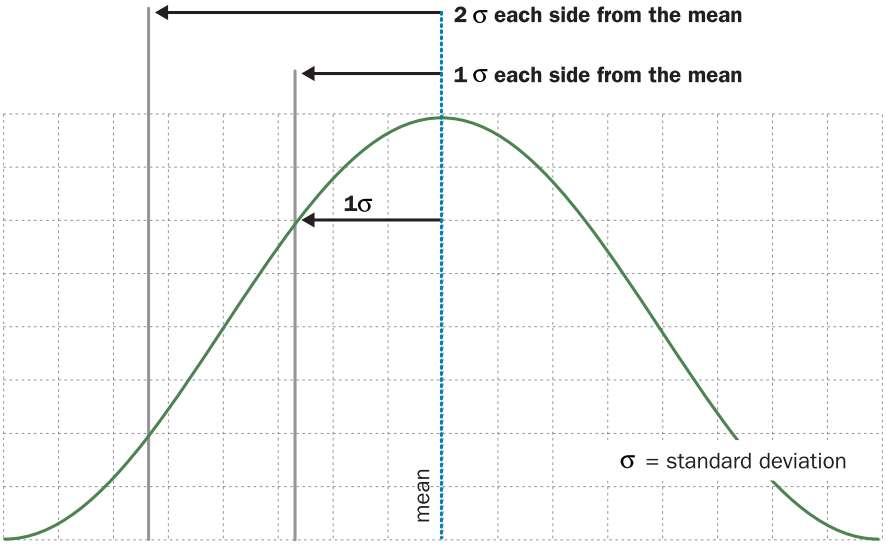
The Six Sigma toolkit has a number of tools and techniques that help teams work through the Six Sigma DMAIC process. The tools outlined below are divided into two categories: 1) tools that analyze sources of variation and problems in the process, and 2) tools that evaluate potential solutions to improve the process.

Problem Identification and Analysis Tools

The initial phases in the DMAIC process involve analyzing the sources of variation and problems in the process. The following tools are examples of tools that exist to gather data and evaluate the existing process.

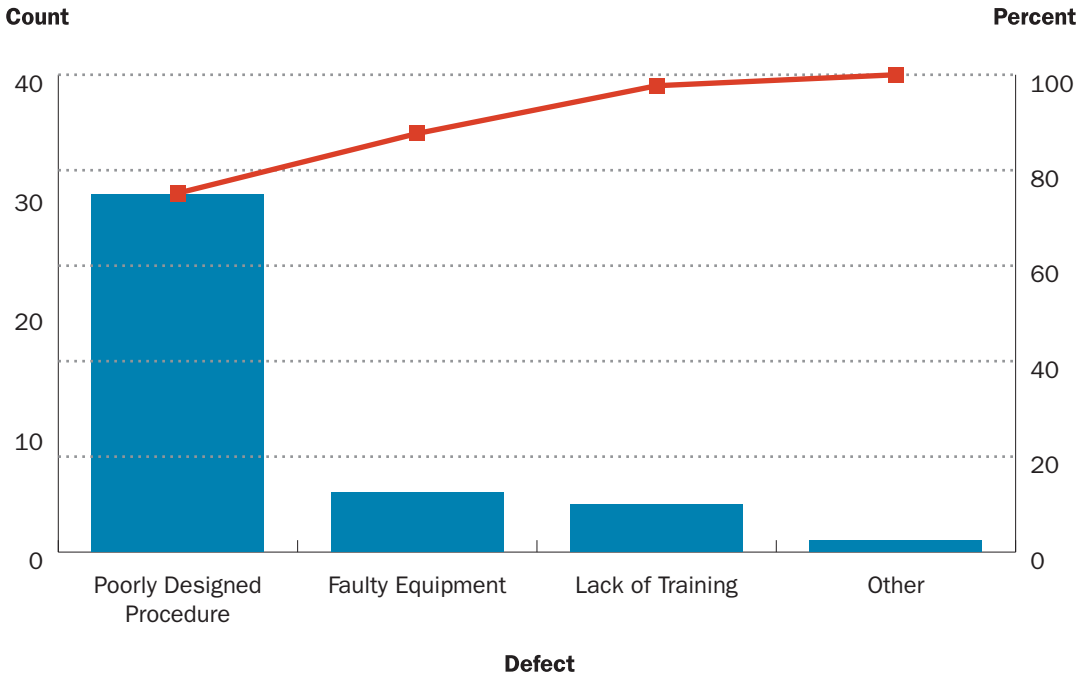
- **Descriptive Statistics:** Statistical tools are used to organize, summarize, and describe data that is collected. The data collected from using statistical tools provide measures of central tendency and measures of dispersion, which are often used as supporting information in the decision-making process.

Figure 3.2: Example of Normal Probability Distribution



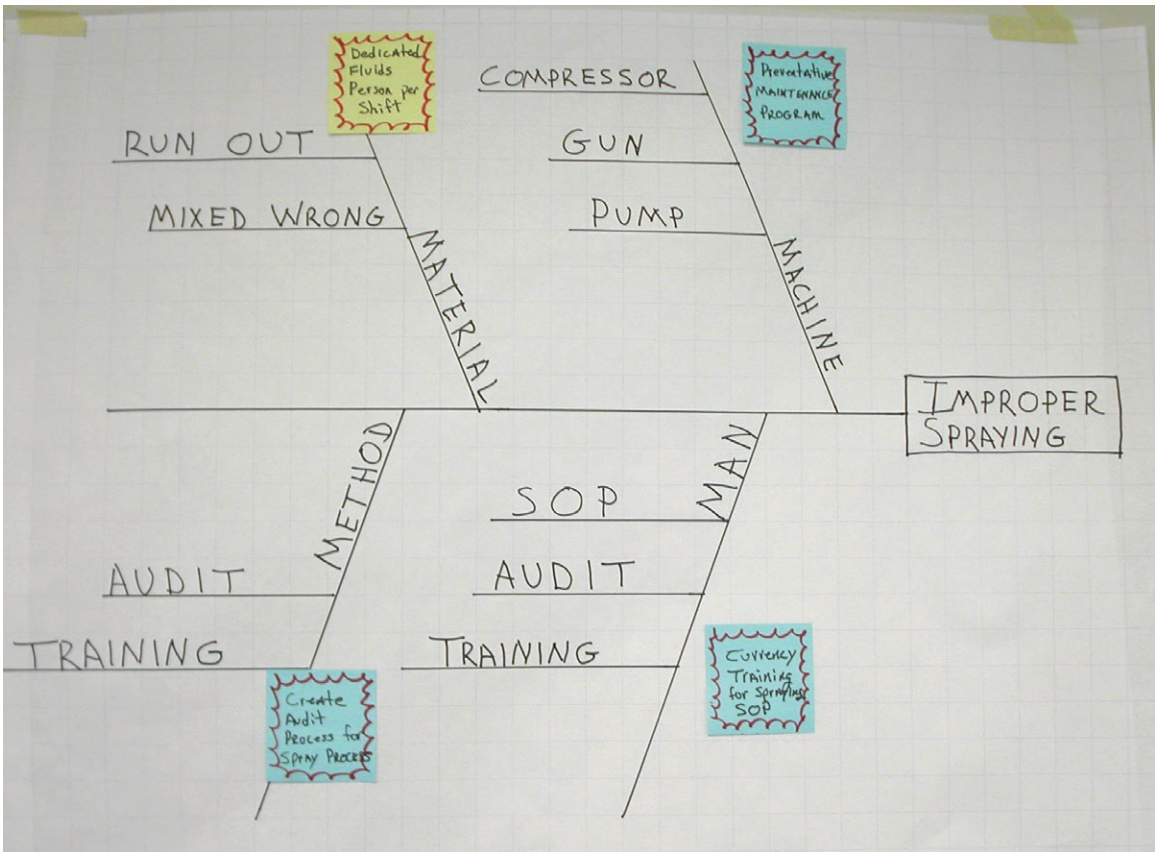
- **5 Whys Approach:** The approach of asking "why" five times is used to explore the cause/effect relationships underlying a particular problem. By applying the 5 Whys method a company can determine a root cause of a defect or problem.
- **Pareto Charts:** Pareto Charts weigh each type of defect according to severity, cost of repair, and other factors in order to determine which types of defects occur most frequently. The Pareto Chart is a bar graph arranged in descending order of size of importance from left to right. This information facilitates prioritization of response actions. Fundamental to the Pareto principle is the notion that most quality problems are created by a "vital few" processes, and that only a small portion of quality problems result from a "trivial many" processes.

Figure 3.3: Example of a Pareto Chart



- **Cause-and-Effect Diagram:** A cause-and-effect diagram is also known as fishbone diagram or an Ishikawa diagram (after its originator, Karoru Ishikawa). This is a useful technique that is used to trigger ideas and promote a balanced approach in group brainstorming sessions where individuals list the causes and effects of problems. Six areas should be considered when constructing a cause-and-effect diagram. The areas (causes) that can contribute to effects are: materials, machine, method, people, measurement, and environment.

Figure 3.4: Example of a Cause-and-Effect Diagram



Tools for Evaluating Potential Solutions

After identifying and analyzing problems within a process, the next step is to identify and evaluate potential improvement methods. The following tools are used for evaluating solutions.

- **Design of Experiments:** Design of experiments is an important element in Six Sigma methodology. DOE offers a structured statistical approach to help you understand the factors that affect a process and then create meaningful and effective tests to verify possible improvement ideas or theories. DOE is useful for discovering and validating the relationships between the inputs and outputs in a process, in order to obtain improved results.

- **Failure Mode Effect Analysis (FMEA):** FMEA is a technique used to identify potential failure modes or causes of failures that may occur as a result of design or process deficiencies. Teams use FMEA to produce estimates of the effects and level of severity of failures in products or production processes, and to identify options for corrective design or process changes.

Figure 3.5: Failure Mode Effect Analysis Diagram

Process Steps	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Corrective Action

Key
SEV = Severity of Effects
OCC = Frequency of Occurrence
DET = Detection Rating
RPN = Risk Priority Number

Severity (SEV) x Occurence (OCC) x Detection (DET) = Risk Priority Number (RPN)

Where to Find More Information on Six Sigma

There are numerous publications, training programs, and websites that provide information on Six Sigma principles and methods. For a list of resources, please see Appendix A, Lean and Six Sigma Resources.

CHAPTER 4
How Do Lean and Six Sigma Relate to the Environment?

This chapter describes how Lean relates to the environment. The sections in this chapter include:

- How Lean Improves Environmental Performance
- Environmental "Blind Spots" of Lean
- Lean's Potential "Friction" with Regulatory and Permitting Requirements
- How Lean Compares to Environmental Initiatives
- Where to Find More Information on How Lean Relates to the Environment

In the rest of the document we've used "Lean" to refer generically to Lean, Six Sigma, or a combination of Lean and Six Sigma.

How Lean Improves Environmental Performance

Research has found that Lean methods improve environmental performance, even without intentionally adding environmental considerations. Some examples of these environmental benefits are listed in Box 4.1. Considerable environmental gains often "ride the coattails" of Lean implementation. There are two main reasons why this occurs:

1. Environmental impacts are embedded within the wastes that Lean targets.
2. Lean produces an organizational culture that is highly conducive to waste minimization, pollution prevention, environmental management systems, and sustainability.

Environmental Benefits Arise From Eliminating Lean Wastes


Key Point

Lean implementation efforts can create powerful coattails for environmental improvement, since environmental impacts are embedded within the production wastes targeted by Lean. Table 4.1 lists examples of environmental impacts associated with the seven "deadly wastes" targeted by Lean methods. Reducing these Lean wastes, therefore, produces environmental gains. For example, less over-processing and more efficient transport results in lower emissions. In addition, less storage and inventory space from the creation of right-sized production unit, results in reduced materials, land, and energy consumed. Six Sigma's focus on reducing variation also helps to bring about environmental improvements associated with eliminating defects.

Environmental Benefits from Lean (Box 4.1)

Even without intentionally incorporating environmental considerations, Lean can result in significant environmental benefits. Below are examples from initial research on Lean manufacturing and environment.

The Boeing Company:

- ✓ Realized improvements in resource productivity (i.e., the amount of raw materials and other inputs needed for a unit of production) ranging from 30 to 70 percent.
- ✓ Decreased chemical use per plane by 12 percent.

General Motors/Saturn:

- ✓ Reduced hazardous waste generation from 9.0 lbs per car in 1992 to 3.2 lbs per car in 1996.
- ✓ Receives over 95 percent of its parts in reusable containers.

Goodrich Corporation:

- ✓ Eliminated four 5,000 gallon tanks with methyl ethyl ketone, sulfuric acid, nitric acid, trichloroethane.
- ✓ Eliminated the potential for spills and need to address Clean Air Act risk management planning requirements.

Sources: US EPA. "Pursuing Perfection: Case Studies Examining Lean Manufacturing Strategies, Pollution Prevention, and Environmental Regulatory Management Implications." 2000.
US EPA. "Lean Manufacturing and the Environment: Research on Advanced Manufacturing Systems and the Environment and Recommendations for Leveraging Better Environmental Performance." 2003.

Table 4.1: Environmental Impacts of Lean's "Deadly Wastes"

Lean Waste Type	Environmental Impacts
Overproduction Manufacturing items for which there are no orders	• More raw materials and energy consumed in making the unnecessary products • Extra products may spoil or become obsolete requiring disposal • Extra hazardous materials used result in extra emissions, waste disposal, worker exposure, etc.

Table 4.1: Environmental Impacts of Lean's "Deadly Wastes"

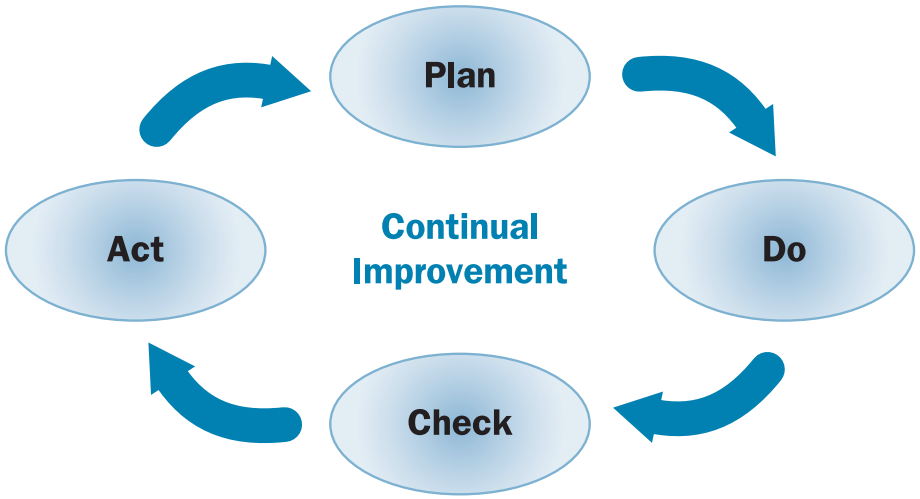
Lean Waste Type	Environmental Impacts
Inventory Excess raw material, work-in-process, or finished goods	• More packaging to store work-in-process (WIP) • Waste from deterioration or damage to stored WIP • More materials needed to replace damaged WIP • More energy used to heat, cool, and light inventory space
Defects Production of off-specification products that result in rework and/or defective materials	• Raw materials and energy consumed in making defective products • Defective components require recycling or disposal • More space required for rework and repair, increasing energy use for heating, cooling, and lighting
Transportation Excess transport of WIP or products **Motion** Human movements that are unnecessary or straining	• More energy use for transport • Emissions from transport • More space required for WIP movement, increasing lighting, heating, and cooling demand and energy use • More packaging required to protect components during movement • Damage and spills during transport • Transportation of hazardous materials requires special packaging to prevent risk during accidents
Over processing Process steps that are not required to produce the product	• More parts and raw materials consumed per unit of production • Unnecessary processing increases wastes, energy use, and emissions
Waiting Delays associated with stock-outs, equipment downtime, capacity bottlenecks	• Potential material spoilage or component damage causing waste • Wasted energy from heating, cooling, and lighting during production downtime

Environmental Benefits as a Result of Culture Change

Key Point

Lean produces an operational and cultural environment that is highly conducive to waste minimization, pollution prevention, and sustainability. Lean methods focus on waste elimination by continually improving resource productivity and production efficiency, which frequently translates into less material, less capital, less energy, and less waste per unit of production. Lean also fosters a systematic, employee-involved, continual improvement culture that is similar to environmental improvement initiatives. Like environmental management systems, Lean uses a Plan-Do-Check-Act model for continual improvement (see Figure 4.1).

Figure 4.1: Plan-Do-Check-Act Model



Environmental Blind Spots of Lean

Despite the considerable environmental performance gains that result from Lean implementation, there are a few environmental "blind spots" that Lean methods, on their own, do not typically address.

Key Point

The two main "blind spots" that Lean methods do not typically consider are environmental risks and life-cycle impacts. For example, Lean may enable a company to reduce the amount of a chemical it uses, but it will not automatically encourage a company to switch to a less toxic or harmful chemical. Similarly, Lean methods do not typically identify or consider the environmental impacts or costs associated with the extraction of materials used in the manufacturing process, the disposal of non-product outputs of production, or the disposal of the resulting product.

Environmental professionals can help Lean practitioners understand the costs associated with environmental wastes and that these costs do not have to be considered "necessary" if the process or product can be changed to generate less of a particular waste. Box 4.2 is an example of how environmental professionals can help Lean teams see blind spots.

There are three mechanisms by which these blind spots occur.

- **Lean methods do not explicitly identify pollution and environmental risk as "wastes" to target for elimination.** Lean implementers often think of waste somewhat differently from the way environmental agencies think of waste. Lean's "deadly wastes" do not explicitly include wastes that are targeted by environmental management activities, such as solid and hazardous waste, air emissions, and wastewater discharges; nor is resource consumption, such as use of materials, energy, and water, directly targeted.
- **Environmental practitioners are not always well-integrated into operations-based Lean efforts.** Often environmental management activities operate in a "parallel universe" to Lean implementation efforts. This appears to be particularly true in the early stages of Lean implementation, when environmental managers may not be familiar with the methods being adopted by their organization. The involvement of environmental practitioners in Lean implementation efforts can both reduce the risk of non-compliance with environmental regulations and increase opportunities for realizing more environmental benefits.
- **The expertise related to waste minimization and pollution prevention is not routinely making it to Lean practitioners.** Environmental agencies and non-profit organizations promoting P2 and waste minimization have developed numerous tools and compiled many specific actions that organizations can take to improve the resource productivity and environmental performance of processes.

Environmental Health and Safety Expert's Role in Lean Events (Box 4.2)

At a facility in Rochester, New York, a Lean practitioner from the Rochester Institute of Technology and an environmental technical assistance provider from the New York State Pollution Prevention Institute conducted a Lean, Energy, and Environment (LE2) value stream mapping project.

- ✓ The Lean practitioner thought that the inventory area at the facility needed to be organized and suggested using 6S (5S + Safety) and visual controls methods.
- ✓ The EHS expert recognized that caustic and hydrochloric acids were being stored side-by-side (see photo), and explained that if a spill or leak initiated mixing of the strong acid and base chemicals, the chemical drums could soften and rupture, leading to violent foaming and hazardous exposure to anyone working near the tanks. The EHS expert's ability to see this safety hazard during the VSM stage confirmed that a detailed 6S audit was warranted.

Finding effective mechanisms to get process-specific pollution prevention and waste minimization ideas and techniques into the hands of Lean practitioners could help seed implementation efforts with ideas for improving resource productivity and environmental performance. Box 4.3 includes examples of what has happened when companies address environmental blind spots.

Examples of Addressing Environmental Blind Spots (Box 4.3)

Toyota Motor Company:

- ✓ Generated competitive advantage by understanding customer preferences related to environment (hybrid synergy drive in Prius)

Rockwell Collins:

- ✓ Prepared checklists for Lean teams to reduce non-compliance risk and to encourage pollution prevention
- ✓ Conducted kaizen events targeting environmental challenges

Lean's Relationship to Regulatory and Permitting Requirements


Key Point

If they are not well coordinated with environmental management procedures, Lean initiatives sometimes can come into conflict with regulatory and permitting requirements. This may occur where environmental regulations do not explicitly contemplate or accommodate right-sized, mobile production systems or fast-paced, iterative operational changes. These situations can either increase the risk of non-compliance or constrain the potential for environmental gains. Such conflicts do not mean that Lean is environmentally harmful, but do call attention to the need for environmental staff to be involved in lean processes.

Such issues most frequently arise around environmentally sensitive manufacturing processes. These processes typically involve hazardous chemicals that have the potential to adversely affect worker health or be released to air, water, or land. Examples of environmentally sensitive processes include:

- Chemical point-of-use management
- Chemical treatment
- Metal finishing processes
- Painting and coating
- Parts cleaning and degreasing

Lack of regulatory precedent or clarity can cause even the most well meaning companies to misinterpret requirements and experience violations, even where environmental improvement has resulted.

One area in which rapid, frequent changes may trigger environmental requirements is air permitting, such as those in the New Source Review provisions of the Clean Air Act. Even if an

operational change only has the potential to alter air emissions at a facility, a permitting action may be required. If changes are made without authorization by an environmental agency, a facility can face stiff penalties. If a permitting action is required, permitting timeframes of several weeks or months can severely impede Lean implementation progress. EHS staff can help to minimize these delays by working with their air permitting authorities. In addition, EPA, in collaboration with State and local permitting authorities, have developed innovative air permitting approaches that can accommodate significant operational flexibility while addressing applicable air requirements and protecting the environment (see Box 4.4).

Addressing Lean Friction in Air Permitting at Baxter Healthcare Corporation (Box 4.4)

Baxter Healthcare Corp.'s Mountain Home, Arkansas facility began its Lean journey in 1998. The facility, which manufactures medical products and devices, found that the rapid, iterative operational change needs identified during Lean events were sometimes constrained by the timeframes needed to accommodate the changes under the facility's air permit. To address this friction, Baxter partnered with the Arkansas Department of Environmental Quality and EPA to design a flexible air permit that would better accommodate rapid Lean change needs while ensuring environmental protection and compliance with all applicable regulatory requirements.

Baxter's flexible air permit was issued in May 2006. The Title V air operating permit established plant-wide limits for volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions. The permit also "advance approved" Baxter's ability to install, move, and modify various VOC and HAP-emitting equipment, provided that the facility addresses specific conditions outlined in the permit. The permit has enabled Baxter to make rapid operational changes during Lean events, while helping the facility to comply with applicable air requirements and reduce emissions.

Sources: Arkansas Department of Environmental Quality Air Permit No. 544-AOP-R5 (http://www.adeq.state.ar.us/home/pdssql/pds.asp); Patrick Waurzyniak. "Going Lean at Baxter," Manufacturing Engineering. Society for Manufacturing Engineers, May 2003, pp. 89-94.

How Lean Compares to Environmental Initiatives


Key Point

Understanding the similarities and differences between Lean methods and environmental initiatives is vital to seeing paths to connect them and bridge the worlds of Lean practitioners and environmental professionals.

Lean and environmental initiatives are rooted in a common heritage and have strong similarities. As discussed earlier in this chapter, Lean and leading environmental initiatives, such as P2 and EMS, are all based on Edward Deming's Plan-Do-Check-Act framework and a philosophy of continual improvement. Lean and environmental initiatives focus on eliminating waste, although there are differences in the scope of how "waste" is defined. In addition, Lean and environmental initiatives seek to foster an organizational culture that emphasizes employee involvement in problem solving.

In summary, Lean and environmental initiative activities seek to:

Although they have some similarities, Lean is not the same as pollution prevention.

- Foster a systematic approach to continual improvement
- Implement systematic and ongoing efforts to identify and eliminate waste
- Engage employees actively in improvement activities
- Emphasize the importance of using metrics to inform decisions
- Engage with the supply chain to improve enterprise-wide performance

While the common heritage and similarities are strong, Lean has fundamental differences from environmental initiative approaches, as follows.

- **Drivers:** Lean's drivers are deeply rooted in business competitiveness, capital productivity, and customer satisfaction. Lean is often implemented as an organization's dominant operational strategy to respond to or prevent crises that may threaten an organization's survival. While environmental initiatives can make important contributions to operational efficiency, the bottom line, and even the top line, the magnitude of benefits from environmental initiatives is often significantly less than those associated with Lean.
- **Methods and Tools:** While some Lean and environmental methods are similar, there are often important differences. For example, Lean value stream mapping and the process mapping techniques commonly used in P2 efforts both visually represent processes, but they have distinct differences in the type and format of information displayed.
- **Definitions of "Waste":** While definitions of "waste" overlap somewhat, Lean's seven "deadly wastes" do not explicitly encompass all types of environmental wastes.
- **Language:** Lean practitioners and environmental professionals have distinct terms, lexicons, and language for describing their work. Without proper translation, language differences can pose barriers to collaboration.
- **Organizational Champions:** Lean is typically driven by senior operations or business managers, while environmental initiative efforts are typically led by EHS personnel. Lean

and environmental champions often have very different access to information and resource and influence over organizational decisions and investments.


Key Point

Lean is fundamentally about competitiveness, not environmental improvement. Bold attempts to shift this basic premise of Lean have the potential to undermine the powerful drivers that are compelling organizations to use Lean, or to inhibit collaboration between Lean Six Sigma practitioners and environmental professionals. This has important implications for the manner in which environmental professionals approach opportunities to bridge Lean with environment efforts. Mistaking the similarities between Lean and environmental initiative approaches as meaning they are "the same thing" can undermine communication efforts. A more nuanced and productive approach to talking about Lean and environment is stated in Box 4.5.

Key Messages about How Lean and Six Sigma Compare to Environmental Improvement Initiatives (Box 4.5)

- ✓ Lean, Six Sigma, and environmental improvement initiatives are highly complementary, but they have fundamental differences that warrant attention.
- ✓ Environmental management approaches and tools can add significant value to Lean initiatives by effectively connecting environmental considerations within Lean methods and tools.
- ✓ Proactive efforts to integrate environmental considerations and tools into Lean and Six Sigma initiatives can help identify more waste while enhancing results.

Where to Find More Information on How Lean Relates to the Environment

The relationship of Lean to environmental performance and the environmental regulatory framework is discussed in detail in EPA's Shingo-Prize winning 2003 report, *Lean Manufacturing and the Environment: Research on Advanced Manufacturing Systems and the Environment and Recommendations for Leveraging Better Environmental Performance.* This report and other information on Lean and the environment are available on EPA's Lean website, www.epa.gov/lean. Appendix B of this guide also lists tools, case studies, and other publications about Lean, Six Sigma, and the environment.

By integrating environmental considerations into Lean, organizations can overcome blind spots, pro-actively address any regulatory friction, and generate even better environmental results. The following chapters provide information on how to talk about Lean and environmental initiatives and how to get started with Lean and environment.

CHAPTER 5
Why Does It Matter How We Talk About Lean and Environment?

This chapter discusses why it matters how we talk about Lean in relation to environmental initiatives. The sections in this chapter are:

- Talking About Lean and Bridging Parallel Universes
- What's in a Name? Branding Lean and Environment

Talking About Lean and Bridging Parallel Universes

This section discusses key strategies environmental professionals have used to effectively communicate with Lean practitioners and bridge the "parallel universes" of Lean and environmental activities at facilities.


How-To Steps

1. **Learn the Language.** Environmental professionals don't need to become experts to learn the language of Lean. Listening, combined with reading and training, can equip you to talk effectively with Lean practitioners about environmental issues. Just as the terminology of Lean may initially be unfamiliar to environmental professionals, Lean audiences may not be familiar with environmental terms and acronyms. Consider exchanging glossaries with Lean practitioners to facilitate improved communications (see Appendix C for a Lean and Six Sigma Glossary and Appendix D for an Environmental Glossary).

2. **Frame "Environment" in Lean Terms.** It's not necessary to convince Lean practitioners to become environmental experts or "environmentalists" to integrate Lean and environmental initiatives. Lean practitioners love nothing more than finding and eliminating waste. If you can help them see wastes that were previously hidden, they will often become zealous partners in improving environmental performance. It is also useful to look for the specific places, or entry points, within Lean methods where asking a simple question can help Lean practitioners see environmental wastes. EPA's Lean toolkits offer many specific ideas of where you can find entry points in Lean methods.


Caution

3. **Learn How to Say "Yes."** *When environmental professionals are viewed as only saying "No" to potential Lean projects, invitations to participate in Lean events can be scarce.* Instead, think creatively about how to address challenges and meet both environmental and operational objectives. Some Lean facilitators even ban the word "can't" and suggest reframing concerns by saying, "We could if…" By working collaboratively to develop solutions—identifying ideas that can reduce environmental wastes, eliminate worker health and safety hazards, and/or

avoid environmental risks associated with regulatory compliance obligations—environmental professionals can cultivate an important new venue for environmental expertise, tools, and information.

In many organizations, there can be functional divides or "silos" between people leading operational improvement activities such as Lean and people responsible for managing environment health and safety issues, regulatory compliance activities, and environmental improvement efforts. Similarly, Lean service providers and environmental technical assistance providers sometimes operate in "parallel universes," even though both types of assistance providers seek to improve the performance of the organizations they work with.

Bridging the "Lean" universe and the "environmental" universe can yield substantial benefits for all parties involved. Fortunately, it doesn't have to be difficult to overcome these differences, break down organizational silos, and work together to achieve common objectives such as waste elimination, continual improvement, and creating a good working environment for employees. Box 5.1 describes a few simple steps that both Lean and environmental professionals can take to help realize these common objectives.

Checklist for Bridging the Parallel Universes of Lean and Environment (Box 5.1)

- ✓ **Convene a Meeting:** Set up a meeting between Lean and environmental health and safety managers to discuss common objectives and brainstorm joint improvement opportunities.
- ✓ **Exchange Glossaries:** Improve communications and understanding by exchanging "glossaries" of Lean terms and environmental terms.
- ✓ **Participate in Each Other's Activities:** Include EHS staff in Lean events and trainings, and involve Lean leaders in environmental improvement projects and initiatives, such as developing an environmental management system.

Key Point

The ultimate goal of Lean and environment efforts is to seamlessly integrate environmental considerations into Lean so that eliminating environmental wastes becomes just another part of doing Lean. Safety is about a decade further along in being integrated into Lean efforts. Many Lean books, training courses, and tools now incorporate safety considerations as standard practices. For example, many organizations commonly refer to 5S as 6S or 5S+Safety. While more work is needed to fully integrate safety issues into Lean, the evolution of safety's relationship to Lean may provide a model for environmental professionals.

What's in a Name? Branding Lean and Environment

Given that much work lies ahead to connect Lean with environmental improvement efforts, how should environmental professionals refer to or "brand" integration efforts? A variety of terms have been used, including "Lean and Environment," "Lean and Green," and "Lean and Clean." These terms can be useful in drawing attention to efforts to integrate the parallel universes of Lean and environment, and, for technical assistance providers, in making a distinction between standard Lean services and integrated services that combine Lean and environmental expertise. At the same time, these "Lean and Environment" terms can imply that environmental considerations are an add-on, something distinct and separate from Lean, when the real goal is more seamless integration. Furthermore, efforts to "paint Lean green" may not get far with all Lean practitioners and promoters.

Environmental professionals should think carefully about what to call Lean and environmental integration efforts. Branding Lean and environment using terms such as those described above may be fully appropriate and useful when communicating with other environmental professionals. Many businesses and operations personnel, however, may be skeptical of the value of incorporating environmental issues into Lean. In addition, as noted previously, saying that Lean and/or Six Sigma are the same as pollution prevention can lead operations personnel to dismiss the ideas of the environmental professional.

When communicating with operations personnel at businesses, a subtle approach to describing Lean and environment may work best. Rather than elevating environmental issues to be on par with Lean, environmental professionals may be better served by leading with Lean and discussing how environmental professionals can help these methods find and eliminate even more waste. The idea of adding one more waste—environmental waste—to Lean's "deadly wastes" is a powerful concept that may increase receptiveness and lower barriers to connecting Lean and environment. Furthermore, consider relabeling "environmental waste" using terms that operational audiences may receive better. Examples of alternate terms for environmental wastes include "process wastes," "fallout wastes," and "material wastes."

Lean and Environment Efforts at Columbia Paint & Coatings (Box 5.2)

Through a Lean and Environment Pilot Project with the Washington State Department of Ecology (Ecology) and Washington Manufacturing Services (WMS), a Columbia Paint & Coatings manufacturing facility in Spokane, Washington realized substantial financial, operational, and environmental savings and built a foundation for continual process improvement.* WMS and Ecology partnered to jointly provide Lean and environmental assistance to the facility to improve productivity and reduce wastes. The project included the following activities:

- ✓ A day-long Lean 101 and environment training session
- ✓ A four-day value stream mapping (VSM) event to identify waste and prioritize improvement projects
- ✓ Three week-long, facilitated "get 'r done" events (another name for kaizen events) to implement process changes
- ✓ Other improvement efforts the facility conducted independently

Value Stream Mapping

WMS and Ecology chose to "lead with Lean," letting the facility determine the focus of the project and assuming that environmental benefits would naturally arise from Lean implementation. Columbia Paint decided to focus on its latex paint lines, which accounted for 80 percent of production volume. The VSM event had this structure:

- ✓ Day 1: Training and orientation
- ✓ Day 2: Observation and analysis of the "current state"
- ✓ Day 3: Developed the current state value stream map; discussed and prioritized future improvement opportunities
- ✓ Day 4: Developed and gave report-out presentation

Participants examined environmental waste (called "process waste") along with other Lean wastes in the VSM analysis. The team selected four targets for get 'r done events, including one event (to rearrange the plant layout) that the facility conducted without outside assistance.

* Columbia Paint was acquired by Sherwin-Williams following the project. WMS is a NIST MEP affiliate.

Box 5.2, Continued

Get 'R Done Events

The get 'r done events supported by WMS and Ecology focused on: (1) developing a "pull" based scheduling system; (2) decreasing the time for the off-line quality control process; and (3) improving raw material organization. These events had the following general structure:

- ✓ Days 1-2: Planning and focused analysis of the process
- ✓ Days 3-5: Implementation, refinement, and report-out presentation

Highlights from the get 'r done events included:

- ✓ After identifying the waste, managers issued an edict requiring all white wash water to be reused and incorporated into products.
- ✓ The reductions in cycle time for the quality control process freed staff time to focus on process improvement efforts.
- ✓ Operators took the lead on identifying and making changes to the layout, organization, and labeling of raw materials in the third event; as a result, the WMS facilitator had a much less directive role.
- ✓ With the project, Columbia Paint saved $209,800/year, reduced wastewater by 36,900 gallons/year, recovered 49,200 lbs/year of paint solids, and cut hazardous wastes by 17,600 lbs/year.*

Culture Change and Continual Improvement

One remarkable thing about the project was that process improvement efforts took on a life of their own, as workers felt empowered to identify ways to reduce waste and improve operations. During the project, workers improved two processes that were outside the scope of the project—shrink wrapping and oil decanting—using Lean concepts.

For More Information

- ✓ A video called "Lean Ecology" that profiles the Columbia Paint pilot project is available at http://strausforest.com/leanecology.html.
- ✓ A case study of this pilot project, along with other case studies and a final report, are available at www.ecy.wa.gov/programs/hwtr/lean.

*The full set of quantified results from the project is included in Appendix E of this Guide.

Lessons Learned about Convincing Companies of the Value of Lean and Environment

Practitioners and service providers with Lean and environment experience have shared the following suggestions on how to talk with companies about the value of Lean and environment.


Key Point

- *It's important to speak the language of business and explain how Lean and environment efforts will address core business needs*, including:
  - Reducing costs
  - Decreasing production lead times
  - Increasing value to customers
  - Staying in business and retaining jobs
  - Addressing key problems and areas of "pain" (i.e., what keeps operations managers up at night?)
- Examples that illustrate the true value of environmental wastes (how much money a company is throwing away), as well as specific results from previous projects, are very useful for developing the business case for Lean and environment.
  - However, it is not necessary to precisely define the anticipated cost savings from process changes in advance, since Lean operates with a presumption of benefit and favors action over planning.
- It can be easier to convince a Lean manager of the value of addressing environmental waste than to convince an environmental manager about the value of Lean and environment. If a company is already implementing Lean, it's likely to be receptive to the idea of addressing other wastes.

The more that Lean practitioners become aware of the business value that can stem from folding environmental considerations into their Lean initiatives, the more environmental benefits will result.

Furthermore, when environmental improvement opportunities are included with Lean initiatives, those ideas receive more management attention and become higher priorities for implementation. Effective integration of Lean and environmental efforts creates a powerful approach to find hidden cost savings, identify and eliminate all forms of wastes, reduce business risks, and improve organizational performance.

CHAPTER 6
Lean and Environment Applications

This chapter describes a range of ways that environmental professionals can improve environmental results by leveraging Lean efforts. This chapter is organized into the following sections:

- Connecting Lean, Six Sigma, and Environmental Efforts at Facilities
- Delivering Lean and Environment Technical Assistance
- Using Lean to Enhance Environmental Programs and Processes
- Lessons from the Field

Connecting Lean, Six Sigma, and Environmental Efforts at Facilities

As described earlier, there are many reasons why environmental health and safety managers and other staff with EHS expertise would want to connect with Lean improvement efforts. Lean can be a powerful vehicle for generating environmental results, yet without active engagement of staff with EHS expertise, there's a risk that these business improvement efforts will overlook environmental opportunities or that they will create regulatory compliance and/or worker health and safety issues.

While ideally EHS personnel should not be the only employees looking for environmental wastes and improvement opportunities; there are several ways that environmental professionals can help integrate environmental considerations into Lean efforts at companies. Three important steps include:

1. **Learn about Lean.** Learning about Lean principles and methods is a good first step for understanding how these efforts can advance environmental objectives. Along with this guide, the EPA has developed a series of Lean and environment publications (see Box 6.1), and many organizations, including NIST MEP centers, offer Lean training courses. Another useful way to learn is to listen to Lean practitioners and to observe Lean implementation efforts. Consider attending the report-out sessions of Lean events or participating in a full event. A little time spent listening and observing can be much more effective than just relying on books and training courses to get a practical understanding of Lean.

EPA Lean and Environment Resources (Box 6.1)

With the assistance of multiple industry and government partners, EPA has developed a series of tools, case studies, and reports related to Lean and the environment. Key resources include:

- ✓ EPA Lean Manufacturing and Environment Website (www.epa.gov/lean), which provides Lean and environment case studies, information on Lean methods, and other resources
- ✓ *The Lean and Environment Toolkit* (www.epa.gov/lean/toolkit), which describes practical strategies and tools for integrating environmental aspects into common Lean methods such as value stream mapping, kaizen events, and 6S (or 5S + Safety)
- ✓ *The Lean and Energy Toolkit* (www.epa.gov/lean/energytoolkit), which outlines how to use Lean methods to reduce energy use, energy costs, and associated greenhouse gas emissions
- ✓ *Lean Manufacturing and the Environment* Report (Shingo Prize winner, www.epa.gov/lean/leanreport.pdf), which describes the relationship of Lean manufacturing to environmental performance and the environmental regulatory framework, and provides recommendations for environmental agencies

2. **Get Involved with Lean Efforts.** If you work at an organization implementing Lean or Six Sigma, set up time to meet with Lean leaders in your organization or geographic area. Often the greatest benefits come from simple conversations and relationships. With Lean's focus on eliminating "waste" in all its forms, there should be some natural synergies and places where EHS personnel could offer to help with Lean efforts. Lean teams often look for people with outside perspectives to participate in events, and directly participating in Lean efforts is one of the most powerful ways to influence them.

3. **Bring a "Problem Solving" Orientation to Lean Teams.** The rapid time frames of Lean (e.g., teams identify and implement process changes in a week) mean that there is a bias for quick and simple solutions. Working effectively with Lean efforts may require environmental professionals to operate in different ways, focusing on quickly identifying simple solutions to reduce wastes as part of cross-functional Lean teams. There may be a need to think creatively about ways to proactively address potential regulatory compliance issues, in order to enable process changes that could improve both environmental and operational results.

By understanding the schedule and scope for upcoming Lean projects, environmental professionals can identify information that can reveal environmental wastes and anticipate regulatory and compliance issues that may affect changes made during the events. Moreover, environmental professionals can open a significant new market for the expertise and tools developed by environmental organizations, including pollution prevention and waste minimization techniques, Design for Environment methods, EMS, and life-cycle analysis techniques.

Environmental agencies can help facilitate the integration of Lean, Six Sigma, and environmental improvement efforts at facilities in a number of ways. Potential roles for environmental agencies include:

- Adapt or "translate" existing environmental tools for Lean and Six Sigma audiences and applications.
- Partner with Lean organizations to integrate environmental considerations into Lean training curriculums, publications, and other efforts.
- Support Lean and environment technical assistance and training programs (see section below).
- Address regulatory barriers or uncertainties with applying Lean tools to environmentally sensitive processes.
- Disseminate results and best practices from Lean and environment efforts.
- Develop Lean and environment tools and educational materials.

The rising prominence of Lean presents a window of opportunity for environmental professionals to help manufacturing companies generate better environmental results while supporting business competitiveness initiatives.

Delivering Lean and Environment Technical Assistance

Environmental technical assistance providers—including not-for-profit pollution prevention centers, government agency technical assistance programs, and private consulting firms—can improve environmental results, provide more value to businesses, and reach new audiences through efforts to integrate environmental considerations into business improvement initiatives such as Lean. Environmental service providers can accomplish this in two primary ways:

1. **Partner with Lean Service Providers:** Environmental service providers can partner with Lean service providers to offer Lean and environment services to facilities. There are several models for this type of joint service delivery, as discussed further below.

2. **Provide Direct Support to Facility Lean Efforts:** Facilities implementing Lean approaches may request assistance or "pull" services of outside environmental professionals to address environmental wastes in the context of Lean. For example, companies have invited environmental agency staff to participate in Lean events on processes with significant environmental impacts. P2 assistance providers have also provided training and technical assistance to facilities to support Lean implementation and address specific operational problems (e.g., training on spray efficiency techniques to develop standard work).

Lean and Environment Efforts Involving Manufacturing Extension Partnership Centers

Several organizations have developed Lean and environment technical assistance programs involving partnerships with National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership (MEP) centers. MEP is a national network of manufacturing assistance centers that provide Lean manufacturing and other services to small-to-medium sized businesses to make them more competitive. A list of MEP centers is located at the NIST MEP website: www.mep.nist.gov. Here are some examples of Lean and environment programs involving MEP centers:

- **Green Suppliers Network (GSN) Program** (www.greensuppliers.gov): In the EPA and NIST MEP Green Suppliers Network Program, environmental assistance providers work with Lean providers at MEP centers to conduct "Lean and Clean" value stream mapping events with small and medium sized companies in the supply chains of large manufacturers.[3] The review teams develop confidential reports that identify a range of improvement opportunities at each participating facility and estimate the potential cost and environmental savings from those recommendations. In 94 projects, GSN review teams have identified $20.3 million per year in potential environmental savings and $31.9 million per year in potential Lean savings. GSN review teams have completed projects in over ten states.[4] Box 6.2 describes one company's experience.

- **Washington State Lean and Green Assistance Program** (www.ecy.wa.gov/programs/hwtr/lean): The Washington State Department of Ecology partners with Washington Manufacturing Services to offer partially subsidized, implementation-oriented Lean and environment services to facilities. The three initial pilot projects each involved lean and environment training, a 3-5 day value stream mapping event, and at least three kaizen events. The projects resulted in nearly $1.6 million in cost savings and multiple environmental benefits.

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[3] Some MEP centers have both environmental and Lean technical assistance providers on staff. In addition, an increasing number of MEP centers are working to integrate environmental and energy considerations into their standard Lean services.

[4] Green Suppliers Network. "Green Suppliers Network Program Results," https://www.greensuppliers.gov/gsn/page.gsn?id=success_stories, accessed on 16 April 2009.

- **California Value and Energy Stream Mapping (VeSM) Program** (www.cmtc.com/energy.php) California Manufacturing Technology Consulting has collaborated with major California utilities and separate energy efficiency analysis consultants to measure energy use in value stream mapping events and conduct process improvement events that reduce energy use and costs for manufacturers and distributors. After completing over 20 VeSM projects in southern California, CMTC has expanded the program statewide.
- **New York LE2 Program:** The New York State Pollution Prevention Institute (www.nysp2i.rit.edu) offers integrated Lean, Energy, and Environment (LE2) analytic services to New York manufacturers. This detailed, in-depth value stream analysis involves a lean practitioner, an EHS professional, and an energy expert taking a critical look at the process and identifying inefficiencies, safety and environmental issues, and energy wastes. The LE2 assessment includes an LE2 value stream map, recommendations, a written final report, and a presentation to management and stakeholders. Assistance and training for the implementation may also be available upon request.

Metalworks Lean and Clean Project (Box 6.2)

Metalworks, a metal filing cabinet manufacturer located in northern Michigan, was invited by its customer, Steelcase, to participate in a Green Suppliers Network (GSN) Lean and Clean review. Representatives from Steelcase and the GSN review team assisted Metalworks employees with the development of value stream maps (VSM) of the Ludington facility's product lines. The review team focused on the facility's use of energy, chemicals, and water. Among other things, this process enabled Metalworks to visualize how much water was wasted in the parts washing process.

After the VSM event, the Michigan Department of Environmental Quality helped Metalworks create an inventory of the amount of water used and lost during the parts rinsing process. Armed with this information, Metalworks hired DuBois Chemicals to aid in the design of a rinsing system where water could be reused. Dubois Chemicals developed a cascade rinsing system for Metalworks that standardized processes across three washing systems, reduced heat, and eliminated a stage in the process. Results from the new rinsing system included:

- ✓ Reduced water use by 16 million gallons, saving $30,000 annually.
- ✓ Reduced the amount of chemicals added to the washing processes by 20 percent, saving $20,000.

These established programs do not represent the full range of "Lean and environment" service delivery efforts. For example, the Oregon Manufacturing Extension Partnership (www.omep.org) has partnered with the Pacific Northwest Pollution Prevention Resource Center (PPRC, www.pprc.org) on a few Lean and environment projects, and the Idaho Department of Environmental Quality (www.deq.idaho.gov) has worked with Idaho TechHelp (www.techhelp.org) and PPRC on a Lean and environment project. In addition, several private consulting companies are developing integrated Lean and environment services


Key Point

While Lean and environment technical assistance programs have had substantial success, it is not necessary to have a separate Lean and environment program to enhance the environmental results of Lean implementation. Some Lean service providers are moving towards integrating environmental and energy considerations into standard Lean training curricula, tools, and service delivery approaches, as part of continually improving their efforts. As discussed in the last chapter, there may be some value in de-emphasizing "environment" and similar terms in talking with businesses about Lean and environment services, because of any false perceptions it may generate.

Using Lean to Enhance Environmental Programs and Processes

Just as environmental tools can add value to Lean efforts, the principles and tools of Lean can enhance the effectiveness of environmental programs and processes. Two example applications are as follows.

- **Applying Lean to Government Processes:** EPA and about 20 state environmental agencies have successfully used Lean methods to improve the efficiency and effectiveness of permitting and other agency processes. The results these agencies have achieved are impressive. For example, the Vermont Department of Environmental Conservation cut the time needed to process a wastewater permit application from a maximum of 542 days to 34 days. The Iowa Department of Natural Resources eliminated a 600-permit backlog in air construction permits within 6 months of a Lean event and cut process steps by 70 percent. For more information, see Box 6.3.

New Tool

EPA Lean Government Resources (Box 6.3)

EPA and the Environmental Council of the States (ECOS) have developed a series of publications related to using Lean and Six Sigma to improve permitting and other agency processes. Resources include:

- ✓ EPA Lean Government Website (www.epa.gov/lean/leangovernment.htm) and ECOS Lean Government Website (www.ecos.org/section/projects/?id=2292), which provide background information, case studies, and resources on the use of Lean and Six Sigma at environmental agencies
- ✓ *The Lean in Government Starter Kit* (www.epa.gov/lean/starterkit), which explains how to get started with Lean implementation at government agencies and provides a collection of practical resources that can be downloaded to support agency Lean efforts
- ✓ *Working Smart for Environmental Protection* primer (www.epa.gov/lean/toolkit/LeanGovtPrimer.pdf), which describes how Lean and Six Sigma apply to government and summarizes the results and lessons learned from the Lean and Six Sigma efforts of five state environmental agencies
- ✓ *Lean in Air Permitting Guide* (www.epa.gov/lean/airpermitting), which builds on the Starter Kit to describe specific examples of how Lean has been used to improve air permitting processes

- **Applying Lean Concepts to Compliance Assistance Resources and Environmental Management Systems:** Visual controls, standard work, 6S (5S + Safety), and other Lean Six Sigma tools can be very effective for increasing awareness and use of appropriate procedures and practices for protecting worker health, safety, and the environment. See Figure 6.1 for an example of using visual controls to assist with regulatory compliance.

Figure 6.1: Visual Controls and Standard Work to Encourage Compliance

Lessons from the Field

Although there is no single "right" way to do Lean and environment, practitioners and service providers with Lean and environment experience have shared a variety of tips and suggestions for environmental professionals based on what has worked well and not well in previous efforts. These suggestions address some common pitfalls when environmental professionals engage with Lean (Box 6.4).

Participating in Lean Activities

- *It's not necessary to be a Lean expert before participating in an event.* Many practitioners recommend, "Just do it." The best way to learn about Lean—and Lean and environment—is to participate in events and look for opportunities where you can add value in the process.
- While environmental professionals can add value in most any Lean or Six Sigma project, they can offer the greatest service in Lean events that include processes with significant environmental impacts or issues. Two key strategic areas for involvement of environmental personnel are:
    - Participating in value stream mapping events, when teams examine the entire value stream or process and plan future Lean activities
    - Planning for and participating in kaizen events that address environmentally sensitive processes or processes that generate significant amounts of environmental wastes
- Some of the best ways to find wastes and improvement opportunities are very simple. For example, walking through the value stream, closely observing how processes actually work, and asking questions can yield considerable benefits (see Box 6.5).
- Similarly, simple tools and solutions tend to work best in Lean. For example, photos and videos of processes are very useful as training tools.

Common Pitfalls When Environmental Professionals Engage with Lean (Box 6.4)

- ✓ Saying "No" without first asking about alternative solutions
- ✓ Trying to do things on one's own, rather than as part of a team
- ✓ Ignoring small and easy improvement opportunities
- ✓ Getting mired in the details and over-analyzing the situation

The Power of "Walking the Shop Floor" and Asking Questions (Box 6.5)

- ✓ At a large company, two Environmental Health and Safety (EHS) professionals were walking the shop floor to identify wastes and noticed workers sorting new, empty shipping boxes into two piles before loading them onto the packing line.
- ✓ The EHS professionals asked the workers why they were sorting boxes and learned that one pile of boxes was being discarded because the printed part number was off center.
- ✓ The discard pile was about the same size as the pile of boxes that would be used.
- ✓ After checking with the customer, the EHS professionals learned that the boxes did not need to have part numbers at all.
- ✓ After years of doing the process the same way, the company asked its supplier to stop printing the old part number on the boxes.
- ✓ The supplier was happy to oblige, and this saved large amounts of new boxes from being thrown away, as well as ink and labor.

Examples like this are common when people take the time to observe processes firsthand and ask questions.

Developing Lean and Environment Service Delivery Partnerships[5]


Key Point

- There is great potential for mutual gain from partnerships between Lean and environmental service providers, such as environmental agency technical assistance programs and NIST MEP centers. Nevertheless, *it is important to be aware of the differences between "government culture" and "manufacturing culture."*
- Lean and environmental service providers may need to make adjustments to work more effectively and efficiently as a team.
- It is important to respect the client's agenda and to work from a results-oriented view. For this reason, it can be helpful to let the MEP or other Lean provider lead the process of marketing the project to clients and negotiating the client interactions to define the scope of the project.

[5] For additional recommendations and lessons learned from joint Lean and environment service delivery efforts, see Washington State Department of Ecology, "Washington Lean and Environment Project Final Report," August 2008, available at www.ecy.wa.gov/pubs/0704033.pdf.


Caution

- Clearly establishing and communicating the roles for environmental personnel, especially those from regulatory agencies, can address common misperceptions. *Workers may assume that people from environmental agencies are there to find regulatory compliance violations rather than to provide technical assistance.*
- Find a balance between metrics that serve the environmental agency and metrics that serve the client. While it may be appropriate to identify "soft" cost savings and benefits in projects, it may not be productive to push for detailed calculation of these benefits. Doing so can take significant effort and potentially undermine the facility's ownership of the results.
- Having grant funding or other financial assistance to "buy into the game" for Lean and environment projects is helpful; however, sometimes subsidized or free services can raise a red flag for companies.
- The amount of staff and funding available for Lean and environment technical assistance efforts influences the scale of those efforts, not whether they are possible to do. For example, it is possible to be strategic about when environmental agency staff engages in Lean activities. Even small Lean and environment efforts can generate compelling results.

With the expansion of Lean implementation in manufacturing and industry, as well as the growing recognition of the importance of environmental, energy, and sustainability issues, environmental professionals are well positioned to leverage Lean business trends to reduce wastes and improve environmental outcomes.

CHAPTER 7
Conclusion

This chapter contains the following sections:

- Reflections on This Guide
- Your Lean and Environment Journey

Reflections on This Guide

As this guide has described, Lean and Six Sigma are powerful improvement methods that are growing in importance to businesses worldwide. Lean and Six Sigma improve environmental results by eliminating production "wastes" and variation. However, on their own, Lean and Six Sigma can create environmental health and safety problems or overlook opportunities to address environmental wastes. Furthermore, Lean, Six Sigma, and environmental professionals often operate in "parallel universes," using different languages and involving different people, despite having synergistic goals and using some similar tools.

There are compelling benefits from linking Lean, Six Sigma, and environmental improvement efforts. Environmental health and safety professionals can leverage the continuous improvement culture fostered by Lean to improve environmental results and deliver greater business value. There are multiple successful models for integrating Lean and environmental improvement efforts. These include ways that organizations have linked Lean to environmental efforts at facilities, as well as partnerships between Lean and environmental technical assistance providers.

Getting started with Lean and environment is as simple as learning about Lean, building relationships with Lean practitioners, and trying it out, even if that means starting small. There is no single "right" way to do Lean and environment—do what makes the most sense for your organization.

Your Lean and Environment Journey

Lean practitioners often talk about Lean as a journey. In many ways, Lean and environment represents one stage in that journey. In the long term, we hope that Lean practitioners will commonly consider environmental wastes as one of the "deadly wastes" targeted by Lean and will see environmental professionals as key partners in improving operational performance. Similarly, we hope that environmental professionals will see the value of Lean for achieving environmental objectives and will integrate Lean into their core activities.

We hope this guide has given you ideas for getting started with integrating environmental initiatives into Lean efforts and provided some strategies and guidance for being successful in those efforts. EPA welcomes your stories and feedback as you embark on your Lean and environment journey.

EPA Lean and Environment Contacts (Box 7.1)

To learn more about EPA's Lean and environment efforts and to share your ideas and experiences, visit the EPA Lean website (www.epa.gov/lean) and/or contact the following individuals.

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APPENDICES

Appendix A

Lean and Six Sigma Resources

This appendix lists Lean and Six Sigma resources, including:

- Books on Lean Thinking and Principles
- Books on Six Sigma
- Books and Articles on Methods Used in Lean and Six Sigma
- Websites

Books on Lean Thinking and Principles

Flinchbaugh, Jamie and Andy Carlino. *The Hitchhiker's Guide to Lean: Lessons from the Road*. Dearborn, MI: Society for Manufacturing Engineers, 2006.

Liker, Jeffrey K. (ed.) *Becoming Lean: Inside Stories of U.S. Manufacturers*. Portland, OR: Productivity Press, 1998.

Liker, Jeffrey K. *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. New York: McGraw-Hill, 2004.

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EPA Lean and Environment Website, www.epa.gov/lean. (This website provides information on the relationship of Lean to the environment, case studies, and tools for integrating environmental

considerations into Lean methods. A separate section of this website focuses on Lean government.)

EPA Lean Thinking and Methods Webpage, www.epa.gov/lean/thinking. (This provides descriptions of methods used in Lean and Six Sigma.)

Lean Enterprise Institute, www.lean.org. (LEI is a non-profit research and training organization focused on value stream mapping and Lean principles.)

National Association of Manufacturers, www.nam.org. (This organization is working towards modernization of U.S. manufacturing and making U.S. manufacturing more competitive.)

National Institute of Standards and Technology Manufacturing Extension Partnership, www.mep.nist.gov. (NIST MEP Centers are non-profit Lean technical assistance providers.)

Productivity Press, www.productivitypress.com. (Productivity Press is a private Lean publishing company.)

The Northwest Lean Network, www.nwlean.net. (The Northwest Lean Network assists manufactures with the implementation of Lean systems.)

Appendix B

Lean and Environment Resources

This appendix lists resources related to the integration of environmental considerations into Lean and Six Sigma sections include:

- Lean and Environment Publications
- Lean and Environment Websites

Lean and Environment Publications

U.S. Environmental Protection Agency. *Lean and Environment Toolkit*. Revised October 2007. www.epa.gov/lean/toolkit.

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Waldrip, Greg. "Integrating the Elements for Sustainable Manufacturing." *Environmental Quality Management* (Winter 1999): 33–43.

Wlodarczyk, Judy, Robert B Pojasek, Dave Moore, and Greg Waldrip. "Using a Systems Approach to Improve Process and Environmental Performance," *Environmental Quality Management* (Summer 2000): 53–62.

Lean and Environment Websites

EPA Lean and Environment Website, www.epa.gov/lean. (This websites provides information on the relationship of Lean to the environment, case studies, and tools for integrating environmental considerations into Lean methods. A separate section of this website focuses on Lean government.)

Green Suppliers Network, www.greensuppliers.gov. (In this EPA and NIST MEP program, Lean and environmental assistance providers conduct "Lean and Clean" reviews with small and medium sized manufacturers.)

Lean and Green Summit, www.leanandgreensummit.com. (The Lean and Green Summit is an annual conference on Lean and environment.)

P2Rx Lean and Environment Topic, www.p2rx.org/topichubs. (A guide to information and resources on Lean manufacturing and the environment.)

Society of Manufacturing Engineers, Lean to Green Sustainability Tech Group, www.sme.org/leantogreen. (This group supports webinars, conferences, and information exchange among members on the topic of using the lessons of Lean manufacturing to face the challenges of sustainability.)

Washington State Department of Ecology, Lean and Environment website, www.ecy.wa.gov/programs/hwtr/lean. (This website contains case studies from Lean and Environment Pilot Projects.)

Appendix C

Lean and Six Sigma Glossary

This appendix contains:

- Lean and Six Sigma Acronyms and Abbreviations
- Lean and Six Sigma Terms and Definitions

Lean and Six Sigma Acronyms and Abbreviations

DFLSS	Design for Lean Six Sigma
DFMA	Design for Manufacturing and Assembly
DMAIC	Define, Measure, Analyze, Improve, and Control
DOE	Design of Experiments
FMEA	Failure Mode Effect Analysis
JIT	Just-in-time
POUS	Point of Use Storage
QFD	Quality Function Deployment
TPM	Total Productive Maintenance
TPS	Toyota Production System
VSM	Value Stream Mapping or Value Stream Map
WIP	Work in Process

Lean and Six Sigma Terms and Definitions[6]

5 Whys Approach	The approach of asking "why" five times to explore the cause/effect relationships underlying a particular problem and determine a root cause of a defect or problem.
5S or 6S	A method used to create and maintain a clean, orderly, and safe work environment. 6S is based upon the five pillars (5S) of the visual workplace in the Toyota Production System, plus a separate pillar for safety. The 6 pillars are: Sort, Set in order, Shine, Standardize, Sustain, and Safety.

[6] Sources of these definitions include Productivity Press Development Team, *LeanSpeak: The Productivity Business Improvement Directory*, Productivity Press, 2002, and the Lean and Green Summit, "Lean and Green Glossary," available from www.leanandgreensummit.com/resources.asp.

3P	Production Preparation Process (3P) is a lean method for product and/or process design. 3P designs and implements production processes, tools, and equipment that support one-piece flow, are designed for ease of manufacturing, and achieve appropriate cost, quality, and lead time. Also known as *Pre-Production Planning*.
A	
A3	Manufacturers use the A3 method to write reports or "storylines" to solve problems, report project status, and propose changes in policy. "A3" refers to the size of paper used.
B	
Batch and Queue	The mass production process of making large lots of a part and then sending the batch to wait in the queue until the next operation in the production process begins. Contrast with *one-piece-flow*.
Bottleneck	Any part of a production line that adversely affects throughput. See also *constraint*.
C	
Cause-and-Effect Diagram	A cause-and-effect diagram is also known as fishbone diagram or an Ishikawa diagram (after its originator, Karoru Ishikawa). This technique is used to trigger ideas and promote a balanced approach in group brainstorming sessions where individuals list causes and effects of problems.
Cell	An arrangement of machinery, tools, and personnel designed to most logically and efficiently complete a production sequence. Cells help enable *one-piece flow*.
Cellular Manufacturing	An approach in where manufacturing work centers (cells) have the total capabilities needed to produce an item or group of similar items; contrasts to setting up work centers on the basis of similar equipment or capabilities, in which case items must move among multiple work centers before they are completed.
Chaku-Chaku	A method of conducting one-piece flow, where the operator proceeds from machine to machine, taking the part from one machine and loading it into the next. Japanese for "load, load."
Changeover Time	The time that elapses between the completion of one production run and the beginning of another production run.
Constraint	Anything that limits a system from achieving higher performance or throughput.
Cycle Time	The amount of time to accomplish the standard work sequence for one product, excluding queue (wait) time. If the cycle time for every operation in a process can be reduced to equal *takt* time, products can be made in one-piece flow.

D	
Define, Measure, Analyze, Improve, and Control (DMAIC)	The DMAIC process is used to guide implementation of Six Sigma statistical tools and to identify process wastes and variation.
Design of Experiments (DOE)	Design of experiments offers a structured statistical approach to understanding the factors that affect a process and then create meaningful and effective tests to verify possible improvement ideas or theories. DOE is a good method for discovering and validating the relationships between the inputs and outputs in a process, in order to obtain improved results.
Design for Lean Six Sigma	A method for designing processes that support Lean Six Sigma objectives, such as reduced variability, to improve yield, reduce waste, and accelerate time-to-market.
Design for Manufacturing and Assembly (DFMA)	A simultaneous engineering process designed to optimize the relationship between design function, manufacturability, and ease of assembly.
F	
Failure Mode Effect Analysis (FMEA)	A technique used to identify potential failure modes or causes of failures that may occur as a result of design or process deficiencies. FMEA is used to estimate the effects and level of severity of failures, and identify corrective design options or process changes.
H	
Heijunka (Load Leveling)	The principle of keeping total manufacturing volume and mix as constant as possible. Synonymous with level load scheduling or production smoothing.
Hoshin Kanri (Policy Deployment)	A method devised to capture goals, projects to achieve the goals, designation of people and resources for project completion and establishment of project metrics. It is also a way to capture flashes of insight about the future and develop ways to make the future a reality.
I	
Inventory	Goods and materials that a business has available in stock.
J	
Jidoka (Autonomation)	Stopping a line automatically when a defective part is detected.

Just in Time	A production scheduling concept that calls for any item needed at a production operation—whether raw material, finished item, or anything in between—to be produced and available precisely when needed.
K	
Kaikaku	This term refers to "quantum leap" or "breakthrough" improvements that are significantly greater than the level of gains typically achieved through daily continual improvement activities. Japanese for "radical improvement of an activity."
Kaizen	The incremental and continual improvement of production activities aimed at reducing waste, and designed around planned, structured worker-oriented events. Kaizen is a combination of two Japanese words meaning "to take apart" and "make good."
Kanban	A card or sheet used to authorize production or movement of an item.
Kanban System	A system that controls production inventory and movement through the visual control of operations.
L	
Large Lot Production	The production of the same product or service in large quantities during a single, designated period of time. This is *not* characteristic of Lean manufacturing.
Lead Time	The total amount of time it takes to produce and deliver a product to a customer, from start to finish, including idle time and other non-value added activities.
Lean Supplier Network	A buyer-supplier relationship where designated lean production protocols, supporting sustained interactions between members, helps produce a network-based competitive advantage.
M	
Mistake Proofing	Technology and procedures designed to prevent defects and equipment malfunction during manufacturing processes. Also known in Japanese as *Poka-Yoke.*
Monument	A production machine or tool that is difficult and/or costly to move due to its size or other physical constraint. Often materials must be brought to the monument in batches.
Muda (Waste)	The Japanese term for any human activity that absorbs resources, but creates no real value (i.e., waste; activities and results to be eliminated). Categories of waste in Lean include: defects, overproduction, transport of materials, unnecessary movement, waiting, inventory, and over-processing.

N	
Non-Value-Added	Activities or actions taken that add no real value to the product or service from a customer's perspective, making such activities or actions a form of waste.
O	
One-Piece Flow	A situation in which products proceed, one complete product at a time, through various operations in design, order-taking, and production, without interruptions, backflows, or scrap. Also known as *single-piece flow*.
P	
Pacemaker	Any process point along a value stream that sets the pace for the entire stream.
Pitch	The time needed in a production area to make one container of products. For example, if *takt* time equals 30 seconds and pack size is 20 pieces, pitch is 10 minutes.
Pareto Charts	Pareto charts weigh each type of defect according to severity, cost of repair, and other factors in order to determine which types of defects occur most frequently. The Pareto chart is a bar graph arranged in descending order of size of importance from left to right.
Point-of-Use Storage (POUS)	Point-of-use is a system in which all necessary supplies, chemicals, etc. are within arm's reach of the worker, and positioned in a logical sequence of use.
Poka-Yoke	See *Mistake Proofing*
Policy Deployment	See *Hoshin Kanri*
Pull Production System	A production system in which nothing is produced by the upstream supplier until a need is signaled by the downstream customer.
Q	
Quality Function Deployment	A method used to transform customer demand into design quality and ultimately the manufacturing process.
Queue Time	The time a material spends waiting in line for use in the production process.
R	
Right-sized	The matching of production tooling and equipment in a scale that enables its use in the direct flow of products such that no unnecessary transport or waiting is required.

S	
Six Sigma	Six Sigma is a continual improvement philosophy and a set of statistical analysis methods quality used to identify and reduce process variation in products and processes.
Supermarket	A tightly managed amount of inventory within the value stream to allow for a pull system. Supermarkets, often called inventory buffers, can contain finished items or work-in-process.
Supply Chain	A group of all suppliers involved in the manufacture of a product, beginning with the simplest part and ending with the production of the final product.
T	
Takt Time	The available production time divided by the rate of customer demand. *Takt* time sets the pace of production to match the rate of customer demand and becomes the beat of a lean system.
Total Productive Maintenance (TPM)	A Lean method that focuses on optimizing the effectiveness of manufacturing equipment. Total Productive Maintenance builds upon established equipment-management approaches and focuses on team-based maintenance that involves employees at every level and function.
Toyota Production System (TPS)	The manufacturing strategy of Toyota, upon which the terms "Lean production" and "Lean manufacturing" are based.
V	
Value Stream	All activities (value added and non-value added) involved in producing a product or delivering a service to a customer, from receipt of raw materials to the delivery of finished products to the customer.
Value Stream Mapping	A process mapping method used to document the current and future states of the information and material flows in a value stream.
Visual Controls	Visual mechanisms for creating a transparent, orderly, and waste-free environment. This includes displaying the status of an activity so employees can see it and take appropriate actions.
W	
Work in Process (WIP)	Production material in the process of being converted into a saleable product.
Y	
Yokoten	The principle of replicating actions and sharing best practices from one project to another, to emphasize learning at an organizational level. Yokoten means "across everywhere."

Appendix D

Environmental Glossary

This appendix includes:

- Environmental Acronym and Abbreviation List
- Lean and Environment Terms and Definitions

Environmental Acronyms and Abbreviations

CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act ("Superfund")
CWA	Clean Water Act
DfE	Design for the Environment
EHS	Environmental Health and Safety
EJ	Environmental Justice
EMS	Environmental Management System
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
GRI	Global Reporting Initiative
LCA	Life Cycle Assessment
P2	Pollution Prevention
OSHA	Occupational Safety and Health Administration
RCRA	Resource Conservation and Recovery Act
TRI	Toxic Release Inventory
TSCA	Toxic Substances Control Act

Environmental Terms and Definitions[7]

B

Biofuel	Fuel created from renewable, biological sources such as plants or animal byproducts, but excluding biological material (such as natural gas, coal, or methane) that has been transformed by geological processes.

[7] Most of these definitions are from the Lean and Green Summit, "Lean and Green Glossary," available from www.leanandgreensummit.com/resources.asp.

C	
Carbon Footprint	The total amount of greenhouse gases emitted directly or indirectly through any human activity, typically expressed in equivalent tons of carbon dioxide.
Clean Air Act (CAA)	Federal legislation passed in 1970 and amended in 1990 that authorizes the EPA to set National Ambient Air Quality Standards and to regulate industry in order to meet those maximum emissions levels.
Clean Water Act (CWA)	Federal legislation passed in 1972 and amended in 1976 that requires the EPA to set maximum pollutant levels for each known contaminant in U.S. surface waters and authorizes the EPA to regulate industrial discharge in order to meet those standards.
Closed-loop Recycling	A process of utilizing a recycled product in the manufacturing of a similar product or the remanufacturing of the same product.
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)	Federal legislation passed in 1980 that established a tax on the petroleum and chemical industries to fund cleanup of hazardous waste sites, as well as establishing EPA authority to assign responsibility for that cleanup to the polluters or purchasers of contaminated land. Often referred to as "Superfund."
Corporate Social Responsibility	The continuing commitment by businesses to behave ethically and contribute to economic development while improving the quality of life of the workplace as well as the local community and society at large.
E	
Ecological Footprint	The total amount of land, food, water, and other resources used by, or the total ecological impact of, a person or organization's subsistence; usually measured in acres or hectares of productive land.
Environmental Justice	The concept of equal access to environmental resources and protection from environmental hazards regardless of race, ethnicity, national origin, or income.
G	
Global Reporting Initiative (GRI)	A reporting standard generally accepted to be the leading international standard for reporting social, environmental, and economic performance.
Green Building	A comprehensive process of design and construction that employs techniques to minimize adverse environmental impacts and reduce the energy consumption of a building, while contributing to the health and productivity of its occupants.

Green Design	The design of products, services, buildings, or experiences that are sensitive to environmental issues and achieve greater efficiency and effectiveness in terms of energy and materials use.
Greenhouse Gas (GHG)	A gas that contributes to the natural greenhouse effect, whereby heat is trapped within the Earth's atmosphere, including: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.
L	
LEED Certification	An acronym for Leadership in Energy and Environmental Design, a program sponsored by the United States Green Building Council that creates standards for developing high performance, sustainable buildings.
Life Cycle Analysis (LCA)	A process of evaluating the effects of a product or its designated function on the environment over the entire period of the product's life in order to increase resource-use efficiency and decrease liabilities; commonly referred to as "cradle-to-grave" analysis.
N	
Natural Capital	A company's environmental assets and natural resources existing in the physical environment, either owned (such as mineral, forest, or energy resources) or simply utilized in business operations (such as clean water and atmosphere).
Non-Governmental Organization (NGO)	A private, non-profit organization that is independent of business and government, that works toward some specific social, environmental, or economic goal through research, activism, training, promotion, advocacy, lobbying, community service, etc.
O	
Open-Loop Recycling	A recycling process in which materials from old products are made into new products in a manner that changes the inherent properties of the materials.
Organic	A term signifying the absence of pesticides, hormones, synthetic fertilizers and other toxic materials in the cultivation of agricultural products; "organic" is also a food labeling term that denotes the product was produced under the authority of the Organic Foods Production Act.
S	
Socially Responsible Investing (SRI)	An investment practice that gives preference to companies that value social and environmental impacts in addition to financial gain.

Sustainability	The successful meeting of present social, economic, and environmental needs without compromising the ability of future generation to meet their own needs; derived from the most common definition of sustainability, created in 1987 at the World Commission on Environment and Development.
Sustainable Design	A process of product, service, or organizational design that complies with the principles of social, economic, and environmental sustainability.
Sustainable Development	Development that utilizes tools, supplies and strategies that protect and enhance the earth's natural resources and diverse eco-systems so as to meet the social and economic needs of the present without compromising the ability to meet the needs of the future.
T	
Toxic Substances Control Act	This Act gives EPA the authority to require companies to report and keep records of the hazardous substances that they use. It also sets testing requirements on certain hazardous chemicals and restrictions on use of certain hazardous chemicals.
Transparency	A measure of increased accountability and decreased corruption in which a business reports on its ethics and performance results through accessible publication of the business' practices and behavior.
Triple Bottom Line	A phrase describing a company's improved top line financial performance over the long term due to sustainable business practices, including less capital investment and increased revenues. The triple bottom line refers to environmental, social, and economic sustainability.
W	
Waste-to-Energy	A recovery process in which waste is incinerated or otherwise turned into steam or electricity, and used to generate heat, light or power through the process of combustion.
Waste-to-Profit	The process of using one company's waste or byproduct as the input or raw material for another company, thereby increasing business profits and decreasing waste; also referred to as "byproduct synergy."

Appendix E

Summary of the Washington Lean and Environment Pilot Projects

The Washington State Department of Ecology's (Ecology) Hazardous Waste and Toxics Reduction (HWTR) Program and Washington Manufacturing Services (WMS) partnered in a project to provide Lean and environmental technical assistance to manufacturing facilities in Washington State through three pilot projects. Participating facilities included:

- **Canyon Creek Cabinet Company** (Canyon Creek), a large manufacturer of custom frameless and framed style cabinetry in Monroe.
- **Lasco Bathware** (Lasco), a manufacturer of fiberglass and acrylic bath and shower fixtures in Yelm.
- **Columbia Paint & Coatings** (Columbia Paint, now part of Sherwin-Williams), a manufacturer of residential, architectural, and industrial paint and coatings in Spokane.

Ecology provided environmental expertise for the pilot projects, while WMS provided Lean manufacturing expertise and management of on-site activities at the facilities. The overall project objectives were to: (1) develop a partnership between Ecology and WMS, (2) evaluate the benefits of deliberately integrating environmental tools into Lean practices, and (3) gain the expertise to offer and promote future Lean and environment projects to manufacturers statewide. EPA, Ecology, and NIST contributed funding to the project, while each facility paid a portion of the costs for WMS' Lean facilitation services.

Project Activities

Ecology and WMS jointly marketed the pilot projects to manufacturers across Washington and selected facilities based on their ability to meet certain criteria (e.g., demonstrating potential for environmental improvement and securing management buy-in). Each pilot project included the following on-site activities:

- Lean 101 and environment training (for facilities new to Lean)
- Value stream mapping workshop (4–5 days) designed to assess the current state of the value stream or process and identify improvement projects
- 3–5 kaizen events (or "get 'r done" events), each lasting 4–5 days, to implement process changes, document results, and develop standard work for the new process or operations

Roles of Environmental Professionals

Ecology's technical assistance staff participated and added value to the Lean and environment pilot projects in a variety of ways, including the following.

Project Design, Scoping, and Planning

- Worked with facilities and Lean service providers to determine the scope and objectives of the Lean improvement projects, and built relationships with participants to support their long-term success.

Lean and Environment Training

- Conducted portions of "Lean 101" training for facility managers and staff, ensuring that Lean efforts consider the full range of wastes.

Value Stream Mapping Workshop Participation

- Helped participants to document the "current state" of the value stream or process, including analyzing data on environmental wastes and costs.
- Built the capacity for employees to "learn to see" environmental wastes and look for environmental improvement opportunities.
- Supplemented value stream mapping with P2 process mapping to look more closely at the inputs and outputs of processes.
- Participated in brainstorming discussions with the lean team to identify process-improvement opportunities and develop an implementation plan.

Kaizen Event (or "Get 'R Done" Event) Participation

- Participated in kaizen events as team members and assisted with the planning and implementation of process changes.
- Worked with the team to collect and analyze "before" and "after" metrics of the process changes, including environmental data and cost savings.
- Assisted the facility with promptly addressing any potential regulatory compliance issues.
- Provided environmental technical assistance and training for staff to support the project's objectives and ensure the sustainability of the results.

Follow Up

- Followed up with the facility to answer questions, check on the status of action items, and identify needs for technical assistance.

Pilot Project Results

The pilot projects yielded impressive operational and environmental results. Cost, time, and environmental savings at each facility are summarized in Table AE-1.

Table AE-1: Washington Lean and Environment Pilot Project Results

	Canyon Creek Cabinet Company		Lasco Bathware		Columbia Paint & Coatings	
Reductions	**Time and Environmental Savings**	**Cost Savings**	**Time and Environmental Savings**	**Cost Savings**	**Time and Environmental Savings**	**Cost Savings**
Raw Material and Solid Waste	1,800 wood sheets 10,400 parts	$376,000	43,200 lbs resin 29,000 lbs overspray[i]	$24,400	49,200 lbs paint solids 18,000 lbs shrink wrap	$109,200
Hazardous Substances and Waste	68,700 lbs purchase 86,400 lbs disposal	$165,600	—	—	17,600 lbs disposal	$10,000
Air Emissions	55,100 lbs of volatile organic compounds	N/A	—	—	—	—
Wastewater	—	—	—	—	39,600 gallons	(included above)[ii]
Labor[iii]	39,000 hours	$624,000	2,200 hours	$35,500	2,500 hours	$90,600
Energy	20,700 therms	$24,000	126,000 therms	$99,300	—	—
Cost Savings Subtotal		$1,189,600	$158,200		$209,800	
Total Cost Savings:	$1,557,600 per year					

[i] Estimated potential savings for production of one of Lasco's common models, based on measurements conducted during the kaizen event in 2007.

[ii] Cost and material savings associated with the paint solids in wash water are included with raw material savings for the Columbia Paint pilot project.

[iii] The labor savings estimates are conservative. Labor hours were reassigned to other value-added activities.

In addition to these savings, other improvements from the pilot projects included:

- Increased production without the need of a Clean Air Act Title V air permit at one facility.
- Reduced total lead time for producing products.

- Increased flexibility and efficiency of production, enabling facilities to be more responsive to customer demands and more competitive in the marketplace.
- Reduced product defects, improved overall workplace organization and ergonomics, and reduced worker exposure levels.
- Enhanced staff morale, improved communication between staff and management, and empowered staff to initiate process improvement activities.

Concurrently with the three pilot projects, WMS and Ecology worked on several separate Lean and environment efforts with other manufacturers in Washington. WMS and Ecology have also continued to develop and enhance their partnership.

For More Information

For more information about the pilot projects, including case studies and a final report describing lessons learned and recommendations, see Ecology's Lean and Environment website at www.ecy.wa.gov/programs/hwtr/lean.

United States Environmental Protection Agency
www.epa.gov/lean
August 2009
EPA-100-K-09-006