Findings and Recommendations on Lean Production and Environmental Management Systems in the Shipbuilding and Ship Repair Sector

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DISCLAIMER

The shipbuilding and ship repair companies interviewed for this report have reviewed the descriptions of their activities for accuracy. The conclusions and recommendations in this report, however, are those of Ross & Associates and do not necessarily represent the opinions of the U.S. Environmental Protection Agency or the shipbuilding and ship repair companies.

Findings and Recommendations on Lean Production and Environmental Management Systems in the Shipbuilding and Ship Repair Sector

The purpose of this report is to summarize research and findings on the relationship between lean production and environmental management systems (EMSs) in the shipbuilding and ship repair sector. In addition, this report includes recommendations for actions the U.S. Environmental Protection Agency (EPA) could consider taking to improve environmental performance related to lean and EMS. The report is organized into the following sections:

I. Research Methodology
II. Background on Lean Production and Environmental Management Systems
III. Lean and EMS Findings
IV. Lean and EMS Opportunity Areas
V. Recommendations for EPA

I. Research Methodology

To research the links between lean production and EMSs, Ross & Associates conducted a background literature review and a series of interviews with environmental, health, and safety (EHS) managers and lean managers at five shipbuilding and ship repair companies. The purpose of the literature review was to gather general information about the companies and their lean and EMS implementation experience and to identify any studies on the relationship between lean and EMS. Ross & Associates also previously conducted research for EPA on lean and the environment (see www.epa.gov/innovation/leanreport.pdf). The shipbuilding and ship repair companies interviewed were:

- Bath Iron Works, Bath, Maine;
- Bender Shipbuilding and Repair Company, Mobile, Alabama;
- Northrop Grumman Newport News, Newport News, Virginia;
- Southwest Marine Inc., San Diego, California; and
- Todd Pacific Shipyards Corporation, Seattle, Washington.

All of the companies have implemented lean production for the last 1-3 or more years, but the companies are at different stages in their implementation of EMSs. Two companies (Bath Iron Works and Newport News) have ISO 14001 certified EMSs, two others (Bender and Southwest Marine) are pursuing or are about to pursue ISO 14001 certification, and one (Todd Pacific) has not yet adopted a formal EMS. In addition to the company interviews, Ross & Associates contacted the Lean Shipbuilding Initiative, a project of National Shipbuilding Research Program, to explore opportunities for outreach to lean practitioners in the shipbuilding industry. A list of the interviewees is in Appendix A.

II. Background on Lean Production and Environmental Management Systems

This section defines “lean production” and “environmental management systems” and compares them on several dimensions.

What is the lean production system?

Lean production refers to a business model that emphasizes meeting customer expectations by delivering quality products and services at the least cost when the customer wants them.[1] The Lean Aerospace Initiative has defined "lean thinking" as:

> *The dynamic, knowledge-driven, and customer-focused process through which all people in a defined enterprise continuously eliminate waste with the goal of creating value.*[2]

The lean production system contains several important principles as well as a collection of tactical methods for achieving them. 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;
- Use *metrics and rapid performance feedback* to improve real-time decision-making and problem-solving; and
- Approach improvement activities from a *whole enterprise or system perspective*.

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. Figure 1 illustrates how lean approaches differ from traditional production paradigms.

Figure 1: How Craft, Mass Production, and Lean Thinking Compare[3]

	Craft Production	*Mass Production*	*Lean Production*
Focus	Task	Product	Customer
Operations	Single items	Batch and queue	Synchronized flow and pull
Overall Aim	Mastery of craft	Reduce cost and increase efficiency	Eliminate waste and add value
Quality	Integration (part of the craft)	Inspection (a second stage, after production)	Prevention (built in by design and methods)
Business Strategy	Customization	Economies of scale and automation	Flexibility and adaptability
Improvement	Master-driven continuous improvement	Expert-driven periodic improvement	Workforce-driven continuous improvement

[1] James Womack, Daniel Jones, and Daniel Roos coined the term "lean production" in their 1990 book *The Machine that Changed the World* to describe the manufacturing paradigm established by the Toyota Production System. Beginning in the 1950s, the Toyota Motor Company pioneered the development of lean principles and methods drawing on concepts developed by Henry Ford and Deming.

[2] Lean Aerospace Initiative. *Lean Enterprise Value: Insights from MIT's Lean Aerospace Initiative*. New York: Palgrave, 2002, p. 90.

[3] Lean Aerospace Initiative, p. 97.

Lean principles are supported by a set of commonly used tactical methods. Common methods in the lean toolbox include 5S, value stream mapping, *kaizen* rapid improvement events, Pre-Production Planning (3P), Total Productive Maintenance (TPM), *chaku-chaku* ("load-load"), *poka yoke* ("mistake-proofing"), just-in-time, and cellular design.[4] Some lean organizations also rely heavily on Six Sigma, which includes a set of statistical techniques for identifying and reducing process variation.[5] Each of these tactical methods and tools have clearly defined process steps, techniques, and desired outcomes. Most lean tools are implemented in short, focused "bursts" that include a condensed planning and implementation phase. 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.

Lean implementation is typically backed by very strong business drivers. Most organizations pursue lean in response to their need to fundamentally improve business competitiveness by reducing costs, while increasing quality and responsiveness to customer needs (e.g., delivery time). These business competitiveness needs can manifest through increases in direct global competition or from evolving customer or supply chain expectations. Lean practitioners often acknowledge that successful lean implementation can require a real or perceived business crisis to justify or foster receptiveness to the significant transformation that lean requires to an organization's culture and processes.

What is an environmental management system (EMS)?

An environmental management system (EMS) is a management framework for reducing environmental impacts and improving organizational performance over time. EMSs provide organizations of all types with a structured approach for managing environmental and regulatory responsibilities to improve overall environmental performance, including areas not subject to regulation such as unregulated risk, resource conservation, and energy efficiency. An EMS helps an organization better integrate the full scope of environmental considerations and get better results, by establishing a continuous process of checking to make sure environmental goals are met. The EMS approach is based on the concept of Total Quality Management (TQM), which was initially developed as a tool by the private sector to achieve higher and more consistent product quality. The framework is based on a plan-do-check-act continual improvement approach that leads an organization through a regular cycle of planning, implementation, performance monitoring, and review/improvement.

With an EMS, an organization develops and routinely evaluates processes and procedures to identify and manage its environmental footprint. An organization looks at selected operations associated with its significant impacts and makes them visible, measurable, manageable, and therefore subject to improvement. An EMS does not impose new technical requirements. Rather, it helps an organization develop its own short- and long-term environmental goals and objectives, its own operational controls, and its own improvement requirements. The EMS may lead an organization to adopt new methods, modify existing ones, or accept the practices it already has in place. The EMS framework can be adapted to support the needs, priorities, and circumstances of the implementing organization. Typically, an EMS

[4] See EPA's *Lean Manufacturing and the Environment* report at http://www.epa.gov/innovation/lean.htm for descriptions of these and other methods.

[5] It should be noted that while the previously mentioned methods are generally unique to lean implementation efforts, there are many organizations that implement Six Sigma without pursuing lean or using other lean methods. In addition, some companies use a problem-solving framework known as DMAIC as part of their Six Sigma implementation. DMAIC refers to a data-driven quality strategy for improving processes, and is an integral part of the company's Six Sigma Quality Initiative. DMAIC is an acronym for five interconnected phases: Define, Measure, Analyze, Improve, and Control.

is used to support continual improvement of activities relevant to environmental performance by helping an organization identify and act on opportunities for improvements.

An organization's decision about whether to implement an EMS, and potentially seek third-party certification (e.g., ISO 14001) for it, is typically based on a comparison of the perceived costs and benefits. To pursue an EMS, organizations typically must decide that one or more of the following outcomes are important to business success:

- A strong environmental compliance management system that reduces the risk of non-compliance situations;
- An effective management system for driving environmental policy objectives through the organization, including into core operations;
- A system to support continual improvement of environmental management processes and performance; and
- A system that generates documentation for purposes of internal and/or external auditability.

In addition to organizations' desires to achieve one or more of these outcomes, there are other drivers that can shift the EMS decision dynamics, such as peer pressure within an industry sector, supply chain pressures or expectations, and the presence of incentives for pursuing an EMS (e.g., EPA's Performance Track Program).

How do lean and EMS systems compare?

Lean and EMS are fundamentally different systems; however, they are highly complementary in certain areas. This thesis is based on a review of literature and research on lean and on EMSs, and it was tested in the context of the interviews conducted with shipbuilding and ship repair companies. At the core, a lean production system is a collection of operationally-oriented tactics and practical tools that are designed to achieve an operating environment that is guided by several philosophical pillars, as identified above. Lean is broad in scope, focusing on the elimination of waste (all non-value added activity) throughout an entire organization and aiming to continually improve processes and products. Lean's drivers are deeply rooted in business competitiveness, capital productivity, and customer satisfaction. An environmental management system, on the other hand, is more of a strategic management framework than a collection of tactical tools. With regard to wastes, an EMS takes a narrower focus than lean by targeting only those wastes that have environmental implications. The drivers for EMS implementation, while often strong, are not typically of the same magnitude with respect to business performance as those behind lean implementation.

While lean and EMS differ significantly along several dimensions, there are also similarities that lead one to expect that they are complementary in nature. First, both lean and EMS have foundations in TQM and rely on a continual improvement philosophy. Second, both lean and EMS focus on eliminating waste, although there are differences in the scope of how "waste" is defined.[6] Third, both lean and EMSs seek to foster an organizational culture that emphasizes employee involvement in problem solving. Figure 2 summarizes lean production systems and EMSs along several dimensions.

[6] EMSs focus on waste in the context of compliance with legal requirements, prevention of pollution, and continual improvement.

Figure 2: Comparison of Lean and EMS

	Lean	EMS
Overall Type	Production philosophy with operationally-oriented tactics and practical tools	Management system framework
Waste Elimination Objectives	Eliminate non-value added activity	Eliminate environmental impacts and risk
Organizational Ownership/ Primary Participants	Operations, with involvement of all employees where appropriate	Environmental professionals, with involvement of all employees where appropriate
Drivers/Motivation	Fundamental business competitiveness and customer expectations; need for improvements in cost, time/ responsiveness, and quality	Need to better or more cost-effectively manage environmental compliance, risk, and performance; and to demonstrate this to external customers/stakeholders
Methods/Tools	Defined toolbox of tactical methods for eliminating different types of waste (e.g., 5S, kaizen, TPM, Just-in-Time)	Programs, processes and procedures designed by organization to support management system framework and to meet objectives and targets
Culture Change	Employee-involved problem-solving culture; empowerment of decision-making to address needs where they occur	Employee-involved problem-solving culture; empowerment of decision-making to address needs where they occur
Improvement	Continual improvement, based on Plan-Do-Check-Act model	Continual improvement, based on Plan-Do-Check-Act model

III. Lean and EMS Findings

This section summarized the findings of the interviews conducted with five companies in the shipbuilding and ship repair sector. Due to the targeted nature of the interview research, these findings may not necessarily apply to all companies within the shipbuilding and ship repair sector, or to organizations implementing lean and/or EMSs in other sectors.

FINDING 1: Common Perception is that EMS and Lean Methods are Synergistic

All of the managers interviewed during this project expressed a strong belief that EMS and lean are compatible and synergistic. They identified the approaches and outcomes of lean and EMS implementation as being complementary. Furthermore, they affirmed that both lean and EMS result in a focus on waste elimination and cost reduction; both have continual improvement orientation; and both depend on common success factors such as management commitment, employee involvement, and adopting a culture of change. For companies that have already decided to pursue an EMS, the interview results indicate that lean initiatives and methods can enhance the success of EMS implementation. In addition, the interview results suggest that an EMS can enhance the environmental benefits derived from lean implementation activities. These potential enhancements are described further below.

FINDING 2: Lean and EMS Integration is "Opportunistic" and in the Early Stages of Planned Coordination

Integration between lean and environmental management are at the early stages in the industry and could generally be characterized to date as more "opportunistic," rather than formally integrated into overall management systems. However, lean and EHS managers are recognizing the value of integration and are

heading towards more planned coordination. For example, EHS managers have found they need to know how changes resulting from lean activities affect environmental aspects and requirements under the EMS and have identified opportunities to implement change management strategies. In addition, lean and EHS managers have found that the similar focus of lean and EMSs on waste reduction presents opportunities to ensure lean activities are attentive to environmental objectives. Moreover, interviewees perceived that there are opportunities for further integration of lean and EMS than have been achieved to date.

Change Management Strategies

Each of the companies interviewed has developed approaches for making sure that changes resulting from lean activities are managed within environmental and health/safety requirements. These change management approaches primarily take the form of EHS personnel involvement in lean events and activities and/or the use of environmental checklists and procedures that ask about environmental implications of proposed process changes.

- Southwest Marine has established a "Tollgate Review" process as part of their lean six sigma activities, which involve the DMAIC (Define, Measure, Analyze, Improve, and Control) process. The "Improve" step in that process includes a check-off list for evaluating environmental impacts. If there are unknowns, the lean project manager must have a face-to-face meeting with the environmental staff. The environmental review includes a weighted system with an aspect identification process.

- Similarly, Bath Iron Works has an environmental checklist that is used for *kaizen* events. Environmental personnel also approve changes to standard work that result from lean events.

- EHS staff and managers often participate in lean process improvement events. Managers from Bath Iron Works, Bender, Todd Pacific, and Southwest Marine all mentioned participating in lean activities such as *kaizen* events and 3P process/product design events. Their participation can be a change management strategy, as the EHS staff bring their knowledge of environmental health and safety requirements and procedures.

Lean Methods to Achieve Environmental Objectives

Companies are beginning to proactively look to lean methods to contribute to achieving their EMS objectives and targets at the least cost. Examples of the environmental benefits of applying lean to environmentally sensitive processes are described further below under the finding 5.

FINDING 3: Lean Thinking about *Muda* (Waste) Did Not Pose a Challenge to EMSs

Lean focuses on eliminating all non-value added activity, or *muda*. Lean practitioners often distinguish between two types of waste: type I *muda*, which is unnecessary and does not add value from the customer's perspective; and type II *muda*, which is an important part of a company's operations that does not necessarily add value to a product or service from the perspective of the customer. In this framework, administrative processes designed to manage environmental performance and compliance with environmental regulations could be considered type II *muda*. Given this, one might expect that a company implementing lean could view certain components of an EMS, such as rigorous documentation requirements, as type I or type II *muda*, or that companies implementing lean might be reluctant to adopt an EMS because of this perception. In our interviews with shipbuilding and ship repair companies, however, lean and environmental managers did *not* believe that EMSs are non-value added in light of adopting lean. In fact, they believed the opposite. They believed that EMSs are a valuable tool for compliance assurance and environmental performance improvement, and noted that many of their

documentation requirements are driven by regulations, not by the EMS itself. Thus, for these companies, an EMS is a useful tool for minimizing the burden of type II *muda* and striving to produce "only what the customer wants."

All but one of the companies involved in the interviews have a formal EMS, but even the company without an EMS believed it had most all of the components of an EMS in place. These companies have adopted EMSs because their industry faces complex environmental management issues. Located on the shores of public waters, environmental management for this sector is high risk and high cost. Environmental management needs range from multi-million dollar storm water management projects to air emissions permits to hazardous waste storage and handling. Interviewees believe that these needs are well supported by the components of an EMS, such as systematic prioritization of risk, defined roles and responsibilities, training, documentation, and standardized procedures.

FINDING 4: EMS Improves/Adds Value to Lean

Interviewees believed that an EMS can add value and improve the implementation of lean methods and activities. An EMS can expand the focus of lean activities by redefining of "waste" to look beyond typical production waste. EMS can also help lean address environmental "blind spots," such as the risk or toxicity of materials used and the full life-cycle impacts of products and processes. For example, an EMS can help focus attention on materials substitution, such as using low volatile organic compound (VOC) paints, which might not be considered under lean (e.g., if high-VOC paints cost less or the same).

FINDING 5: Lean Improves/Adds Value to EMS

Interviewees believed that lean initiatives can improve both the effectiveness and efficiency of an EMS. Lean can improve the effectiveness of an EMS by connecting its continual improvement activities to larger financial drivers. For example, using lean activities to achieve EMS objectives provides a framework to include lean priorities of customer needs and least cost. Since lean has powerful financial drivers (e.g., capital productivity savings and competitiveness benefits from reduced lead times), the marginal effort of incorporating EMS objectives into a lean event can be significantly lower than the effort required to pursue the EMS objectives independently. Lean can also provide techniques for implementing more consistent operational controls in the form of standard work and visual controls.

Interviewees described several ways that lean can help improve the efficiency of an EMS by streamlining EMS implementation. Adopting lean principles has led companies to streamline the documentation maintained under their EMSs. Duplicative/redundant copies of procedures were removed from the shop floor. EMS Manuals were streamlined to reference, rather than contain, many procedures. As standard work procedures are updated and improved as part of lean implementation, the EMS Manual remains current. Furthermore, some of the companies were in the early stages of applying lean to improve administrative processes within the companies' environmental departments. Because of lean production's whole systems view, applying lean techniques to environmental administrative processes has the potential to improve both their efficiency and their effectiveness at managing environmental impacts.

FINDING 6: Lean Activities Result in Improved Environmental Outcomes

At each of the shipyards, interviewees had examples of how lean activities have resulted in improved environmental outcomes, as the following anecdotes illustrate. Most of the evidence available is anecdotal because the companies have not yet collected much data on the environmental improvements resulting from their lean activities. These examples could have been done with or without an EMS; however, a pro-active and deliberate integration of lean and EMS could lead to an approach where lean methods are employed in ways that achieve environmental objectives defined under an EMS.

5S (Sort, Shine, Set in Order, Standardize, and Sustain)

Bath Iron Works uses a lean technique called 5S to organize, clean up, and maintain orderly workspaces. These activities have also helped Bath Iron Works meet its solid waste reduction goals and improve how it collects wastes. Prior to implementing lean, the company had one container for recycling and one "trash hill." By employing 5S, Bath Iron Works moved to a color-coded system with separate bins for different recyclables and waste. This new bin system improved the efficiency of source recycling and achieved higher rates of recycling.

At Todd Pacific Shipyards, 5S improved the company's handling and storage of hazardous materials and waste. Now materials are kept in one area for use, and there is one area for the accumulation of hazardous wastes. The labeling and marking of materials are checked daily. As a result of 5S, the company has reduced the movement of hazardous materials and wastes, and thus reduced the risks of spills and mishandling. Todd Pacific's use of 5S to organize the shipyard has also halved the number of forklifts needed to move materials from one part of the yard to another. This dramatic reduction in forklift use has reduced amount of oil drips on the ground, improving the quality of stormwater runoff.

Kaizen Events

Environmental managers at Bender Shipbuilding & Repair Company volunteered to do a study with EPA on weld smoke emissions reduction, as part of their EMS efforts. Bender used a lean *kaizen* event—a short, structured event to rapidly identify and implement process improvement—involving 13 staff and a welding expert to think about how to improve the welding process and reduce emissions. Although initiated for environmental reasons, participants in the event did not limit themselves only to process changes that would improve environmental performance; they also examined other potential process improvements. Through the *kaizen* event, Bender found that it was over welding and producing more smoke than necessary. Participants also did a sampling of size of welds and found that they were able to reduce the weld size and use less material. These process improvements yielded two primary benefits: lower costs and fewer smoke emissions.

Using a similar approach, Bender conducted a *kaizen* event to rework processes at its paint shop. Environmental personnel participating in this event helped ensure that environmental issues were considered along with "the bottom line." Paint and solvents were identified as a primary source of hazardous waste, which has high environmental risk and associated costs. Because of the lean event and the resulting process improvements, Bender was able to reduce hazardous waste by almost half, and it is no longer a major generator.

Value Stream Mapping

Bath Iron Works used some of the tools and techniques of Value Stream Mapping—a lean process mapping method to identify process steps within a product line and set priorities for future lean activities—to examine processes for cleaning equipment, as well as other processes within the value stream. Because these processes involved solvents and other chemicals, Bath Iron Works assumed that any improvements made to these processes (e.g., to improve flow or achieve other lean objectives) would also reduce hazardous waste generation. Using Value Stream Mapping, the company found out how much wash solvent was used and that they could significantly reduce solvent use by reusing the wash solvent. Bath Iron Works also used Value Stream Mapping to examine its "preservation value stream," which covers prepping, blasting, and painting steel. This examination led the company to determine that 90 percent of the waste stream was driven by the painting process. The company streamlined the painting

process, thus reducing hazardous waste generation by producing less waste paint and using fewer thinners/solvents.

Just-in-Time Production

Northrop Grumman Newport News's application of Just-in-Time production has reduced the amount of unused paint waste it generates. Historically, the company would purchase paint in high volumes (e.g., 50,000 gallons at a time) in order to receive a lower, high-volume price from its suppliers. Because paint has a limited shelf-life, Newport News sometimes found itself in a situation of having to dispose of unused paint, which is considered a hazardous waste. As part of its lean efforts, Newport News developed a new type of contract with its suppliers wherein they commit to buying 50,000 gallons of paint within a given time frame, but the supplier delivers paint in smaller quantities as its needed, reducing the amount of unused paint. The reduction in unused paint has reduced hazardous waste volumes and disposal costs. Also, the paint is getting delivered in larger, 1,000 gallon tanks, instead of 5-gallon buckets. These larger tanks are rinsed out and reused, unlike the 5-gallon buckets which went into the waste stream.

It is important to note that while each of the above examples resulted in environmental performance gains, the lean process improvement activities were not necessarily initiated for environmental reasons, nor were the benefits of the activities limited to environmental outcomes. Environmental waste is only one type of waste in a production system. Overly narrow applications of lean tools (for example, looking only at the environmental impacts of a process without considering other production wastes such as excess movement, waiting time, and defects) could undermine the effectiveness of the lean activities overall, including their potential to reduce environmental impacts.

IV. Lean and EMS Opportunity Areas

As the interview findings confirm, shipbuilding and ship repair companies have successfully combined lean and environmental management practices to improve their environmental performance and reduce costs. The primary strategy these companies used to integrate their lean and environmental efforts was to involve environmental health and safety personnel in lean activities and to adapt their EMS change management procedures for the lean operating environment. Interviewees also suggested other opportunities to improve environmental performance, including integrating lean and EMS process mapping methods, targeting lean activities on processes with significant environmental impacts, and using lean techniques to streamline EMS processes and documentation. These opportunity areas are further described below.

- ***Integrate Lean Value-Stream Mapping and EMS Aspects and Impacts Analysis:*** The lean process mapping method known as Value-Stream Mapping is similar in many respects to the process of identifying environmental aspects and impacts for an EMS. In both methods, cross-functional teams identify the activities associated with different business processes, map the sequence or flow of activities, document important characteristics of those activities, and set targets for future activities based on the process maps. Combining lean and EMS process mapping methods would allow companies to look more holistically at the performance attributes and environmental characteristics of different processes, and to identify desired future states and process improvement activities that best meet all of the company's objectives. Several companies recommended more explicitly deploying Value-Stream Mapping in the context of EMS aspects and impacts analysis, even though they had not yet done so themselves. Specific actions EPA could take to facilitate this integration include:

- Identify metrics that could be used in Value-Stream Maps to describe the environmental performance of processes; and
- Develop an overlay or symbol(s) that lean practitioners could use to flag places in value-stream maps where there are likely to be environmental impacts.

- ***Adapt EMS Change Management Processes to Align Lean Activities with EMS Objectives:*** Because of the rapid operational changes that occur in lean production, the companies recognized the value of aligning their environmental and lean management practices to ensure that lean activities consider environmental performance and compliance considerations. Regardless of whether or not they had a formal EMS in place, interviewees said it was important to bring EHS expertise to lean improvement activities that affect environmentally sensitive processes such as painting, welding, transferring fuel, sand blasting, and wastewater disposal. Several of the companies also have more formal mechanisms in place (e.g., review loops and checklists) to link lean and EMS change management activities. Making these connections can help lean teams identify opportunities to recycle wastes, use environmentally preferable materials, reduce exposure to hazardous chemicals, and avoid the need for expensive pollution control equipment. Strategies for aligning lean changes with environmental objectives include:
  - Involve EHS staff in kaizen rapid process improvement events, 3P product and process design events, Value-Stream Mapping, and other lean activities that affect environmentally sensitive processes;
  - Incorporate questions in checklists or other forms used in lean to "trigger" consultation with EHS personnel and identify any necessary adjustments to EMS documentation and/or to the standard work or other process changes resulting from lean efforts; and
  - Cross-train environmental and lean managers on EMS objectives and procedures, lean principles and techniques, and how lean and EMS work together.

- ***Use Lean Methods to Meet EMS and Other Performance Objectives:*** As described above, the companies used a variety of lean techniques, and this resulted in improved environmental performance. This has been done by conducting lean activities specifically on processes with important environmental endpoints as well as by "piggy backing" onto lean activities initiated on other types of processes. These environmental benefits could have occurred in the absence of a formal EMS; however, an EMS could help companies to target lean improvement efforts on processes with significant environmental impacts and to build in explicit environmental review criteria into lean implementation. Example strategies for improving the environmental performance of lean activities include:
  - Track the environmental performance changes that result from lean implementation as a means of encouraging continual improvement;
  - Ensure that EMS-identified significant environmental impacts are addressed during *kaizen* events on environmentally sensitive processes;
  - Use visual controls to illustrate environmental, health, and safety procedures in the context of the standard work for a process;
  - During 5S events, segregate recyclable materials and hazardous wastes from other wastes and clearly label disposal areas to improve waste management and recycling practices;
  - When working with suppliers to provide just-in-time delivery of parts and materials, consider requesting "right-sized" quantities of paint and/or other chemicals when needed, or purchasing chemical management services instead of the chemicals themselves;
  - Incorporate environmental issues into andon (signal) systems to quickly call attention to environmental problems when they occur; and
  - Integrate environmental design criteria into implementation of 3P, the lean product and process design method.

- ***Apply Lean to Environmental Administrative Processes:*** Lean techniques can be used to eliminate excess documentation, unnecessary process steps, and other "wastes" in an EMS as well as to improve the efficiency and effectiveness of a company's environmental department. Two companies interviewed—Bender and Bath Iron Works—streamlined their EMS procedures and documentation using lean, and another two companies—Southwest Marine and Newport News—plan to apply lean to their environmental support functions in the future.

V. Recommendations: Potential Action Areas for EPA

Based on the research and interviews, Ross & Associates believes there are several areas where EPA should consider follow-up activities to leverage opportunities to enhance the environmental performance outcomes associated with the implementation of both lean and EMS. These suggestions are divided into activities and products.

Activities

- ***Outreach and Awareness-Raising on the Lean-EMS Relationship.*** *Objective:* Help to "jump-start" company efforts to coordinate and integrate lean and EMS initiatives by fostering discussions on the topic.

  In some cases, the interviews conducted as part of this effort were the first time that the companies' lean and environmental managers had met to explicitly consider the relationship between lean and EMS. The interview questions, however, proved quite effective at stimulating ideas among company representatives and spurring them to identify opportunities for lean-EMS coordination. Ross & Associates believes that similar idea sharing and brainstorming can be encouraged by increasing the visibility of the topic at shipbuilding and ship repair sector conferences and meetings on both lean and environmental management. EPA can play a role by making presentations and actively working to facilitate these discussions among company representatives in the sector.

- ***Lean-EMS Partnership(s).*** *Objective*: Work with one or more companies implementing lean to identify, develop, and test models for coordinating and integrating lean and EMS implementation activities.

  A lean-EMS partnership in the shipbuilding sector could be similar to the partnership models being developed by EPA's Lean & Environment Initiative, with a specific focus on lean and EMS. Todd Pacific Shipyards in Seattle, WA has expressed interest in such a partnership with EPA. As an alternative, it may be possible to work with a consortium of shipbuilding and ship repair companies through an organization such as the National Shipbuilding Research Program and its Lean Shipbuilding Initiative to identify, develop, and test lean-EMS integration ideas and models. Partnership results could inform the development of products discussed below.

Products

- ***Develop a Guide to Lean-EMS Coordination and Integration.*** *Objective*: Help to "jump-start" company efforts to coordinate and integrate lean and EMS initiatives by profiling and disseminating ideas, "best practice" examples, and lessons learned.

The interviews revealed many good ideas for improving coordination and integration of lean and EMS, although company representatives indicated they are just beginning to think about ways to fully leverage these opportunities. At the same time, discussion with company representatives indicates that there is significant interest in understanding and leveraging the relationship between lean and EMS to support the effective coordination and integration of lean and EMS initiatives in the shipbuilding and ship repair sector. The development of a guide that profiles ideas, best practices, and lessons learned could help shorten the learning curve within individual companies. A guide could help introduce environmental managers in the shipbuilding and ship repair sector to lean, and help them navigate lean methods to find the biggest opportunities for enhancing EMS performance and environmental outcomes.

The lean-EMS integration opportunities identified within the shipbuilding and ship repair sector are likely to be relevant across all or most industrial sectors. While the interviews indicated that practical, sector-specific examples are essential to effective communication on lean-EMS coordination and integration opportunities, Ross & Associates believes it is worth considering whether and how research on lean-EMS coordination in the shipbuilding sector could be applied in other sectors where there is significant lean and EMS activity. For example, it may be possible to develop a lean-EMS integration guide template that could be adapted to the specific circumstances and examples present in other sectors (e.g., hospitals, aerospace, and construction).

- ***Align Sector-based Products to be Relevant in Lean Context.*** *Objective*: Ensure that subsequent products and activities developed through EPA's Sector Strategies Program for the shipbuilding and ship repair sector are relevant in the context of lean implementation.

  While it does not appear that changes are advisable to existing EPA Sector Program materials developed for the shipbuilding sector (e.g., EMS Business Case document), Ross & Associates believes it would be useful to consider lean in the development of any new sector materials. For example, efforts to develop Best Management Practice guides should explore whether there is a need to identify examples of how recommendations or other information may differ in the context of lean implementation.

- ***Identify Best Practices for Applying Lean to Environmentally-Sensitive Processes***. *Objective*: Identify, profile, and encourage approaches for applying lean to specific environmentally-sensitive processes that are common in the sector (e.g., paint removal, painting and coating, welding, etc.) in a manner that maximizes environmental performance.

  While products in this area would not directly relate to an EMS, several company representatives indicated that it could be useful to share best practices or examples of approaches for maximizing the environmental performance of certain environmentally-sensitive processes in the context of lean implementation. It should be noted, however, that there may be competitiveness sensitivities that limit the amount of information that companies are willing to share about specific lean process configurations.

Appendix A: List of Interviewees

Bath Iron Works, Bath, Maine

- Vince Dickinson, Environmental Manager
- Charlie Hammond, Lean Section Manager

Bender Shipbuilding and Repair Company, Mobile, Alabama

- Dale Jermyn, Director of Process Improvement and Training
- Rob Manning, Manufacturing Manager
- Jackie Morris, Environmental and Quality Manager
- Pat Roberts, Industrial Engineer

Northrop Grumman Newport News, Newport News, Virginia

- Tom Clark, Director of Production Engineering
- Frank Thorn, Environmental Manager

Southwest Marine Inc., San Diego, California

- Shaun Halvax, Director of Environmental Services
- Paul Stephens, Manager of Lean Six Sigma Program

Todd Pacific Shipyards Corporation, Seattle, Washington

- Dale Baugh, Director of Ship Repair Processes and Resource Development
- Allen Rainsberger, Director of Environmental/Occupational Safety & Health

Lean Shipbuilding Initiative

- Jim House, Advanced Technology Institute (ATI)