The Integration of Safety and Ergonomics into a Lean Manufacturing Process: A Case Study

by

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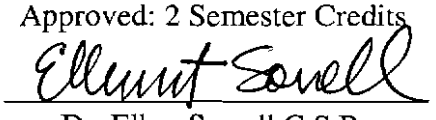

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ABSTRACT

The purpose of this study is to investigate the opportunity of integrating safety and ergonomics into a lean manufacturing process in the assembly operations at Company XYZ. In order to achieve this purpose the following objectives were developed and served as the basis for the study: evaluate the potential opportunity to include safety and ergonomics into lean, develop a process to integrate safety in lean processes and evaluate the effectiveness of a lean process that includes safety. The methodology in this study included a review of literature, a review of previous lean improvements at Company XYZ as well as the use of an interview instrument in an onsite interview with personnel involved in lean activities at Company XYZ. The researcher was able to determine how ergonomics and safety are integrated into lean manufacturing. It appears that process improvement strategies such as lean can have both favorable and unfavorable

consequences for ergonomics and safety. If properly integrated, the process improvement strategy can enhance the manufacturing process as well as the ergonomic process, thereby decreasing losses due to direct and indirect costs associated with WMSDs and creating competitive advantage for the company. With the results of this data areas the researcher feels would further the integration of safety initiatives into the organization's lean system were recommended.

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Chapter I: Introduction

Many industries in the U.S. are undergoing necessary changes to compete in a global economy that is becoming increasingly interconnected and competitive. Examples of these industries include manufacturing and service such as aerospace, automotive, electronics, furniture production, and health care (Environmental Protection Agency, 2003a). Competitive advantage can be realized by implementing process improvement strategies designed to systematically identify improvement opportunities and minimize waste created by imperfect processes. Over the years, there has been several process improvement initiatives developed for the purpose of enhancing operational efficiency and effectiveness. These process improvement strategies oftentimes improve an organization's competitive advantage, which enhances their ability to be competitive. One such process improvement strategy is called lean. "Lean Manufacturing" is a business model that focuses on the principles and processes that reduce cost through the systematic elimination of all non-value added activities known as waste (Congleton, 2007). Examples of waste include: overproduction, waiting, transportation, over-processing, inventory, motion, rework and underutilization of people (Humantech, 2005). Developed in the 1950's by Toyota Motor Company, lean production has now become a leading improvement strategy in the U.S. Lean production is known by other names such as lean thinking, lean enterprise, and lean transformation.

Processes typically not singled out in these process improvement initiatives include processes related to improving safety and risk control including ergonomic considerations. Ergonomics can be defined as designing the workstation to fit the people expected to operate the job (Humantech, 2005). The aim of ergonomics is "the evaluation

and design of facilities, environments, jobs, training methods, and equipment to match the capabilities of users and workers, and to reduce the potential for fatigue, error, or unsafe acts" (Chengalur, 2004, p. 658). Ergonomic process improvements that effectively control ergonomic risk factors such as force, repetition, awkward postures and duration on the worker, can result in an increase in employee performance, improvement in productivity and quality, and a decrease in work-related musculoskeletal disorders (WMSDs) thereby creating a competitive advantage for a company. (Humantech, 2005).

Company XYZ (termed XYZ because of confidentiality) is a framing manufacturing enterprise that is one of the many U.S. manufacturers implementing lean process improvement into their facilities. The enterprise currently has twenty locations internationally and has approximately 9,000 employees. The facility of interest is a 220,000 square foot assembly only facility that was established in the year 2000 and began implementing lean improvements in 2003. At this site, Company XYZ employs approximately 300 associates, manufacturing approximately one million units per year.

Statement of the Problem

From a competitive advantage standpoint, the opportunity to incorporate safety into lean improvements may have a significant impact, increasing productivity and quality while decreasing losses due to direct and indirect costs associated with WMSDs.

Purpose of the Study

The purpose of this study is to investigate the opportunity of integrating safety and ergonomics into a lean manufacturing process in the assembly operations at Company XYZ and to clearly define how ergonomics and safety are integrated into lean manufacturing.

Goals of the Study

The main objectives of the study are to:

1. Evaluate the potential opportunity to include safety and ergonomics into Lean.
2. Develop a process to integrate safety in lean processes.
3. Evaluate the effectiveness of a lean process that includes safety.

Background and Significance

Though it is accepted and displayed in many studies and books how the implementation of lean into company processes can eliminate non-value added activities, reduce production resource requirements and cost, and improve product quality, adding to company profits and competitiveness, many do not address the role and effect the integration of risk control/ergonomics plays in a lean process improvement. This case study may add to the present state of knowledge related to risk control and lean.

While it is expected that ergonomic improvements in the assembly-process at Company XYZ may reduce the occurrence of WMSDs and the direct and indirect cost associated with them, productivity and quality issues such as cycle time, throughput, process capability/flexibility as well as worker moral may also be expected to improve. Understanding these benefits and having a process to utilize them may add to Company XYZ's profits and competitiveness.

Limitations of the Study

This study has a number of limitations. They have been identified as:

1. This study is limited to the dates between 2/1/08 and 5/15/008.
2. This study pertains to a specific work stations at Company XYZ, the results should be considered in this way.

Definitions of Terms

The following definitions and terms are included for clarification and understanding:

Ergonomics. "The study of the design of work in relation to the physiological and psychological capabilities of people" (Chengalur et al., 2004, p. 658).

Lean Manufacturing. "five-step process: defining customer value, defining the value stream, making flow, pulling from the customer back, and striving for excellence." (Liker, 2004, p. 7).

Process. "the sequence of operations needed to design, manufacture, and deliver a product or service." (Productivity Press, 2002, p. 5).

Pull. "A system of cascading production and delivery instruction from down stream to upstream activities in which nothing is produced by the upstream supplier until the downstream customer signals a need. The opposite of push." (Womak, Jones, 1996, p. 309).

Value. "A capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer." (Womak, Jones, 1996, p. 311).

Value-added. "any operation in a process that changes raw material into value for the customer" (Productivity Press, 2002, p. 5).

Waste. "any human activity which absorbs resources but creates no value" (Womack, Jones, 1996, p. 15).

Chapter II: Review of Literature

The purpose of this study was to investigate the opportunity of integrating safety and ergonomics into a lean manufacturing process in the assembly operations at Company XYZ. With the integration of safety into lean improvements, work-related injuries and illnesses as well as the direct and indirect cost associated with them, could potentially decrease. Productivity and quality issues such as cycle time, throughput, process capability/flexibility as well as worker morale may also be expected to improve (Manuele, 2007). Understanding these benefits and having a process to utilize them may add to Company XYZ's competitive position. The following is a review of selected topics related to this study. These topics include: Loss, waste and cost associated with doing business, What is Lean, Direct and indirect costs associated with work related musculoskeletal disorders, Seven wastes of lean, Ergonomics, Workplace design and anthropometrics, Safety and lean, Integrating ergonomics into lean processes and Summary.

Loss, waste and cost associated with doing business

Peter Drucker, a well-known author, professor, and guru on corporate management explains the value of reducing losses within a business; "the first duty of business is to survive and the guiding principle of business economics is not the maximization of profit, it is the avoidance of loss" (p. 164). Similarly, another awarded and prominent management author Lois Allen, comments that, "managing loss is as much improvement as maximization of profit" (as cited by Clarke, 2004, p. 164). In the context of lean, loss and waste are synonymous. Waste includes any imperfect process and in the context of risk control and ergonomics these losses include direct and indirect costs associated with

work-related musculoskeletal disorders (WMSDs). This chapter will further delineate losses as they are associated with lean and risk control/ergonomics.

What is Lean?

The Toyota Motor Company developed a system during the 1950's that was characterized by flexible manufacturing systems, small-lot production, a short set-up time, small inventories, workers taking responsibility for quality on the production line, and a focus on eliminating wasted time and material from every step of the production process-from raw material to finished goods (Wokutch, 1992). What has become known as the Toyota Production System (TPS) is the basis for lean manufacturing (Liker, 2004). As coined by Womack and Jones, their popular book *Lean Thinking* defined lean manufacturing as a five step process that includes: defining customer value, defining the value stream, make the value-creating steps "flow" toward the customer, let customers pull value from the next upstream activity (a pull system), and striving for excellence (Kincaid, 2004). Another key fundamental principal of lean production was explained as the systematic elimination of waste. Waste, from a lean thinking standpoint, is any activity that consumes resources but creates no value, in other words any activity that is not value-added to the customer. In lean, these non value-added activities become a target for elimination by application of lean techniques (Womack & Jones, 1996).

In industry today, many companies are undergoing the necessary changes to compete in a global economy that is becoming increasingly interconnected and competitive. Industries are making these changes by implementing lean. Lean can allow better customer responsiveness, product quality, and cost. Some lean experts claim that approximately 30-40 percent of all U.S. manufacturers have begun implementing lean

methods. Examples of these industries include manufacturing and service such as aerospace, automotive, electronics, furniture production, and health care (Environmental Protection Agency, 2003a).

Seven wastes of lean

The creators of the Toyota Production System identified common types of waste. Identified below are the eight identified wastes and examples of each type of waste provided by Liker (2004):

- *Overproduction.* Producing items for which there are no orders, which generates such wastes as overstaffing and storage and transportation cost because of excess inventory. Overproduction may require stressful manual material handling, which present ergonomic risk.
- *Waiting for the next processing step (time on hand).* Workers merely serving to watch an automated machine or having to wait for the next processing step, tool, supply, part, etc., or having no work because of stockouts, lot processing delays, equipment downtime, and capacity bottlenecks.
- *Unnecessary transport or conveyance.* Carrying work in process long distances, creating inefficient transport, or moving materials, parts, or finished goods into or out of storage or between processes. This unnecessary transport may increase the potential for powered vehicles to collide or strike workers as well as increased material handling.
- *Overprocessing or incorrect processing.* Taking unneeded steps to process the parts. Inefficient processing due to poor tool and product design, causing unnecessary motion and producing defects. Waste is generated when providing

higher-quality products than is necessary. Overprocessing may increase the use of the machinery in the process, which therefore adds risk.

- *Excess inventories.* Excess raw material, work in progress, or finished goods causing longer lead times, obsolescence, increased chance for damaged goods, transportation and storage costs, and delay. Extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.
- *Unnecessary movement.* Any wasted motion employees have to perform during the course of their work, such as looking for, reaching for, or stacking parts, tools, etc. Similarly from an ergonomic and workplace design standpoint, unnecessary movements are targeted for elimination because they can add elements of risk.
- *Defects.* Production of defective parts or correction. Repair or rework, scrap, replacement production, and inspection mean wasteful handling, time, and effort.
- *Unused employee creativity.* Losing time, ideas, skills, improvements and learning opportunities by not engaging or listening to your employees.

The commonality between the general types of wastes identified in lean and the sources of ergonomic risk factors will be explored further in this chapter.

Direct and indirect costs associated with WMSDs

Since H.W. Henrich's publication in 1931 of his book *Industrial Accident Prevention*, it has been accepted that indirect costs are generally greater than direct costs. The extent of the actual ratio is dependant on a case-by-case basis (according to Peterson, 2003). Dan Peterson (2003), a highly respected consultant, speaker, and author in the

fields of safety management and organizational behavior, defines these two types of losses.

> Direct costs are those medical and compensation costs paid to the claimant by the insurance company; indirect costs are those so-called "hidden" costs not covered by insurance and, in fact, not easily observed or recorded. Indirect costs include time lost by others who observed or gave help at the time of the accident and time lost by the supervisor in investigating (p. 176).

From a risk control/ergonomic standpoint, other potential losses or hidden cost that may affect the bottom line of a company are: lost productivity, equipment damage and down time, production delays, goodwill, reputation in the community, OSHA penalties, hiring costs, clean-up time, rental costs, unhappy customers, spoiled product, materials, training costs, re-work, legal fees, increased insurance costs (MNOSHA, 2007). In the paradigm of lean manufacturing these direct and indirect losses can all be viewed as waste.

WMSDs account for one-third of all workers' compensation costs in the U.S. The total economic burden of WMSDs in the U.S. is estimated to range from 15$ to $20 billion (Occupational Safety and Health Administration, 1999).

The average cost of a work-related cumulative trauma disorder (CTDs) in the U.S according to the National Council on Compensate Insurance is $9,112, according to Liberty Mutual Group is $10,000 and according to the National Safety Council is $11,420. The average cost of work-related strains and sprains in the U.S. according to the National Council on Compensate Insurance equaled $8,759 and according to the National Safety Council is $13,611. The average cost of work-related low back injury in the U.S. according to the National Safety Council equaled $10,698 and according to the National Council on Compensate Insurance is $23,916 (Christensen, C., & Manuele, F. A., 1999).

Studies have shown that ergonomic programs have had a direct affect on workers compensation costs (Humantech, 2005). However, workers compensation is only one aspect of the overall cost of risk. According to Bird and Davies (1996), workers compensation accounts for only 40.2% of the overall cost of risk. Even though WMSDs account for one aspect of the cost off risk, from a financial standpoint, WMSDs can further affect organizations' efficiency & productivity issues as a result of waste in the form of workers compensation/ergonomic issues. Bird and Davies (1996) conclude that the average direct and indirect cost of risk to American companies is a minimum of 25% of their net profit. Since direct and indirect costs of occupational accidents and illnesses have economic consequences, adequate work place design and ergonomics can potentially reduce losses by enhancing functional effectiveness while maintaining or improving human welfare, therefore reducing waste (Karwowski & Marras, 1998).

Ergonomics

Ergonomics can be defined as designing the workstation to fit the people expected to operate the job (Humantech, 2005). The aim of ergonomics is "the evaluation and design of facilities, environments, jobs, training methods, and equipment to match the capabilities of users and workers, and to reduce the potential for fatigue, error, or unsafe acts" (Chengalur, 2004). From a lean standpoint, potential for fatigue, error, or unsafe acts could all be seen as contributing factors to waste. The goal of ergonomic design is to optimize performance of an individual, thus to remove all waste.

The benefits of well-designed workstations include productivity, safety, and increased satisfaction for the employees (Chengalur, 2004). Ergonomic process improvements that effectively control ergonomic risk factors on the worker can result in an increase in

employee performance, improvement in productivity and quality, and a decrease in WMSDs thereby adding to the bottom line and creating a competitive advantage for a company (Humantech, 2005). Smith (2003) reiterates this goal by stating three objectives of ergonomics: to safely maximize human efficiency, minimize exposure to recognized ergonomic risk factors, and proactively strive for continuous program improvement early in the design process. To guide design of and enhance the human-machine interface, analytic tools such as anthropometric data are available.

Workplace design and Anthropometrics

Anthropometry is the branch of human sciences that focus on body measurements. Originally derived by the military, there is abundant anthropometric data from all over the world (Chengalur, 2004). Anthropometric data can be used as guidelines for workplace design improvements. According to the Canadian National Centre for Occupational Health and Safety (2005), "the guiding principle in workplace design is to fit the workplace to the worker. Proper design of the workstation decreases the effort required of the worker to maintain a working position" (p.1). Likewise, proper tool design can significantly decrease awkward postures and force to complete the task, thereby optimizing human performance while decreasing the potential for WMSDs and associated losses (Canadian National Centre for Occupational Health and Safety, 2005). Research has shown a design criterion that considers ranges of body sizes, motions and strengths can achieve safety, efficiency and ease of humans in the work environment, and therefore decrease sources of loss adding to profitability (Chengalur, 2004). As Karwowski and Marras succinctly state in *The Occupational Ergonomics Handbook* (1998), to design tasks, tools or workstation for a "regular" person would be unwise for

the reason that "no such person exists, and design for the average fits nobody well" (p. 163). With this in mind, thorough knowledge of the job requirements and anthropometric data, the inefficiencies or waste in processes can be eliminated. One example of this is improper work heights; improper work heights can lead to awkward postures, which in turn can contribute to fatigue and eventual injury. Other inefficiencies or waste in such a process can occur as people slow down to compensate for extra work that is created to overcome height differences and defects due to fatigue (Chengalur, 2004).

Safety and Lean

Adding value and eliminating waste is a shared goal of both ergonomics and lean manufacturing; therefore, there are natural integration points between the two. Despite these common goals, there are cases when these shared goals are realized and when these common goals are not (Wilson, 2005). In 2005 Newman & Braun gave insight into the relationship between safety and the lean process by stating that, "unfortunately, lean doesn't necessarily mean safe though the two should go hand in hand.... a poorly designed task that requires a worker to reach excessively is not only inefficient, requiring more time and motion than needed but is also likely to cause injury. In the worst-case scenario, an overzealous company may implement extreme lean manufacturing strategies where safety is not merely overlooked, but compromised" (according to Manuele, 2007, p. 28). Such a scenario is contradictory to fundamental goals of lean which is the elimination of all wastes. In that case processes overlooked in these process improvement initiatives include processes related to improving safety/ergonomics. In such a case, during a productivity and quality enhancement, the focus is on the process and product rather than on the worker (Chengalur, et al. 2004). From this standpoint, the goal of the

enhancement itself can be undermined in the form of losses involving the worker, such as the direct and indirect costs associated with musculoskeletal disorders, and can ultimately affect productivity, quality and profitability (Humantech, 2005). These aspects of lean and safety are apparent in the following cases.

According to Wilson (2005), in 1993 an automobile manufacturer, who implemented lean, experienced a 100 percent increase in cumulative trauma disorder (CTD) cases and also received a citation from the California OSHA. A couple years later the same automobile manufacturer implemented lean on a second assembly line, this time integrating safety into their lean process, and experienced a similar rise in productivity, and quality, but this time reduced injuries by 30 percent. Unfortunately as seen in this example, during the elimination of waste, ergonomic considerations were not considered. By "improving" efficiency, lean processes can become highly repetitive with little pause and restorative breaks for the worker. This in addition to awkward postures, high forces or other ergonomic risk factors can ultimately add to losses or waste. (Wilson, 2005).

In a similar comparison study completed between manufacturing processes in Sweden and China, Kazmierczak et al. (2005), found a higher prevalence of forceful and non-neutral postures as well as frequent stops in the Chinese process. Conversely, the Swedish process had addressed these issues and was regarded as more "efficient," however, the differences in terms of WMSDs was small. The researchers concluded a process spent in "value-added activities would lead to increased frequency and velocity of movements" (p. 736) which lead to a WMSD potential (as cited by Wells et al. 2007).

In a study which focused on time, i.e., duration, as it relates to musculoskeletal health and manufacturing, Wells et al. (2007) explain that time is a key issue for both

ergonomists and engineers during production system interventions. Current trends in industry, such as lean, can include specialized and more time-intensive production systems with a larger occurrence of standardized, short cycle tasks. Rate of repetition as well as force and posture have been known to increase the risk of WMSDs.

Landsbergis et al. (1999) point out another factor involved in this trend toward lean production: many companies have concentrated on downsizing as one of the keys to minimizing waste, which has in turn increased biomechanical exposures and ergonomic risk factors. As seen at Swedish manufacturing industries, this also reduced work cycle times, created more standardized work tasks, and furthered the intensification of work. (as cited by Wells et al. 2007).

Integrating Ergonomics into Lean Processes

Similar to Newman and Braun (2005), according to Manuele's article published in the 2007 August edition of Professional Safety, by including safety during the design phase, waste that would otherwise occur in the future is minimized. For example, lost production time and "retrofitting expense," are two forms of waste that potentially could have been avoided. Wilson (2005) also agrees with Manule, stating that, the integration of ergonomics begins in the planning stages of a lean process and that "ergonomics is simply an additional tool for lean teams to use to eliminate waste and create value in an organization" (p. 46). Further, ergonomics should not be viewed as another step it should be part of the process (Wilson, 2005). Dan MacLeod expresses a similar point in his 1993 book, *The Ergonomics Edge: Improving Safety, Quality, and Productivity.* Macleod states, that the concepts, tools, and approaches of the quality process can be used to solve ergonomic issues which in turn can readily be used to improve quality.

This integration of safety into the process is observed in Liker's 2004 book, *The Toyota Way*, he explains that it is common for Toyota plants to not only focus on quality, goals of cost, and timely delivery, but that Toyota also follows a common practice in Japan known as QCDSM (quality, cost, deliver, safety and morale). Taiichi Ohno, founder of the TPS wrote:

> Every method available for man-hour reduction to reduce cost must, of course be pursued vigorously: but we must never forget that safety is the foundation of all our activities. There are times when improvement activities do not proceed in the name of safety. In such instances, return to the starting point and take another look at the purpose of that operation. Never be satisfied with inaction. Question and redefine your purpose to attain progress (p. 34).

Further, Liker (2004) points out that "the Toyota way" is more than tools and techniques; it is a system with a culture that has a centrality of people, which oftentimes missed when companies are applying lean. This results in short term improvements and unsustainable competitive advantage.

In an article published in the *Jounal of Engineering Manufacture,* the author addresses this point of creating a "culture" from a ergonomics perspective describing the results of a good ergonomics culture to include: reduced injuries and their related costs, loss reduction, increased productivity, improved quality, better workforce stability and morale gains (Smith, 2003).

Other aspects of lean in some circumstance seem to inherently improve safety. One-piece flow, one of the key aspects of lean, can ultimately add to the elimination of waste. As Wiremold Corporation experienced, one-piece flow in terms of safety translates into smaller batches meaning less forklifts and traffic, which are a major cause

of incidents. This as well as lifting and moving smaller containers of material translated into a reduction in WMSDs (Liker, 2004).

Summary

A review of literature suggests that process improvement strategies such as lean can have both favorable and unfavorable consequences for ergonomics and safety. If properly integrated, the process improvement strategy can enhance the manufacturing process as well as the ergonomic process, thereby creating competitive advantage for a company. Without the proper consideration, the process improvement can potentially create a decrease in employee performance, decline productivity and quality, and an increase in WMSDs, thereby creating a competitive disadvantage.

Many goals of an ergonomic improvement and a lean improvement are shared, these goals include: the maximization of human efficiency (elimination of waste), minimization of recognized ergonomic risk factors (potential for waste), proactively strive for continuous improvement (common goal of ergonomics programs and lean programs), reduce costs, increase productivity, improve quality, better workforce involvement, increase stability and morale (Smith, 2003). When safety considerations are integrated from the planning stages of lean improvements, the common goals of ergonomics coupled with lean can be realized.

Chapter III: Methodology

The purpose of this study was to investigate the opportunity of integrating safety and ergonomics into a lean manufacturing process in the assembly operations at Company XYZ.

The objective of this study is to evaluate the potential opportunity to include safety and ergonomics into lean, develop a process to integrate safety in lean processes and evaluate the effectiveness of a lean process that includes safety.

This chapter describes the methods and procedures used to achieve the objectives of this field study. The methods and procedures used in this study included a review of literature related to aspects and objectives of lean and ergonomic process improvements to provide an evaluation of the potential opportunity to include safety and ergonomics into lean. This included academic, business, news, and internet publication addressing lean manufacturing trends, methods, case studies and results. Moreover, the methodology included a review of previous process improvements to evaluate the effectiveness of a lean process that includes safety as well as define how ergonomics and safety are integrated into lean manufacturing. An interview regarding lean and ergonomics was conducted with the safety manager to gather the information about the company's policies and the extent of safety and lean integration and potential for improvement.

Sample Selection

In order to investigate the opportunity of integrating safety and ergonomics into a lean manufacturing process in the assembly operations at Company XYZ, the safety manager was selected for an interview. The safety manger of the facility was interviewed

based on the information regarding lean and ergonomic process improvements and general management controls at Company XYZ.

In addition to the interview, workstations at Company XYZ that previously underwent lean and ergonomic improvements were identified and selected due to their process improvement status as well as the existing pre- and post- implementation data. This data was used to help define how ergonomics and safety are integrated into lean as well as the effectiveness of a lean process that includes safety.

Instrumentation

The study required the use of two survey instruments. The first instrument was a personal interview guide (Appendix A). The assessment consisted of an on-site personal interview with a semi-structured format. The literature review provided the framework and served as a guide for developing interview criteria to ensure all study objectives are addressed. Specifically, the questions where focused on management-based practices and procedures in place regarding process improvements as well as the goals of this field study.

A data collection sheet was also developed to collect and compare data describing safety and lean issues at the workstation pre-and post- implementation (Appendix B). Specifically categories developed addresses injury data (where available), quality issues (customer complaints, etc.), employee symptom surveys, medical data, ergonomic analysis results, initial reason change was initiated (quality/safety improvement), lean method by which the waste was reduced (parts presentation, inventory control, etc.) and cycle time.

Data Collection

The safety professional of company XYZ was contacted and informed by phone and email one week before the scheduled interview. The interview questions as well as the questionnaire were provided at this time. The participant was asked to complete the consent form provided by the researcher and mail it back. The researcher performed an on-site personal interview. At which time, pre-/post-implementation data was provided by the company to the researcher in electronic and hard-copy form.

Data Analysis

The primary purpose of this study was to investigate the opportunity of integrating safety and ergonomics into a lean manufacturing process in the assembly operations at Company XYZ. The information obtained from the literature review, data provided, and interview conducted was evaluated based established goals of this field project:

I: Evaluate the potential opportunity to include safety and ergonomics into lean.

II: Develop a process to integrate safety in lean processes.

III: Evaluate the effectiveness of a lean process that includes safety.

Limitations of the Study

This study has a number of limitations. They have been identified as:

1. This study is limited to the dates between 2/1/08 and 5/15/008.
2. This study pertains to a specific work stations at Company XYZ, the results should be considered in this way.

Chapter IV: Results

Introduction

The purpose of this study was to investigate the opportunity of integrating safety and ergonomics into a lean manufacturing process in the assembly operations at Company XYZ.

The following objectives served as the basis for the study:

1) Evaluate the potential opportunity to include safety and ergonomics into lean
2) Develop a process to integrate safety in lean processes
3) Evaluate the effectiveness of a lean process that includes safety

To achieve the stated objectives, the methodology in this study included a review of literature, a review of previous lean improvements at Company XYZ as well the use of an interview instrument in an onsite interview with personnel involved in lean activities at Company XYZ. The interview instrument provided a series of questions regarding aspects of each objective. Objective I resulted six interview questions, objective II resulted eight interview questions and objective III resulted five interview questions. The literature review provided the framework and served as a guide for developing interview criteria to ensure all study objectives were addressed. Specifically, the questions where focused on management-based practices and procedures in place regarding process improvements as well as the goals of this field study.

Results from Interview Instruments

Table 1

Objective I: Evaluate the potential opportunity to include safety and ergonomics into lean.

Question 1 from Interview Instrument:	*Why would an organization choose to integrate lean and ergonomics/safety?*
Response Safety Coordinator:	There must be a need to even begin a concentrated effort on ergonomics. This is often the result on incidents that are measurable and affect safety performance goals and/or the financial implications with injuries and illnesses. Ergonomics is easy to integrate into lean, or vice-versa, when individuals who are held accountable for both realize the similarities between the two philosophies. A company would also choose to integrate the two if ergonomics is engineering based and if lean is engineering driven, as the engineering function must resource both efforts. If ergonomics were a safety function and only safety people worked on ergonomics, I would not expect the same result. Also, if lean is only supported by Operations staff and not engineering supported, you likely wouldn't get the same benefits in reducing the duplication of efforts between the two disciplines.
Question 2 from Interview Instrument:	*How do you and your company view the relationship between management of safety/ergonomics and the management of other parameters?*
Response Safety Coordinator:	Safety and ergonomics are managed and resourced like other business functions. Essentially, safety and ergonomic efforts need to be measured, prioritized and resourced with other resource demanding support functions; such as quality and lean. Both safety and ergonomics are viewed as vital to the effective performance of production in a similar way that quality is used as a tool to effective production. It also goes without saying that not everything can be a safety or ergonomic showstopper. There are acceptable and known levels of risk; as there are with quality, which is driven by specifications and tolerances of acceptability. But also like quality, there are some aspects of safety and ergonomics that are known issues with a high likelihood for injury that do come before production.

Table 1 continued

Question 3 from Interview Instrument:	*Does management value safety/ergonomics and lean improvements?*
Response Safety Coordinator:	The value of ergonomics and lean improvements come from the results of previous successes or the true elimination of risk. During the beginning of both lean and ergonomic efforts, management must put trust in the principles of both and the anticipated gains in productivity or reduction in waste/cost. With ergonomics, these anticipated gains can be measured by ergonomic risk reduction measurement tools (BRIEF) coupled with current WC losses. With lean, waste of waiting, transportation, etc can all be measured and assumptions of timesavings and therefore production increases can be anticipated. Where both lean and ergonomics take hold is when past successes have shown measurable results and be benefits of the investments in both are realized. This then allows management to have a greater comfort level in making the investments with less up-front work to provide the anticipated gains; essentially trust in the processes and people has been established with eliminates a lot of obstacles and allows the teams to implement at a faster pace and take greater risks to yield larger gains.
Question 4 from Interview Instrument:	*Does the safety personnel take an active role in lean improvements? How would you describe the lines of communication between engineering and safety personnel during lean improvements?*
Response Safety Coordinator:	I am a very active member in the implementation of ergonomic improvements with engineering. From leading kaizens (rapid improvement teams), to brainstorming concepts, to reviewing machine design, I am involved every step of the way. This has created great relationships and partnerships between safety and engineering and there is not a feeling that the safety guy did a dump and run on engineering. This forces the safety person to expand the scope of their job into engineering but it is rewarding to be a part of the process with engineering and production associates. It also gives the safety person a strong connection to the production floor and earns respect with both production associates and engineering. Engineering uses the safety professional as a sounding board for checks and balances during lean improvements. This allows both disciplines to be on the same page so that there aren't any surprises that may jeopardize the project; it also adds another level of support and an ally for implementations, brainstorming, and in the communication chain. Active involvement by both disciplines also helps to eliminate an

Table 1 continued

	adversarial relationship which could develop where individuals are feeling like it is not there issue or job to do this or that. Active involvement creates partnerships, which benefits all support functions.
Question 5 from Interview Instrument:	*Are the goals of lean and safety/ergonomics viewed as separate?*
Response Safety Coordinator:	Both yes and no. Lean looks at unneeded motion as a waste. This motion can often be due to poor ergonomics (reaching, bending, turning, walking) so that is an easy connection to make. If the waste of motion is eliminated in lean; 9 times out of 10 the ergonomics at the station will be improved unless the task becomes more manual due to lifting where maybe there was an assist before but that's rarely and issue. The goals of lean are really focused on the elimination of waste to allow more work to be completed; therefore more product. Ergonomics goal is not to create more product, it is to create product without having injuries due to ergonomic risk factors. So, on a real basic level the goals of ergo and lean are not the same but the goals of ergonomic and lean within the principles and wastes of lean are very similar. As important, the corrective actions that reduce ergonomic risk and lean waste are more often then not beneficial to each other.
Question 6 from Interview Instrument:	*Is safety ever perceived to be a detriment to the lean efforts?*
Response Safety Coordinator:	Typically not. One situation would be when LOTO must be done for a tooling change. This obviously stops the line and adds change over time. Engineering and safety need to work together to identify picker ways to accommodate both which may mean quicker change tooling, trapped key LOTO systems, or other means to meet LOTO requirements and lean expectations. Within ergonomics, ergonomic assist devices can sometimes add more time than doing an ergonomic at-risk task manually. In these situations, the team once again needs to identify create ways to get both and if not, ID a compromise which is acceptable to all. Some of these may mean risk acceptance or leaving waste in place because it is less critical than the risk of injury.

Table 2

Objective II: Develop a process to integrate safety in lean processes.

Question 7 from Interview Instrument:	*Is there a process through which safety and lean concepts can be addressed concurrently?*
Response Safety Coordinator:	For the most part, the process for both is really a product of the cultures of both imbedded in individuals who are making improvements in either and have the eyes to see the benefits of both. The Company XYZ safety assessment process does prompt a safety review of equipment and/or process changes but this is a pretty formal process that doesn't get used a lot for continuous improvement lean improvements. The process works well for major moves that are likely to have safety or ergonomic implications. Otherwise, the process for concurrently improving lean and safety is from the individuals implementing the change in either area, and those individuals that support the change.
Question 8 from Interview Instrument:	*Is safety viewed as a separate activity to lean concepts?*
Response Safety Coordinator:	Nope, I think some of my other responses answered this question.
Question 9 from Interview Instrument:	*How would or does employee involvement influence lean/ergonomic improvements?*
Response Safety Coordinator:	Associate involvement is critical to the success of either. Changes must be fully supported and owned by the operators to get buy-in. This ownership and support comes through active involvement. Associates are the experts at their jobs and know the details about items that can make or break an improvement. There are so many small and large factors which individuals who do not work on the production floor everyday will miss if associates are not involved; this is to no fault of engineering or the other support functions but it is very difficult to know every detail and decision of what production associates make to keep things moving. Active involvement by production associates in improvement projects allow support staff and associates to work on the same playing field and see the benefits from everyone working together toward the common goals.

Table 2 continued

Question 10 from Interview Instrument:	*What will prevent your company from achieving success with lean and ergonomics?*
Response Safety Coordinator:	The one thing that would slow us down is if resources get pulled from engineering or if associates are not able to get involved in kaizens and other continuous improvements events. Otherwise, the culture has been created for continuous improvement of both areas.
Question 11 from Interview Instrument:	*Are safety/ergonomic and lean improvements viewed as "continuous improvements?"*
Response Safety Coordinator:	Absolutely. These are not projects; these both are definitely processes that do not have an end target, end date, or completion date. After one improvement is complete, the question then needs to be, what's next on the list? Both lean and ergonomic improvements should have a list of priorities that is fluid and dynamic based on potential impacts and required resources. Because most of these initiatives are continuous improvements to existing processes and equipment, timing with other project and changes, business conditions, and resource availability often drives the implementation timetable. In addition, often changes are initiated because they can be piggybacked with other changes that we know are going to be happening due to fulfillment changes, computer systems, etc.
Question 12 from Interview Instrument	*What are some challenges during lean/ergonomic improvements?*
Response Safety Coordinator:	The challenge is always how do we take good ideas and resource them into reality. To resource them includes both engineering (or people) and financial. Everyone's plates are always full so finding available time is often a matter of hw it falls into prioritization and timing. Additional challenges have to do with getting team buy-in and communication of changes. With so many people involved in production areas, job rotations, and multiple shifts, it becomes nearly impossible to get input from everyone and to share everything with everyone. This really drives the point that various means of communication and a lot of allies need to be used to get the messages out and feedback from many people. Communication is probably the single most difficult item in making improvements and making them successful, which drives ownership.

Table 2 Continued

Question 13 from Interview Instrument:	*Do engineering goals incorporate safety and ergonomic aspects?*
Response Safety Coordinator:	All ergonomic and most safety goals are on the engineering projects list. Ergonomic and safety projects are prioritized with all other engineering projects with a bias toward those with strong ergonomic or strong safety implications. We also prioritized based on the number of individual affected by each change and additional benefits from implementing a change. Obviously, those changes that have multiple benefits and benefits to a lot of individuals yet have limited engineering requirements are prioritized higher than those that affect fewer individuals, require more resources, and have a lesser impact on multiple functions.
Question 14 from Interview Instrument:	*How is safety represented in the Lean process?*
Response Safety Coordinator:	Safety and ergonomics are represented in the lean process by our Lean steering team, which comprises of plant management, facilities/maintenance, engineering manager, fulfillment manager, and the plant's industrial engineer. As the resident expert but, I am consulted by the team for the most part the IE and engineering manager are able to work with the steering team to integrate safety and ergonomics. In addition, the culture of ergonomic and lean integration is strong so each individual takes and active roll into ensuring that the two work together.

Table 3

Objective III: Evaluate the effectiveness of a lean process that includes safety.

Question 15 from Interview Instrument:	*To what extent are you personally satisfied with the safety performance of your organization?*
Response Safety Coordinator:	Very satisfied. The culture is strong with safety integration, support and resources are well established, and safety and ergonomics are appropriately prioritized. As a result, the plant continues to meet our safety performance goals and have goals that are currently about 1/3 of the industry average for incident rate. In addition, the WC loss trends clearly demonstrate that our investments in ergonomics are paying the anticipated dividends.
Question 16 from Interview Instrument:	*Have past projects shown significant commonalities between goals of lean and safety/ergonomics?*
Response Safety Coordinator:	Yes, to the point that it is difficult at times to remember why we initiated a change; was it prompted by lean or ergonomics?
Question 17 from Interview Instrument:	*Have lean improvements had an affect on safety?*
Response Safety Coordinator:	Safety performance has continued to show measurable results in traditional safety performance measures and WC loss. Everything that the plant has done in all areas contributes to the reductions in injuries and illnesses. The degree is really unknown because it is extremely difficult to predict the effects of cumulative trauma on individuals and which risk factor reductions had a valid correlation to the avoidance and an injury.

Table 3 continued

Question 18 from Interview Instrument:	*Have workplace design improvements that incorporated ergonomics shown to increase productivity while eliminating safety issues?*
Response Safety Coordinator:	Yes, it is understood by all that safety and ergonomic improvements cannot have a negative affect on productivity or we must go back to the drawing board. In order to be successful during an ergonomic improvement implementation, we must have a measurable reduction in cycle time.
Question 19 from Interview Instrument:	*How effective are your project teams?*
Response Safety Coordinator:	For the most part, very effective. Effectiveness will always depend on our opportunity to implement and that has everything to do with how we are able to resource it.

The data provided by Company XYZ regarding a previous lean improvement is shown in Table 4 below.

Table 4

Objective III: Evaluate the effectiveness of a lean process that includes safety

Workstation Improvement name	Bead roll hand assist (see Appendix C.)
Initial reason change was initiated by lean team:	Productivity: entire line height was driven by the optimum height needed to place the top and bottom pieces of bead. Safety/Ergonomics: minimize bending for the bottom bead AND minimize over-shoulder reaching for the top bead.
Lean Benefits: Type of waste identified	• *Overprocessing or incorrect processing.* Taking unneeded steps to process the parts. Inefficient processing due to poor tool and product design, causing unnecessary motion and producing defects. Waste is generated when providing higher-quality products than is necessary. • *Unnecessary movement.* Any wasted motion employees have to perform during the course of their work, such as looking for, reaching for, or stacking parts, tools, etc. • *Defects.* Production of defective parts or correction. Repair or rework, scrap, replacement production, and inspection mean wasteful handling, time, and effort.

Table 4 continued

Impact Categories	Pre-Implementation	Post-Implementation
Ergonomic/Safety	• Ergonomic survey score of 32 (High ergonomic risk) • Numerous associates physically could not roll bead on large sash due to their height • 40 lbs of downward force required to roll bead	• Ergonomic survey score of 7 (Low ergonomic risk) • No injuries from rolling bead since the installation of the six assists • 10-15lbs. of push/pull force required to roll bead
Quality	• Bead not consistently set	• Bead firmly set • Ensures the bead is fully set. • Allows for optimal amount of downward pressure to set bead (pneumatic regular) • Ensures the rolling bead is properly placed directly over the specific area • Reduces problems with commodities that are not optimal but are within tolerance, prior to machine, bead was rejected because it was hard rolling
Productivity	• 30 second cycle time • Entire sash line height was driven by the optimum height needed to place the top and bottom pieces of bead	• 27 second cycle time • Reduced cycle time by 2-3 seconds • Positive impact on operation cycle time
Miscellaneous Impacts	• Several associates who dreaded rolling bead before now prefer it in the rotation • $24,500 for the first assist; $19,500 for each additional (DH only) • Roller concept was designed into the new workstation • Positive feedback from associates	

Discussion

The primary objective of this study was to investigate the opportunity of integrating safety and ergonomics into a lean manufacturing process in the assembly operations at Company XYZ. The review of literature included a review of selected topics related to this study. These topics include: Loss, waste and cost associated with doing business, What is Lean, Direct and indirect costs associated with work related musculoskeletal disorders, Seven wastes of lean, Ergonomics, Workplace design and anthropometrics, Safety and lean, and Integrating ergonomics into lean processes.

The literature review provided the framework and served as a guide for developing interview criteria to ensure all study objectives are addressed as well as the defined the overall objectives of lean, safety/ergonomic and the commonalities between them.

Many goals of an ergonomic improvement and a lean improvement are shared, these goals include:

- The maximization of human efficiency (elimination of waste),
- Minimization of recognized ergonomic risk factors (potential for waste)
- Proactively strive for continuous improvement (common goal of ergonomics programs and lean programs)
- Reduce costs
- Increase productivity
- Improve quality
- Better workforce involvement
- Increase stability and morale (Smith, 2003).

The study confirmed that when safety considerations are integrated from the planning stages of lean improvements, the common goals of ergonomics coupled with lean can be realized. Process improvement strategies such as lean can have both favorable and unfavorable consequences for ergonomics and safety. If properly integrated, the process improvement strategy can enhance the manufacturing process as well as the ergonomic process, thereby creating competitive advantage for a company. Other considerations addressed in the results include the importance of top management support, resource availability, and open lines of communication between departments.

The literature review also suggests without the proper consideration, the process improvement can potentially create a decrease in employee performance, decline productivity and quality, and an increase in WMSDs, thereby creating a competitive disadvantage.

Summary

This chapter addressed the results of the objectives established for this study. These results fashioned the basis for the conclusions and recommendations presented in chapter five.

Chapter V: Summary, Conclusions & Recommendations

Summary

Statement of the Problem: From a competitive advantage standpoint, the opportunity to incorporate safety into lean improvements may have a significant impact, increasing productivity and quality while decreasing losses due to direct and indirect costs associated with WMSDs.

Purpose of the Study: The purpose of this study is to investigate the opportunity of integrating safety and ergonomics into a lean manufacturing process in the assembly operations at Company XYZ and to clearly define how ergonomics and safety are integrated into lean manufacturing.

Goals of the Study: The following objectives served as the basis for the study:

1) Evaluate the potential opportunity to include safety and ergonomics into lean
2) Develop a process to integrate safety in lean processes
3) Evaluate the effectiveness of a lean process that includes safety

Procedures: To achieve the stated objectives, the methodology in this study included a review of literature, a review of previous lean improvements at Company XYZ as well the use of an interview instrument in an onsite interview with personnel involved in lean activities at Company XYZ. The interview instrument provided a series of questions regarding aspects of each objective. Objective I received six interview questions, objective II received eight interview questions and objective III received five interview questions. The literature review provided the framework and served as a guide for developing interview criteria to ensure all study objectives are addressed.

Specifically, the questions where focused on management-based practices and procedures in place regarding process improvements as well as the goals of this field study.

Findings: Objective I: Evaluate the potential opportunity to include safety and ergonomics into lean. The study determined that:

- Ergonomics and safety can be integrated into lean when individuals accountable for both realize the similarities between the two philosophies.
- Safety ergonomics should be managed and resourced like other business functions such as quality and lean.
- Active involvement between safety and engineering as well as strong lines of communication benefits all support functions.
- Safety should typically not be perceived as a detriment to lean efforts, however compromise such as leaving waste in place because it is less critical than the risk of injury or the acceptance of risk may need to be identified by the lean improvement team.
- Many goals of an ergonomic improvement and a lean improvement are shared

Findings: Objective II: Develop a process to integrate safety in lean process. The study determined that:

- Lean and safety improvements are not viewed as projects but processes that do not have an end target, end date, or completion date.
- Safety is not viewed as a separate activity to lean concepts.
- Associate involvement is critical to the success of lean improvements and ergonomic improvements.

- Changes must be fully supported and owned by the operators to get buy-in.
- Culture of continuous improvement is important in both lean and ergonomics/safety
- Safety/ergonomic and lean improvements are viewed as "continuous improvements."
- Proper resources and the ability of associates to be involved in improvement teams and other continuous improvement events allow success with lean and ergonomics.
- Communication is a difficult item in making improvements and making them successful, which drives ownership.
- Engineering goals incorporate safety. All ergonomic and most safety goals are on the engineering projects list.
- Safety and ergonomics are represented in the lean process by Lean steering team which comprises of plant management, facilities/maintenance, engineering manager, fulfillment manager, and the plant's industrial engineer.
- A strong culture of ergonomics and lean integration can ensure their integration

Findings: Objective III: Evaluate the effectiveness of a lean process that includes safety. The study determined that:

- Safety performance has continued to show measurable results in traditional safety performance measures and WC loss.

- It is an understood by all that safety and ergonomic improvements can not have a negative affect on productivity.
- Project teams overall are very effective. Effectiveness will depend on the opportunity to implement, which depends on how you are able to resource it.

Conclusions

Objective I: The first objective of this study was to evaluate the potential opportunity to include safety and ergonomics into lean. Based on the results of the study, the study concluded that:

- Lean produces an operational and cultural environment that is highly conducive to risk minimization and injury prevention
- Organizations must recognize and be familiar with the common goals of lean and safety/ergonomics. Lean and Safety share the common goal of maximizing manufacturing throughput at the lowest risk and waste

Objective II: The second objective of this study was to develop a process to integrate safety in lean process. Based on the results of the study, the study concluded that:

- Top management commitment and resources allocated will have great effect on the success of Lean processes that includes safety
- Organizations must incorporate safety into engineering goals and project goals
- Effective communication between the safety department and engineering department is critical

- Employee involvement in improvement teams and other continuous improvement events allow success with lean and ergonomics and is a crucial part of the process
- Annual goals for engineering must include ergonomic and safety projects
- Safety representative must be actively involved in lean improvements and communication must be strong
- Safety must not be viewed as a separate activity that is a non-value-added effort with objectives contrary to lean concepts

Objective III: The third objective of this study was to evaluate the effectiveness of a lean process that includes safety. Based on the results of the study, the study concluded that:

- Past projects have shown significant commonalities in goals between lean and ergonomics
- Safety performance has continued to show measurable results in traditional safety performance measures and WC loss
- Ergonomic improvements are helping to meet plant safety performance goals

Recommendations for Improvement

There are four areas that the researcher feels that Company XYZ should look to improve upon. These areas include the development of a formalized Lean/safety program, Lean training, utilization of lean/safety tools, and the distribution of lean/safety based recommendations.

These areas are:

1) Lean/Safety formalized program

Integrating the safety initiatives into the organization's management system ensures that the initiatives and improvements are sustained over time. Similarly, the development and formalization of a lean/safety process and program that follows a well designed plan and is monitored and tracked on a regular basis will ensure that the initiatives and improvements are sustained over time. Such a program will also address key challenges and components in the process such as communication, management support and employee involvement as mentioned in the result section of this study.

The program for lean/safety improvements should include well-defined roles, responsibilities, and accountabilities of the lean improvement team and/or ergonomic team. The process should also include the creation of a mission statement that describes the goals of the process and the process should ensure participants have proper amount of time to commit to the process. The program should include four key continuous improvement elements as described by Humantech, 2005:

Plan: Structuring the process

- Understand the current situation and develop goals and strategies
- Document the plan with what, when, and who.

- Identify applicable regulations and define current status
- Identify trends and site needs
- Establish goals and measures
- Establish improvement plans
- Provide adequate resources to support the process

Do: Initiate the job improvement, demonstrate success, and implement a management process and infrastructure to meet goals

- Establish a support infrastructure
- Provide training for skills and awareness
- Ensure corrective action plans are implemented to reduce risk
- Evaluate new products, technologies and workstations
- Manage WMSD health effects

Check: Monitor progress towards meeting goals

- Review process annually
- Monitor progress to waste/risk reduction goals and plans
- Validate waste/risk reduction

Act: Standardize effective activities and improve ineffective activities.

- Report results of the process review
- Apply effective controls to other exposures or imperfect processes
- Sustain Progress

This type of formalized well-documented process will ensure that the improvement process will continually improve, has checks and balances, defines lines of communication, and will continue if key personnel are replaced. At present the process for concurrently improving lean and safety at Company XYZ is from the individuals implementing the change, a formalized process has not been implemented.

Additional elements may include:

- Metrics and accountability for team members. For example, metrics such as the number of safety contacts, accident investigations, employee training sessions, etc. A metrics-driven operational setting that emphasizes rapid performance feedback and leading indicators is preferable.
- Development of in-house ergonomic standards disseminated to engineers for existing and new equipment.
- The monitor progress of previous improvements, track process measures toward the site goals and plans.
- Development of documentation regarding acceptable compliance strategies for applying lean methods to other safety sensitive processes. All successes should be documented.
- Quantification of the financial impact of lean ergonomic/safety outcomes. Cost savings in productivity,

quality, and workers compensation claims can be essential to attaining continued support from top management and help to ensure the processes' sustainability.

2) Lean training

Lean, being a continuous improvement philosophy, lean training must also continuously improve. All lean team members should understand the mission of the lean process and the role ergonomics/safety plays in the successful implementation of the process. During lean training, safety must be incorporated; this will insure safety is not leaned out during improvement activities. Basic ergonomic concepts and ergonomic design factors can be included in the training to enable team members during development stages. As mentioned in chapter two, it is imperative that safety is not perceived as inhibiting process improvements. Persons formally trained in lean concepts will view safety concerns as an integral and consistent part with lean concepts.

In order to promote a strong safety culture and give engineers, designers and manufacturing staff sufficient ability to apply safety in their engineering and design activities, knowledge-based training will allow safety to be incorporated into their regular duties. With a well trained capable workforce, performance outcomes can be met.

3) Lean/Safety tools

Utilization of tools and documentation such as Lean Event EHS checklists, waste finding checklists, and 6S inspection and audit questions during lean improvements will ensure that changes proposed during lean events identifies safety impacts. Example checklists shown in Appendix C and Appendix D.

4) Distribute lean/safety based recommendations

This project covered just one line within company XYZ, there is potential for lean/safety improvements in other areas as well as other facilities within Company XYZ. In order to ensure the continuation of the lean philosophy of continual improvement, working with similar companies and facilities to document and disseminate case study examples of that have successfully integrated safety activities into lean would be beneficial. This should also include the distribution of lean/safety based recommendations and best practices to other facilities within Company XYZ.

Areas of Future Study

1) Conduct similar research using a larger sample size to strengthen results. For example using multiple comparable sized organizations in similar industries.
2) Explore what OSHA and safety agencies can do to embrace and help companies include safety into lean operations to enhance the safety benefits.

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Appendix A

INTERVIEW GUIDE

1. Why would an organization choose to integrate lean and ergonomics/safety?
2. How do you and your company view the relationship between management of safety/ergonomics and the management of other parameters?
3. Does management value safety/ergonomics and lean improvements?
4. Does the safety personnel take an active role in lean improvements? How would you describe the lines of communication between engineering and safety personnel during lean improvements?
5. Are the goals of lean and safety/ergonomics viewed as separate?
6. Is safety ever perceived to be a detriment to the lean efforts?
7. Is there a process through which safety and lean concepts can be addressed concurrently?
8. Is safety viewed as a separate activity to lean concepts?
9. How would or does employee involvement influence lean/ergonomic improvements?
10. What will prevent your company from achieving success with lean and ergonomics?
11. Are safety/ergonomic and lean improvements viewed as "continuous improvements?"
12. What are some challenges during lean/ergonomic improvements?
13. Do engineering goals incorporate safety and ergonomic aspects?
14. How is safety represented in the Lean process?
15. To what extent are you personally satisfied with the safety performance of your organization?
16. Have past projects shown significant commonalities between goals of lean and safety/ergonomics?
17. Have lean improvements had an affect on safety?
18. Have workplace design improvements that incorporated ergonomics shown to increase productivity while eliminating safety issues?
19. How effective are your project teams?

Appendix B

Workstation Data Collection Sheet

Workstation Improvement name:	
Initial reason change was initiated by lean team:	
Lean Benefits: Type of waste identified	

Impact Categories	Pre-Implementation	Post-Implementation
Ergonomic/Safety		
Quality		
Productivity		

Appendix C

Lean Event EHS Checklist

LEAN EVENT CHECKLIST FOR EHS IMPACTS		
1. TITLE OF LEAN EVENT		2. ORGANIZATION/DEPARTMENT
3. DATE	4. BUILDING/PROCESS AFFECTED	
5. LEAN TEAM LEADER	6. PHONE NUMBER	7. E-MAIL ADDRESS

To ensure that changes proposed during Lean events identify potential environmental compliance, health, safety, and/or fire protection impacts, this form must be completed by the team leader for all organizations undergoing Lean activities.

Background Information: Impacts (either positive or negative) could occur as a result of altering chemicals/materials use, the location of the process, or facility alterations. Any potential impacts must be addressed prior to implementing any changes. Potential changes that must be identified on this form include:

- Changes to the type, volume, or introduction/issuance procedure for chemicals and materials use, the location of the process, or facility exposure. This may change the procedure for gathering data to report to regulatory agencies.
- Changes to the type of volume of waste generated by a process. This includes all media such as air emissions, water emissions, liquid/solid waste, etc.
- Changes proposed to either the physical layout of the process (i.e., moving work or storage areas) or to the facility (moving, replacing, or installing items such as vent hoods, floor drains, stacks, or process tanks).

Instructious: Describe the Lean event/process and answer the following questions about proposed process changes. If any of the questions are answered either "Yes" or "Unk" (unknown), there may be the potential for environmental impacts that need to be reviewed by EHS staff. Please contact _____ immediately upon identification of potential impacts or with questions. **Brief Summary of the Event/Process**:

Appendix C continued

Physical Environment			
As a result of the Lean event, will there be:	**Unk**	**Yes**	**No**
Any changes to the locations where either maintenance work or use of hazardous chemical/material will occur?			
Any changes to your personnel's work zone assignments?			
Any new equipment or modifications to existing equipment, or movement of existing equipment that has the potential to produce air or water emissions (e.g., rinse equipment/operations, cleaning tank, heating ovens)?			
Any changes to the facility (e.g., vents, stacks, floor drains, oil/water separators)?			
Any changes in the location(s) of the current flammable storage locker/areas?			
Any new confined space entry activities or procedures (e.g., personnel entering fuel tanks for cleaning)?			
Material/Chemical Use and Storage			
As a result of the Lean event, will there be:	**Unk**	**Yes**	**No**

Appendix C continued

Any changes to the type or volume of materials issued to personnel and/or used? This includes the introduction of new chemicals, elimination of chemicals, etc.			
Any changes to the chemical introduction or issuance procedure for chemicals/materials containing hazardous materials?			
Any changes in the volume of chemicals/materials stored?			
Any flammable materials that are not returned to the storage cabinets at the end of each shift?			
Waste Management			
	Unk	**Yes**	**No**
As a result of the Lean event, will there be:			
Any change(s) to the waste profiles for wastes stored at any initial accumulation points?			
Any change(s) to the location or number of initial waste accumulation points?			
Any change(s) to the volume of waste(s) that require disposal (i.e., wastewater, hazardous or solid waste) or to the volume of material that will be recycled or reused?			

(Environmental Protection Agency, 2003b).

Appendix D

6S Safety Audit Checklist

Document Title:	Document No.	
6S AUDIT RECORD (SAFETY)	Revision No.	Page: 1 of: 4
Required by:		

Audit Type: ☐ Initial Certification ☐ Sustaining

Auditors:
Name: _____ Date: _____
Name; _____
Workplace Representatives:
Name: _____ Name: _____

Subject	Questions	Yes	No
1. Aisles	A. Are aisles marked? 29 CFR 1910.22(b)(2)		
	B. Are aisle widths maintained? 29 CFR 1910.22(b)(1)		
	C. Are aisles in good condition? 29 CFR 1910.22(b)(1)		
	D. Are aisles and passageways properly illuminated?		
	E. Are aisles kept clean and free of obstruction? 29 CFR 1910.22(b)(1)		
	F. Are fire aisles, access stairways, and fire equipment kept clear? 29 CFR 1910.178(m)(14)		
	G. Is there a safe clearance for equipment through aisles and doorways? 29 CFR 1910.176(a)		
2. Chemicals	A. Are all hazardous chemicals appropriately labeled? 29 CFR 1910.1200(f)(5); 29 CFR 1910.1200(f)(6)		
	B. Are workers nearby aware of the content of chemical piping systems? 29 CFR 1910.1200(e)(1)(ii); 29 CFR 1910.1200(f)(5); 29 CFR 1910.1200(f)(6)		
	C. Is there a list of hazardous substances used in your work area? 29 CFR 1910.1200(e)(1)(I)		
	D. Is there a material safety data sheet readily available for each hazardous substance used? 29 CFR 1910.1200(g)(9); 29 CFR 1910.1200(g)(10)		
3. Electrical	A. Do extension cords being used have a grounding conductor? 29 CFR 1910.1200(f)(5); 29 CFR 1910.304(f)(5)(v); 29 CFR 1910.334(a)(3)		
	B. Is sufficient assess and working space provided and maintained about all electrical equipment to permit ready and safe operations and maintenance? 29 CFR 1910.303(g)(1); 29 CFR 1910.303(h)(3)		
	C. Are all cord and cable connections intact and secure? 29 CFR 1910.305(g)(2)(iii)		
	D. Are all disconnecting means legibly marked to indicate their purpose, unless located so that their purpose is evident? 29 CFR 1910.303(f)		
	E. Are flexible (extension) cords and cables free of splices or taps? 29 CFR 1910.305(g)(2)(ii)		

Appendix D continued

Document Title:	Document No.	
6S AUDIT RECORD (SAFETY)	Revision No.	Page: 2
Required by:		

Subject	Question	Yes	No
4. Exits	A. Are exits properly marked? 29 CFR 1910.37(q); 29 CRF 1910.37(H)		
	B. Are exits kept free of obstruction? 29 CFR 1910.36(d)(1)		
	C. Are the directions to exits, when not immediately apparent, marked with visible signs? 29 CFR 1910.37(q)(5)(6)		
	D. Are doors, passageways or stairways that are neither exits nor access to exits and which eould be mistaken for cxits, appropriately marked "NOT AN EXIT" "TO BASEMENT," "STOREROOM," etc.?		
5. First Aid	A. Do you have emergency eye wash and shower faeilitics within the immediate work area where employees are exposed to injurious corrosive materials? 29 CFR 1910.151(c)		
	B. Do you have first-aid kits easily aecessible to eaeh work area, with necessary supplies availablc, periodically inspected and replenished as needed? 29 CFR 1910.151(b)		
	C. Are emergency phone number posted where they can be readily found in case of an emergency? 29 CFR 1910.38(a)(2)(v)(vi)		
6. Flammable/ Combustible Containers	A. Are approved containers and portable tanks used for the storage and handling of flammable and eombustible liquids? 29 CFR 1910.106(d)(2); 29 CFR 1910.144(a)(1)(ii)		
	B. Are safety cans used for dispensing flammable or combustible liquids at a point of use? 29 CFR 1910.106(d)(5)(iii)		
	C. Are storage cabinets used to hold flammable liquids, labeled "Flammable – Keep Fire Away"? 29 CFR 1910.106(d)(3)(ii)		
7. Forklift Operations	A. Are all industrial trucks not in safe operating eondition removed from service? 29 CFR 1910.178(q)(1)		
	B. Are your forklifts inspected before being placed in service? Inspections should be at least daily, or aftcr eaeh shift, if used around the clock. 29 CFR 1910.178(q)(7)		
	C. Are industrial trucks equipped with flashing lights, hom, ovcrhead guard, and name plate (load limits)? 29 CFR1910.178(a)(2)		
8. Hazardous Waste Management	A. If your operations generate waste from oil or grease, do you handle it in an approved manner? 40 CFE 279.22		
	B. If your operations generate waste from fluorescent light bulbs, do you handle it in an approved manner? 40 CFR 273.14(e)		
	C. If your operations generate hazardous waste, do you handle it in an approved manner according to 40 CFR 262?		
9. Hearing Conservation	A. Are workers protected from sources of excessive noise? 29 CFR 1910.95(a)		
	B. Is approved hearing protective equipment available?		
10. Housekeeping	A. Are work areas clean? 29 CFR 1910.95(i)(1); 29 CFR 1910.141(a)(3)		
	B. Are mats, grating, etc. used where drainage is needed?		
	C. Is the compressed air for cleaning less than 30 psi?		
	D. Are work surfaces kept dry or are appropriate means taken to assure the surfaces are slip-resistant?		
	E. Are all spilled materials or liquids cleaned up immediately?		

Appendix D continuted

Document Title:	Document No.	
6S AUDIT RECORD (SAFETY)	Revision No.	Page: 3
Required by:		

Subject	Question	Yes	No
11. Lockout	A. Is all machinery or equipment capable of movement, required to be de-energized or disengaged and locked out during cleaning, servicing, adjusting or setting up operations, whenever required? 29 CFR 1910.147(c)(1); 29 CFR 1910.147(c)(2)(I)		
	B. Are correct lockout/tagout procedures in use? 29 CFR 1910.147(c)(4); 29 CFR 1910.147(d); 29 CFR 1910.147(e)		
	C. Are suspended loads or potential energy (such as compressed springs, hydraulics or jacks) controlled to prevent hazards? 29 CFR 1910.147(d)(5)		
12. Machine Guarding: General	A. Are rotating or moving parts of equipment guarded to prevent physical contact? 29 CFR 1910.212(a)(1); 29 CFR 1910.219(F)		
	B. Are all moving chains and gears properly guarded? 29 CFR 1910.219(f)(1); 29 CFR 1910.219(f)(2)		
	C. Are machinery guards secure and so arranged that they do not offer a hazard in their use? 29 CFR 1910.212(a)(2)		
13. Machine Guarding: Portable Power Tools	A. Are grinders, saws, and similar equipment provided with appropriate safety guards? 29 CFR 1910.243(a)(1); 29 CFR 1910.243(c)(1)-(4); 29 CFR 1910.243(e)(1)(I)		
	B. Are power tools used with the correct shield, guard, or attachment recommend by the manufacturer?		
14. Machine Guarding: Stationary Equipment	A. Is fixed machinery provided with appropriate safety guards to prevent injuries to the operator and other employees resulting from point of operation, in-going nip point, rotation parts, flying chip, and spark hazards? 29 CFR 1910.212(a)(1)		
	B. Are foot-operated switches guarded or arranged to prevent accidental actuation by personnel or falling objects? 29 CFR 1910.217(4)		
	C. Is there a power shut-off switch within reach of the operator's position at each machine? 29 CFR 1910.213(b)(1)		
	D. Are fan blades protected with a guard having openings no larger than ½ in., when operating within 7ft of the floor? 29 CFR 1910.212(a)(5)		
15. Personal Protective Equipment	A. Are all employees required to use personal proteetion equipment (PPE) as needed? 29 CFR 1910.132(a)		
	B. Is PPE funetional and in good repair? 29 CFR 190.132(e)		
	C. Are all employees required to use personal protective equipment (PPE) when handling chemicals (gloves, eye protection, respirators, etc.)? 29 CFR 1910.132(a)		
16. Extinguishers	A. Are appropriate fire extinguishers mounted located and identified so that they are readily accessible (not obstructed) to employees? 29 CFR 1910.157(c)(1)		
	B. Are all fire extinguishers inspected monthly and servieed annually, and noted on the inspection tag? 29 CFR 1910.157(e)		

Appendix D continued

Document Title:	Document No.	
6S AUDIT RECORD (SAFETY)	Revision No.	Page: 4
Required by:		

Subject	Question	Yes	No
17. Walkways	A. Are pits and floor openings covered or otherwise guarded? 29 CFR 1910.22(c); 29 CFR 1910.23(a)		
18. Compressed Gases	A. Are compressed gases properly stored and used? 29 CFR 1910.253(b)(1)-(5)		
	B. Are compressed gas cylinder storage rules posted in the storage area?		
19. Work Environment	A. Are all work areas adequately illuminated?		
	B. Are combustible scrap, debris, and wastes stored safely and removed from the work site promptly? 29 CFR 1910.141(a)(4)(ii)		

(Environmental Protection Agency, 2003c).