

# **THE APPLICATION OF LEAN ENTERPRISE TO IMPROVE SEAPORT OPERATIONS**

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## **Mr. Nicholas Loyd (Corresponding Author)**

Research Engineer

University of Alabama in Huntsville  
Huntsville, AL 35899

Telephone number: (256) 824-3025

Fax Number: (256) 824-6974

Email: Nicholas.Loyd@uah.edu

## **Ms. Lauren C. Jennings**

Research Scientist

University of Alabama in Huntsville  
Huntsville, AL 35899

Telephone number: (256) 824-6652

Email: Lauren.Jennings@uah.edu

## **Mr. Jeff Siniard**

Research Scientist

University of Alabama in Huntsville  
Huntsville, AL 35899

Telephone number: (256) 824-6202

Email: Jeff.Siniard@uah.edu

## **Mr. Michael L. Spayd**

Research Scientist

University of Alabama in Huntsville  
Huntsville, AL 35899

Telephone number: (256) 824-6275

Email: Michael.Spayd@uah.edu

## **Mr. Anthony Holden**

Research Engineer

University of Alabama in Huntsville  
Huntsville, AL 35899

Telephone number: (256) 824-6289

Email: Anthony.Holden@uah.edu

## **Mr. George Rittenhouse**

Research Scientist

University of Alabama in Huntsville  
Huntsville, AL 35899

Telephone number: (256) 824-6240

Email: George.Rittenhouse@uah.edu

**ABSTRACT**

This paper discusses the implementation of Lean Enterprise management, principles, and tools in seaport operations. The paper begins by providing an overview of the necessary management training, strategy, and structure necessary for a successful lean implementation. An analysis of appropriate lean tools to be applied in seaport operations is provided, citing specific examples of the implementation of those tools at the Port of Mobile, Alabama. The paper also investigates the importance of integrating lean concepts in support functions such as accounting, maintenance, and human resources in order to holistically enhance overall port operations. The paper concludes with a discussion of keys to successful lean implementation, issues relative to sustaining improvement efforts, and suggestions for additional focuses of improvement for implementing lean in port operations.

## INTRODUCTION

### Overview of U.S. ports and the Case for Improvement

Marine commerce plays a vital role in supporting economic development. The increase in world populations, the industrialization of nations, and a heavier reliance on world trade have accelerated the need for the efficient travel and transfer of goods between overseas ships and domestic trucks, trains, and barges. In the United States, foreign trade accounted for about 22 percent of the Gross Domestic Product (GDP) in 2006 and approximately 95 percent of this foreign trade is moved by ship. (1)

This reliance on trade has increased port volumes by an average of 7 percent per year since 1990, and in 2003, an estimated \$1 trillion worth of goods carried in more than 39 million Twenty-Foot Equivalent Units (TEUs) moved through North American ports (2). Most major North American ports have not been able to increase capacity as the demand for their services has risen, thus, it is estimated that most of these ports are operating near capacity and will start to show significant capacity deficits by 2010 (2). With some reports predicting that port volume will double by 2020, the lack of port capacity will pose serious problems for maintaining efficient goods movement and facilitating a competitive economy.

Increasing port capacity is a complex issue. Even if sufficient dock capacity exists to load and unload ships, an efficient port relies on trucks navigating congested roadway networks, rail lines with limited capacity and expansion issues, and intricate logistic systems requiring coordination of goods for global dispersion. These issues coupled with the significant costs, lengthy timetables, and stakeholder groups with differing or even competing objectives are significant obstacles to providing additional port capacity in an expedient manner. Due to these constraints, methods to increase port capacity without significant investment in new resources are needed.

### Overview of Lean Enterprise as an Improvement Methodology

Lean Enterprise is a systematic approach to identifying and eliminating waste through integrating technical tools and a continuous improvement culture (3). The concepts of Lean Enterprise were derived from the Toyota Production System (TPS), pioneered by Taichii Ohno and Shigeo Shingo. The objective of TPS is to reduce the time between when a customer places an order and when the company is paid by removing non-value-added activities, or waste (4). Waste is any activity which does not add value to the product or service expected by the customer. Toyota identified seven categories of deadly waste that prevent the ability to add value (4):

- Defects
- Overproduction
- Waiting
- Transportation
- Inventory
- Motion
- Excess Processing

Waste elimination is guided by five basic principles set forth in the book *Lean Thinking* by Womack and Jones (5).

- Specify Value: identification of what activities add value.

- Map the Value Stream: creating a visual representation of all activities to easily identify wastes.
- Flow: products and services should move immediately between value adding activities.
- Pull: customer demand should dictate the rate of flow.
- Perfection: improvement should be continuous.

To promote continuous improvement, lean utilizes several tools for training and implementation, many of which are applicable to seaports and are discussed in this paper. These tools are defined in more detail in Table 1: (3, 4, 5, 6, 7, 8, ,9, 10, 11)

**TABLE 1 Definition of lean terms.**

<b>Value Stream:</b> All the activities currently required to bring a product or service to completion, including both the material flow activities (from arrival at the facility to departure) and information flow activities (including receiving customer requests, issuing requests to suppliers, and communicating what to work on to employees).
<b>Value Stream Mapping:</b> Value stream mapping is a planning tool that provides a holistic view of the value stream and allows for a systematic application of process level improvement tools.
<b>The 5s System:</b> A step-by-step methodology that goes beyond basic housekeeping to provide a safe, clean, organized work area. The 5's are Sort, Set-in-Order, Shine, Standardize and Sustain.
<b>Visual Workplace:</b> The use of simple, self-explanatory signals that give immediate and accurate understanding of a situation or condition. This includes using pictures, symbols, outlining, labeling, and color-coding as a means of communication so that workers can spend less time interpreting the work situation and more time being able to effectively react to the work situation.
<b>POUS (Point of Use Storage):</b> The technique of storing all needed resources such as tools, equipment, materials, supplies, and information as close as possible to where they are needed.
<b>Layout Analysis:</b> Layout analysis involves evaluating the location of equipment and resources needed to perform steps in a process. Layout improvement leads to a reduction in the waste of transportation between successive value-added steps in an operation, and less time in transit means more time to perform the actual work and a more prompt completion time.
<b>SMED Principles:</b> Analysis of all activities, separating them as internal or external tasks, and streamlining to eliminate unnecessary steps in order to reduce time between value-added activities.
<b>Standardized Work:</b> A documented, set procedure to be followed based on the best currently known method of producing a consistent result from a process.
<b>Quality at the Source:</b> The idea of being proactive about quality issues by having processes in place to catch the defects as they happen, or prevent them from happening at all.
<b>Total Productive Maintenance (TPM):</b> Organization-wide equipment maintenance program that covers the entire equipment life cycle and requires participation by every employee.
<b>Kaizen:</b> A continuous improvement process that involves gathering a small team and performing an intensive, focused waste elimination effort on a specific process. There are varying incarnations of kaizen, the most typical form being a kaizen blitz event, which is a project led by a kaizen leader and lasts from 3-5 days. Other forms of kaizen include kaizen super blitzes, which last for 1 day and are often performed on an individual level, and kaizen projects, which last from 2 weeks to several months and involve upper management

### **Overview of the Port of Mobile and the Case for Improvement**

The Port of Mobile, Alabama (the Port) is the only deep water port in the state and one of only four deep water U.S. ports on the Gulf of Mexico. The Port is the home to both private and public operated terminals, with the public terminals being owned and operated by the Alabama State Port Authority (ASPA). The public terminals handle containerized, bulk, break-bulk, roll-on/roll-off, and heavy lift cargoes and accounted for 26.9 million tons in 2007 (12).

The Port is experiencing growth issues reflective of those being experienced nationwide. McDuffie Coal Terminal, the Port's largest revenue division, is the nation's largest import coal

terminal and second largest coal terminal overall with a designed capacity of 20 million tons per year. In 2003, one of McDuffie's major import customers informed the Port of a desire to double the amount of coal coming through the facility. Additionally, the container terminal has gone from handling 12,992 TEUs in 1997 to 63,480 TEUs in 2007 (a 389% increase) (6). The demand for revenue-producing car moves at the Port's Terminal Railroad (TRR) division has almost doubled since 2005. Facing this level of growth, the Port management team realized they needed to address inefficiencies in their processes and equipment. The Port management team was introduced to the principles of Lean Enterprise and continuous improvement in late 2003 through a series of meetings with experts on continuous improvement from the Alabama Technology Network at the University of Alabama in Huntsville (ATN-UAH), and agreed to try the approach to alleviate their constraints to growth (13).

### **LEAN ENTERPRISE IMPLEMENTATION AT THE PORT OF MOBILE, AL**

The implementation of Lean Enterprise at the Port, under the guidance of ATN-UAH, was initiated strategically from the executive management level. Realizing that a successful lean transformation is dependent on the education and empowerment of employees at all levels of the organization to identify and eliminate waste, the Port invested in initial lean training for key management and developed a high-level strategy for integrating Lean Enterprise training and implementation into the organization's business activities. Next, each operational division at the Port performed value stream mapping to set a manageable implementation road map prior to application of specific lean tools. Finally, appropriate lean tools were identified and applied to improve the Port's processes.

#### **Management Strategy and Training**

Executive management at the Port began their transformation to a Lean Enterprise by prioritizing the order in which each of its operational divisions would experience the rollout of the lean improvement process. McDuffie was chosen to serve as the pilot division for implementation because of its revenue prominence and vast potential for improvement. As McDuffie was facing the previously mentioned increase in customer demand, the facility was already operating 7 days per week, 24 hours per day, 360 days per year and struggling with equipment issues.

The Lean Enterprise implementation strategy was as follows:

- Year 1- Begin lean training and implementation at McDuffie
- Year 2- Continue at McDuffie, and begin lean training and implementation at the TRR division
- Year 3- Continue at McDuffie and TRR, and begin lean training and implementation at the Bulk Material Handling Plant (BMHP) division and the Port's corporate office
- Year 4- Continue all previous implementation, and begin lean training and implementation at the General Cargo division and various support functions (such as Human Resources, Technical Services, Central Maintenance, Central Garage, etc.)
- Year 5- Continue all previous implementation efforts, growing and sustaining improvements

Prior to investigating Lean Enterprise, strategic planning had been nonexistent at the Port. Strategic planning is a formal process of identifying an entity's vision, mission, and operating plan over a long-term horizon in order to harmonize all business activities (14). Each major

division began their Lean Enterprise rollout by conducting a strategic planning exercise that clearly aligned the objective of developing a lean continuous improvement program with supporting their vision and mission statements.

At the onset of lean implementation, each major division established a Lean Steering Committee to oversee the management of the continuous improvement program. The roles of the Lean Steering Committees were defined as:

- Providing direction and vision
- Managing the dissemination of lean understanding through training and employee involvement initiatives
- Establishing and mapping value streams
- Selecting and prioritizing improvement activities and setting goals
- Establishing, tracking, and enforcing appropriate performance metrics to drive the behavior necessary to sustain any success associated with lean improvements.

Training at all levels of the organization is imperative to the success of a true Lean Enterprise. With the assistance of ATN-UAH, the Port developed a plan for training. Prior to beginning implementation at McDuffie, an initial 40 hour Lean Enterprise Series(LES) training course was held on-site for 25 members of management at the Port. The participants in this training were primarily managers from McDuffie, but also included key representatives from the TRR and Bulk Handling facilities to ensure their understanding of management's role in the lean process. The Port's training plan also provided for other key members of each division's management to attend open enrollment, off-site installments of the LES course at later dates. In addition, all Port employees participated in a 4 hour Lean Concepts overview course. The Lean Concepts training course included a live simulation, which provided first-hand understanding of the benefits of lean. Throughout the entire implementation of Lean Enterprise at the Port, over 45 Lean Concepts courses have been delivered to more than 400 employees at the beginning of their respective division's phase of implementation. Additional training on specific lean tools, including training on Total Productive Maintenance, Lean Office Principles, leadership, and Kaizen Facilitation, were provided to appropriate employees as needed.

### **Using Value Stream Mapping to Manage Lean Implementation**

Proper value stream management is critical to a successful lean transformation. At the Port, value streams were identified and mapped at McDuffie, the Terminal Railroad, the General Cargo division, and many administrative and support functions. Each value stream mapping exercise was conducted with a team of key personnel and resulted in an implementation plan and the assignment of a value stream manager. Each value stream manager was then given the responsibility of following through and updating the plan through completion, ensuring proper management of the implementation process.

A value stream map consists of three deliverables-- a current state map, a future (or ideal) state map, and a detailed implementation plan (6). The first step in the value stream mapping process is creating a current state map-- a one-page, visual representation of how the current process operates, integrating all the material and information flow steps involved in the operation. The purpose of the current state map is to provide a high-level, simplistic view of the value stream's present mode of operation, allowing the opportunity to see wastes that exist. The team constructing the value stream map then reviews the current state and brainstorms waste that

is evident. Countermeasures are then developed to address as many of these wastes as possible and become the basis for the design of the future state map.

The future state value stream map is a visual representation of how the value stream's processes would ideally operate, with waste that was identified in the current state eliminated or greatly reduced, at the end of some designated time period for the planning horizon (6). Typically future state maps are designed on a one year timeframe and reflect any process changes that are expected from the implementation of the desired improvements by showing countermeasures as "improvement bursts." The future state value stream map for the Port's TRR division is shown in Figure 2.

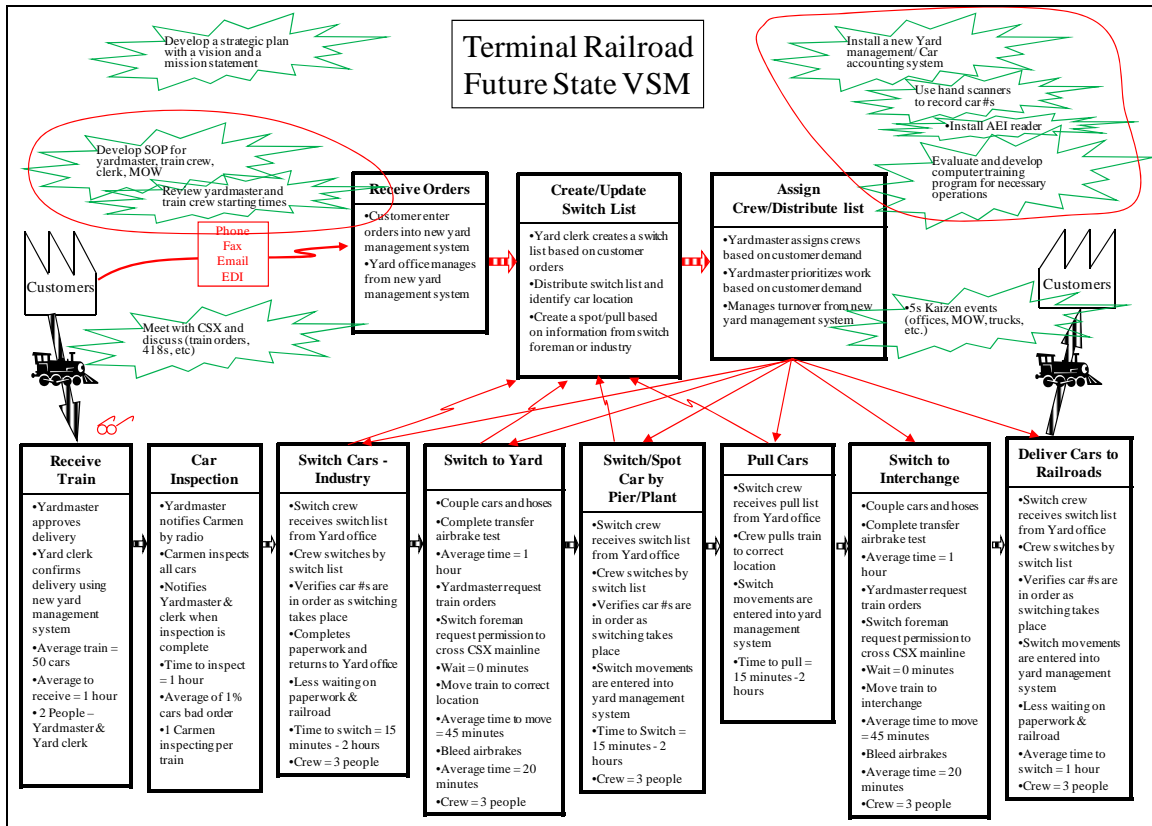


FIGURE 1 TRR future state map with improvement bursts.

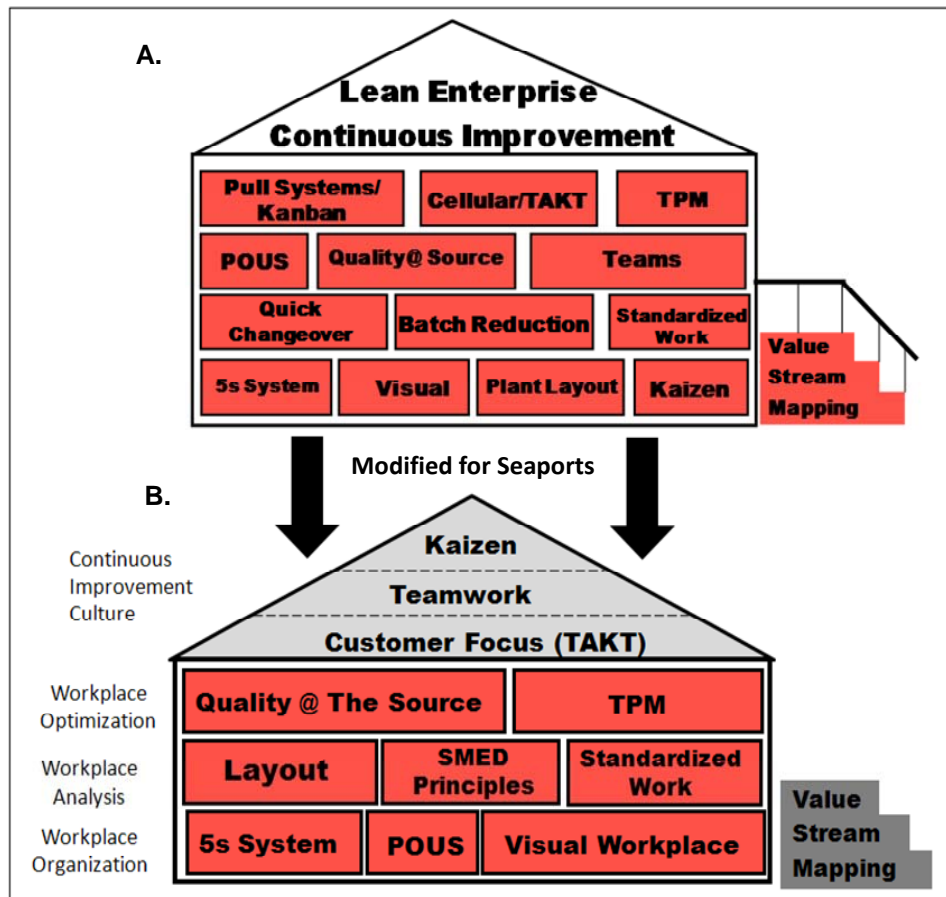
The final component of a value stream map is the implementation plan. The implementation plan is a detailed roadmap of how to get from the current state to the future state (6). Countermeasures that were developed are converted into detailed action items, prioritized, put into a timeline, and assigned to employees who will be responsible for completing each action item. Each value stream manager then manages to the plan, holds reviews on each action item, makes adjustments and decisions based on the reviews, and updates the value stream plan accordingly.

Diligent management to the implementation plan is the key to the success of a Lean Enterprise transformation and an organization's overall performance. The TRR was handling less than 100,000 revenue cars (not including empty cars) in early 2006 at the beginning of Lean Enterprise implementation. In 2008, the TRR is handling in excess of 130,000 revenue cars (an increase of over 30%) in a more productive manner, with value stream management being an

integral component to guide improvements and management decisions to increase capacity during this time of business growth.

**Lean Implementation Tools for Seaports**

Several tools exist to achieve the Lean Enterprise objective of eliminating waste. The National Institute of Standards and Technology’s (NIST) Manufacturing Extension Program (MEP) has developed a model demonstrating these tools, shown in Figure 2A (7). An error that organizations often make in attempting to understand and implement a Lean Enterprise program is trying to force the use of certain lean tools in situations where they do not fit. Lean is a business philosophy with a goal of eliminating waste to be responsive to customer demand; the tools are just options of achieving this goal. Each company has the potential to construct their own lean implementation model featuring only the tools that are appropriate for their industry or organization. Based on tools that have been identified as applicable and successful during the implementation of lean at the Port, ATN-UAH has developed a modified Lean Enterprise implementation model for seaports. This model is exhibited in Figure 2B:



**FIGURE 2** Lean Enterprise implementation model modified for seaports.

The Lean Enterprise implementation model for seaports is represented by a multi-tiered house. The foundation of the house consists of workplace organization tools which are necessary before upper level tools should be applied. The second and third levels of the house are composed of workplace analysis and workplace optimization tools. As previously mentioned,

the value stream mapping is a management tool that serves as the stairway into the house of lean tools and provides a plan of how to best apply those tools to eliminate waste. All of the lean tools should be applied under the roof of a continuous improvement culture.

### *Continuous Improvement Culture*

The continuous improvement culture section of the Lean Enterprise for seaports model is composed of the ideas of customer focus, teamwork and kaizen. Every specific improvement event or project should be linked to an action item on the value stream mapping implementation plan, which in turn should be designed to support the customer demand of that value stream. For example, McDuffie Coal Terminal's import coal customer expressed a desire to double the amount of coal coming through. This was reflected in the value stream map for import coal. Because import coal arrives on ships and leaves on barges, the initial improvement efforts at McDuffie were focused on the ship unloading and barge loading processes.

Many U.S. organizations have errantly applied the principles of Lean Enterprise by assigning a dedicated lean specialist to implement without utilizing teams of employees. The result of this method is a process that is often not optimally improved due to the lack of consultation with the people actually performing the job. Additionally, even if the appropriate tools were applied and the process was technically ideal, the chances of success are minimized due to the lack of buy-in that comes from not utilizing the employees' ideas. Teamwork is a vital component to the implementation of lean tools.

Cross-training of employees is another critical teamwork principle of Lean Enterprise and leads to greater flexibility when responding to customer demand. Cross-training was identified as a significant gap at the Port. During the initial stages of lean implementation, the Port had many employees with 20-40 years of experience that were on the verge of retirement. With no succession plans, cross-training, or documented procedures in place the organization was facing a massive loss of irreplaceable knowledge and competence. Several improvements were initiated at the Port to alleviate this gap, including:

- Revamping and utilizing "cubbing" development training and mentoring programs at the TRR for all categories of employees
- Creation of assistant foreman positions at McDuffie to allow more employees to learn under existing foreman and develop supervisory skills
- Development of standard operating procedures; every division and support function identified the need to document and train personnel on standard procedures in their value stream mapping implementation plans

The vehicle through which lean tools are implemented is called kaizen. Kaizen, in a literal sense, is Japanese for "change for the good" and is a word that has become synonymous with improvement, not only at work but in everyday life (11). Kaizen, as used in lean implementation, is a continuous improvement process that involves gathering a small team and performing an intensive, focused waste elimination effort on a specific process. Since beginning Lean Enterprise implementation in 2004, the Port has performed over 40 kaizen events involving more than 350 employees and trained 8 internal employees to facilitate kaizen events. Results from some of these kaizen events are discussed later in this paper.

### *Workplace Organization Tools*

**Overview of Workplace Organization.** The foundational tools of Lean Enterprise are those focused on workplace organization. Workplace organization is the concept of having a safe, clean, neat arrangement of the work area that provides a specific location for everything and eliminates anything not required (7). The tools used to construct this foundational layer are the 5s system, visual workplace, and point-of-use storage (POUS).

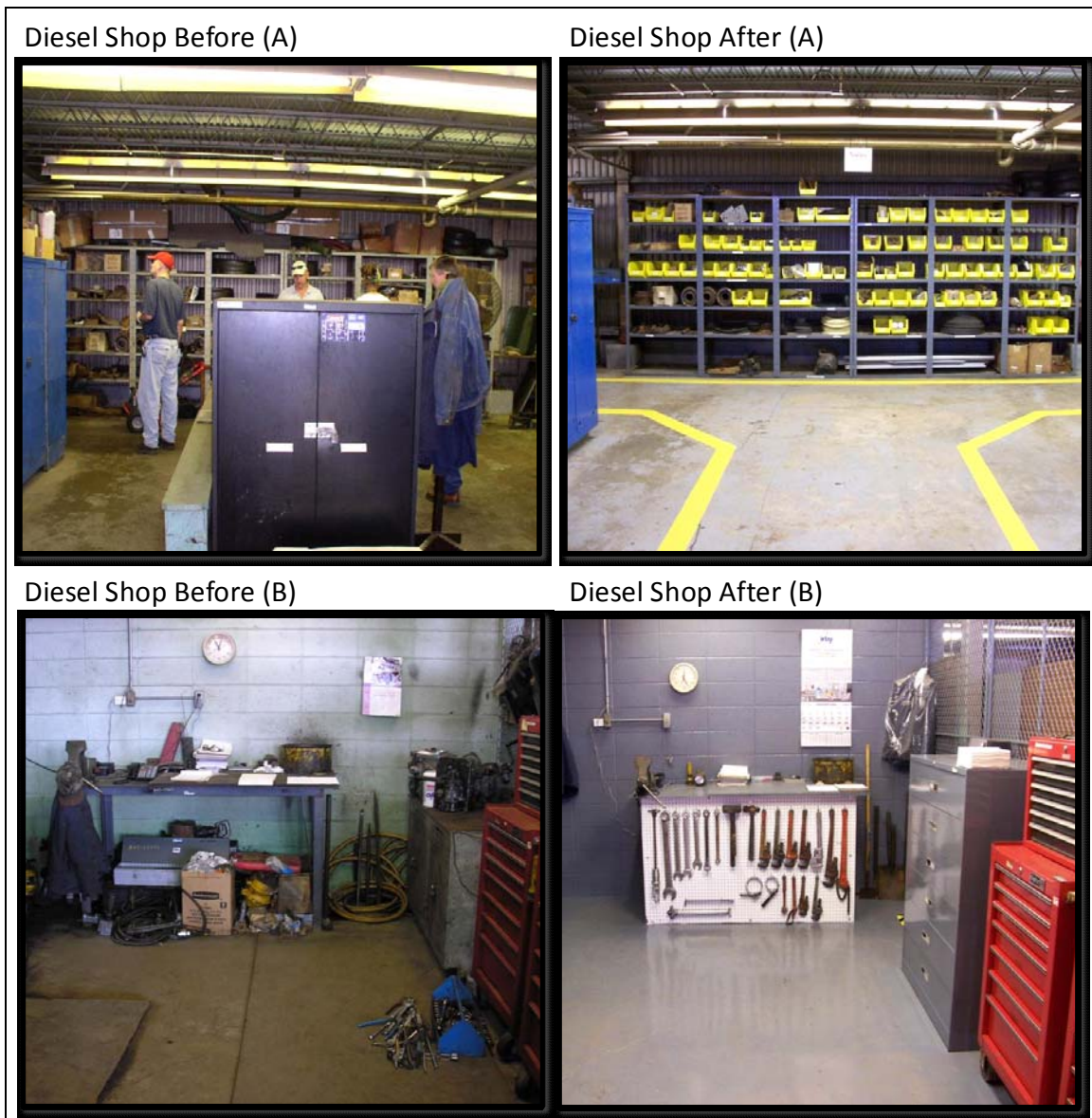
The 5s system, when applied properly, creates an environment where all needed resources are located in a designated location, preventing the need to search for them. Clearly identified, designated locations also make it obvious when needed resources are not present. Visual workplace and point-of-use storage are most effective when incorporated in the set-in-order component of the 5s system, but can also be used individually.

Workplace organization tools are considered foundational to Lean Enterprise because, unlike other lean tools, they can be applied in every situation in every company wishing to implement lean. These tools can also be applied at a relatively low cost and low risk, which allows for quick, visible success while also applying the tools using kaizen to lay the groundwork for the continuous improvement culture necessary for the success of subsequent lean tools.

**Workplace Organization at the Port.** The Port used the workplace organization tools in the initial phases of lean implementation at all major divisions. McDuffie implemented the 5s system in their maintenance warehouse and electrical shop. The Terminal Railroad applied 5s in their diesel shop and to the field trucks used by the maintenance-of-way track repair group. The Bulk Handling Facility utilized the 5s system in their maintenance shop. Both the Central Garage and Central Maintenance departments performed 5s kaizen events as their initial implementation efforts.

A routine was established early on so that all workplace organization efforts at the Port would be consistent. A 5s score sheet was developed to provide a standard for scoring the level of organization in each area. The same score sheet is used in rating the area before the initial 5s kaizen event, immediately after the kaizen event, and periodically thereafter. The 5s score sheet allows for a range of 0 (worst) to 100 (best) and gives each value stream manager a metric with which to manage in order to facilitate the sustainability of the workplace organization implementation. As examples, the McDuffie electrical shop scored a zero on its initial 5s score, and scored a 70 at the end of the first 5s kaizen. The diesel shop at the Terminal Railroad scored an 8 initially, and followed up with a 79 at the end of the kaizen. The Bulk Handling Facility's maintenance shop scored an 8 before applying the 5s system, and scored a 61 at the end of the kaizen event. These scores are typical because only the first 3 Ss are feasible to achieve on the short-term basis of a kaizen event. The last Ss are long-term activities that take months to establish and scores should rise over time as efforts become standardized and sustained. Monthly audits are performed in each area and a new 5s score is issued.

The Port has realized many benefits of workplace organization beyond the measurable gains of the 5s scores. All of the areas have experienced valuable gains in floor space utilization, improved lighting, and better visibility of spare parts. Consequently, it takes less time to perform repairs and other critical work vital to keeping the Port's operations going. Finally, the visual effects of workplace organization have resulted in improved morale and give the facilities an impressive appearance as a world class seaport. Figure 3 shows sample before and after pictures of one of the workplace organization efforts in the diesel shop at the TRR.



**FIGURE 3 Before and after pictures of workplace organization at the Port.**

To gain ownership of the Lean Enterprise transformation process, the Port dedicated two full-time employees as lean coordinators to shadow all ATN-UAH efforts and each division identified two employees to be trained as internal kaizen facilitators. The success of the initial workplace organization efforts caused excitement at the Port and the momentum spread quickly in the form of employees taking the initiative of performing internal 5s kaizen events at McDuffie in the fabrication shop and the TRR break room and yard office. This evidence of internal ownership exhibits signs of the continuous improvement culture needed for a Lean Enterprise to prosper.

### *Workplace Analysis Tools*

Once a solid foundation of workplace organization is developed, specific process problems often become more obvious. The tools at the workplace analysis level of the Lean Enterprise implementation model for seaports provide methods for analyzing processes and identifying opportunities to abolish waste by reducing unnecessary steps. Tools for workplace analysis include layout improvement, Single-Minute-Exchange-of-Dies (SMED) principles, and standardized work.

**Layout Analysis.** While much of the equipment at the Port is extremely large and unable to be moved, there were several methods that were still applicable relative to layout improvement. One example of layout improvement is the Central Garage, a support division that performs maintenance activities on all rolling stock vehicles and equipment.

The initial kaizen event at the Central Garage, as identified during the value stream mapping process, was to evaluate the layout of the garage. A major activity performed at the garage is the maintenance of tires, including mounting and balancing. At the beginning of the kaizen event, the tire balancing machine was located at the opposite end of the garage from the mounting equipment, approximately 144 feet away. This resulted in the mechanics having to roll each tire being serviced (an average of 16 tires per day). A countermeasure implemented during the kaizen involved a redesign of the tire work area, relocating and hooking up the balancing machine next to the mounting machine so that tires could go immediately to the next step without being transported. The result of this was the reduction of over a half mile of travel each day, equating to over an hour of time. This time savings could then be directly invested back into performing more value-added activities.

**SMED Principles.** Opportunity for improvement also lies in an analysis of what activities are performed within a process. This analysis can be performed using the principles of SMED by evaluating internal and external elements to reduce time between performing value-added activities. Internal elements are activities that can only be performed during the period between when the value-added step has concluded and when it begins again. External elements are activities that can be performed in parallel with the value-added activities (8). Without the application of SMED principles, these activities often are intermingled and result in inefficiency.

A SMED analysis of the barge loading process at the BMHP revealed many steps could be performed as external activities in parallel with the arrival of empty barges. A checklist was developed so that these activities could consistently be performed externally, as opposed to waiting until the empty barge arrives, allowing for faster loading time between the arrivals of empty barges.

**Standardized Work.** The final tool in workplace analysis is to document the improved process in a medium that can be used to effectively train personnel. This involves the development of standardized work, or standard operating procedures (SOPs). The Port had very little or no documentation of processes at any division. SOPs have been implemented in numerous areas to both provide an institutionalization of knowledge, as well as to provide simple, visual, and effective training for personnel stepping into new roles. SOPs were developed for all key operations at McDuffie including the unloading and loading of barges and ships, and the loading and dumping of train cars. The TRR has utilized SOPs in key areas as well, including all roles on the train crew, maintenance crews, and the yard office. Many other divisions, such as the

BMHP, Central Garage, Central Maintenance, medical services, and human resources have identified the need to develop SOPs on their value stream plans.

Benefits of workplace analysis tools are often very obvious but difficult to measure. However, the Port has also experienced many measurable results from implementing and following SOPs. Table 2 demonstrates a sample of beneficial results at various operations at the Port:

**TABLE 2 Summary of SOP kaizen results at the Port.**

Process	Metric Before	Metric After	% improvement
<b>Barge Loading</b>	<b>1 hr, 59 min</b> (avg. of month prior to kaizen)	<b>53 min</b> (measured 3 barges following SOP)	<b>125%</b>
<b>Ship Unloading</b>	<b>28000 Tons/day</b> (avg. of month prior to kaizen)	<b>35245 Tons/day</b> (measured following SOP at end of kaizen)	<b>26%</b>
<b>Barge Unloading</b>	<b>1 hr, 42 min</b>	<b>60 min</b>	<b>70%</b>
<b>Ship Loading</b>	<b>25000 Tons/day</b>	<b>36000 Tons/day</b>	<b>44%</b>
<b>Train Car Dumping</b>	Avg. Time to dump/train = <b>over 8 hrs</b>	Avg. Time to dump/train = <b>4 hrs</b>	<b>100%</b>

#### *Workplace Optimization Tools*

The upper layer of the Lean Enterprise implementation model for seaports consists of tools to optimize processes that have already been organized and analyzed. These lean tools are quality-at-the-source and total productive maintenance (TPM).

**Quality at the Source.** Quality-at-the-source is the idea of being proactive about quality issues by having processes in place to catch the defects as they happen, or prevent them from happening at all (8). The causes of quality problems can often be categorized into a few categories. First, mistakes have the potential to occur due to a lack of training, or inadequate training, for the personnel performing the job. The Port has taken strides to address this cause with the previously mentioned training development plan and the creation of visually documented SOPs for key operations.

Second, even with the best training on a job available, mistakes have the potential to occur if hiring or promotion practices do not allow for the people with appropriate knowledge, skills and abilities (KSAs) to perform a job to be placed in that job. In addition to Toyota's 7 deadly wastes, implementation of lean concepts in the U.S. has resulted in the addition of an 8<sup>th</sup> waste—not utilizing people's KSAs (7). The Terminal Railroad held a kaizen event to determine critical KSAs relative to jobs for which they most frequently hire, such as carmen and train crew. After appropriate KSAs were identified, pre-employment tests were developed by the kaizen team to increase the likelihood of hiring individuals that possess those KSAs.

Finally, mistakes can also occur due to process problems. The Japanese concept of poka yoke, or mistake-proofing, is part of Shingo's Zero Quality Control system (ZQC) at Toyota and provides inexpensive techniques to increase quality levels (9). The ship unloading process at the BMHP loses an average of 2 hours per day because of downtime to replace hopper liners due to wear. A recent kaizen event at the BMHP yielded a design of a relatively inexpensive hydraulic-actuated system to adjust liner height, along with a move to vulcanizing conveyor belt splices

instead of the current method of using metal fasteners, which cause the majority of liner wear. These improvements not only reduce wear but also mistake-proof the process because liner wear results in coal spillage. These improvements are projected to save almost 2 hours of capacity time per day at the BMHP, allowing the unloading of between 4-5 additional ships annually.

**Total Productive Maintenance.** For any port, the equipment that is necessary to perform the loading and unloading of materials and cargo is the lifeblood of the operation. The Port of Mobile is no exception, especially at McDuffie and the Bulk Handling Facility. Prior to Lean Enterprise implementation, equipment maintenance was mostly performed on a reactive basis after breakdowns occurred. Any preventative or predictive maintenance that was performed at the Port was sporadic and inconsistent. The need to be proactive in the care of equipment was identified as a priority, and a systematic implementation of a TPM program began in the fourth year of lean implementation at the Port. TPM is a system of productive equipment maintenance performed on a company-wide basis involving all employees (10).

Similar to the rollout of the lean program in general, the rollout of TPM began at McDuffie. ATN-UAH trained all McDuffie employees in a 2 hour overview of TPM. Because no previous maintenance system or history existed, a paper work order system was then developed to manage maintenance activities. A kaizen event was held to develop critical spare parts lists for each of McDuffie's major pieces of equipment, reducing long periods of downtime due to waiting for ordered replacement parts to arrive. After getting personnel used to tracking maintenance activities with the paper system, a move was then made to phase into using an existing computerized maintenance management software (CMMS) system. McDuffie has recently invested in dedicated personnel to help facilitate the expansion of their TPM program. At present, McDuffie has a few items entered into the CMMS that are generating proactive maintenance work orders and are in the process of collecting and adding data to encompass more of their maintenance activities in the CMMS. Like McDuffie, the BMHP had no existing proactive maintenance efforts. While only recently beginning improvements to equipment maintenance, the BMHP has already identified benefits to streamlining in that area.

While TPM's ultimate goal of zero unplanned downtime is far from being reached at the Port, steady improvement has been evident. A fully implemented TPM program can result in a 60% reduction in unplanned equipment downtime, an 80% reduction in breakdown cost, and a 30% reduction in spare part cost (7). A continuing focus on a complete TPM implementation and a drive toward these benefits will be necessary for the Port to effectively handle their anticipated growth.

## **LEAN ENTERPRISE IN THE OFFICE AND SUPPORT FUNCTIONS**

Many companies have made great strides in implementing lean and eliminating waste from the operations side of their business. However, an organization cannot be a true Lean Enterprise without also focusing on eliminating waste from the support functions that are in place to complement the operations (15). In the fourth year of Lean Enterprise implementation at the Port, 13 training courses were held for all corporate administrative and support personnel (over 100 employees) on the topic of Lean Office. Additionally, 7 value stream maps have been developed for administrative or support functions including Purchasing/Accounts Payable, Payroll, Central Garage, Central Maintenance, Medical Services, Harbor Master, and Human Resources. Additional lean tools are scheduled to continue to be implemented in the

administrative and support functions based on their respective value stream plans in an effort to eliminate waste at all levels of the Port's organization as they strive to become a true Lean Enterprise.

## **CONCLUSIONS**

In summary, the authors of this paper offer the following conclusions:

The philosophy of Lean Enterprise can be successfully applied at seaports to address capacity issues relative to growth. The lean objective is to identify and eliminate non-value-waste in order to be more responsive to customers. A modified implementation model of lean tools was developed specifically for seaports and was employed at the Port of Mobile. The Port has experienced positive results that can directly provide additional capacity, including the ability to handle more revenue railcars (30% increase) and a reduction in barge loading times (125% improvement), barge unloading times (70% improvement), ship unloading times (26% improvement), ship loading times (44% improvement), and train car dumping times (100% improvement).

A systematic application of Lean Enterprise is imperative to achieving successful results in any arena. Lean should be integrated into the organization's business strategy, investment in training should be made at all levels, and critical value streams should be identified and managed. Lean tools should be implemented in phases via the kaizen process, choosing a highly visible pilot area and then spreading across the entire organization. The Port has used this approach in their endeavor of becoming a Lean Enterprise seaport.

Lean Enterprise transformation is a journey, not a destination. The Port has been implementing lean for almost 5 years. While implementation has reached the majority of divisions at the Port and many successes have been realized, opportunities for improvement still exist. As performance improves, it can be expected that customer demand and growth will continue to increase. Continuous improvement through investing in employees and focusing on establishing mature lean tools at the workplace optimization level is necessary to further eliminate waste to accommodate this demand.

## **RECOMMENDATIONS**

The authors would like to offer the following recommendations to the Port, and all seaports in general, relative to Lean Enterprise:

The Port should focus heavily on the workplace optimization section of the Lean Enterprise implementation model. While strides have been made to establish more proactive current maintenance activities, a plan should be established to progress to a full TPM program. This will involve the inclusion of equipment operators as well as maintenance personnel. Data should continue to be collected on all pieces of equipment and entered into the CMMS to establish a maintenance history and a medium of generating preventative and predictive work orders. The previously discussed potential benefits of a TPM program would give the Port a significant amount of additional capacity on their existing equipment. Additionally, continuing to develop specific hiring procedures and training development programs for individual jobs, along with making inexpensive mistake-proofing modifications to equipment, would increase the quality of work and reduce the likelihood of defects and mistakes.

The Port should continue to make establishing a continuous improvement culture a priority. Investment in training at all levels and the involvement of over half the Port's employees in kaizen activity has begun the creation of this culture. The Port has also identified dedicated lean resources and trained internal kaizen facilitators at each major division. Additionally, the Port has worked with ATN-UAH to license training materials in an effort to internalize the lean knowledge. The Port should continue to focus efforts on establishing and growing these internal lean resources under the mentorship of experts so that the organization becomes less dependent on outside resources. This would allow for an increase in the capacity to perform lean improvements and create a culture where it is a way of life at the Port.

Further research should be performed to develop a complete performance measurement system for Lean Enterprise at seaports. While operational level metrics have been established for many improvements at the Port (such as barge loading time, etc.), no system has been established to tie these metrics to higher level strategic objectives. The result has been improvements capable of meeting projected growth (barge loading improvement at McDuffie provided over double the previous capacity) yet no sustainment of those improvements has existed. Two years after the initial improvement in barge loading, the average time to load a barge had returned to over 2 hours. A follow-up kaizen event with a different team of employees following the same SOP established in the first kaizen event exhibited an ability to consistently load a barge in even less time than the initial improvement (49 minutes). This suggests the lack of sustainment can be attributed more to management of the process than to the process itself. The establishment of port-wide performance metrics, cascading these metrics down into appropriate measures of all levels of the organization, and proper management to these metrics would drive behavior more conducive to sustaining the improvements that can be realized through Lean Enterprise.

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