Fall 2010

An analysis of the integration of lean and safety

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AN ANALYSIS OF THE INTEGRATION OF LEAN AND SAFETY

by

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A THESIS

Presented to the Faculty of the Graduate School of the

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

In Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE IN ENGINEERING MANAGEMENT

2010

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PUBLICATION THESIS OPTION

This thesis consists of a publication submitted to the Journal of Safety Health and Environmental Research. The publication is:

Pai, P., Murray, S., and Cudney, E. (2010) “Relationship between Lean and Safety”, *Journal of Safety Health and Environmental Research*.

ABSTRACT

The lean philosophy has proven potential to help businesses improve productivity and reduce its losses. Lean can give businesses a cutting edge in this age of global competition. The fundamental principle of lean is to identify wastes in the system and reduce or eliminate them. There is a concern that during lean implementations, the focus on productivity may result in health and safety issues being ignored or worse, changes driven by lean may introduce new hazards. The relationship between lean and safety is not clearly understood. Lean and safety should be compatible. Both strive to improve processes. Both are against safety hazards and accidents; safety by definition and lean because the money spent on compensation claims is a waste.

An online survey was conducted to gauge the effects of lean initiatives on safety and to understand the level of integration of the two. Results have been provided in the lean areas for value stream mapping (VSM), one piece flow, material handling, and single minute exchange of dies (SMED). As lean and safety have the common goal of reducing wastes, there are natural opportunities where they integrate into each other.

ACKNOWLEDGEMENTS

First and foremost, I offer my sincerest gratitude to my advisors, Dr. Susan Murray and Dr. Elizabeth Cudney, who have supported me throughout my thesis with their patience and knowledge. One simply could not have wished for better or friendlier advisors. They have been a great source of inspiration.

I would also like to thank Dr. Abhijit Gosavi for serving on my committee. I am grateful to the Ms. Krista Chambers, Senior Secretary, Engineering Management and Systems Engineering Department, for always taking care of all the formalities so that the students can concentrate on their curriculum. A special thanks to the Curtis Laws Wilson Library and their staff in the circulation desk department, interlibrary loan department and the reference section.

I would also like to thank my friends and my roommates Sumant Joshi, Anand Prabhala, Vikas Nahar, Sagnik Saha, Krutik Patel, Nishant Chouhan, Abhinav Saxena, Varun Bhakta, Shanil Anshuman and Ajay Pappu, for their constant support and help and for making my life much easier in Rolla. Thanks also to my instructors and friends at Youn Wha Ryu Martial Arts Association's division at the university.

I want to dedicate my thesis to my father Mahesh Pai and mother Meera Pai who were always there for me and motivated and supported me in all my endeavors. I would also like to thank my brother Tejas Pai for being part of my support system and always encouraging me. I would like to thank all my friends and well wishers for their love and blessings.

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NOMENCLATURE

Abbreviation	Description
NVA	Non Value Adding
WIP	Work in Process
MTS	Made to Stock
MTO	Made to Order
MSD	Musculosketal Disorder
SMED	Single Minute Exchange of Dies
TPS	Toyota Production System
VSM	Value Stream Mapping
JIT	Just In Time

1. INTRODUCTION

Lean is a popular manufacturing philosophy which organizations all over the world have adopted to increase profits, cut costs, and remain competitive. Lean helps organizations achieve this goal of increasing productivity by identifying and eliminating wastes related to material, time, and effort. Although lean was primarily developed for the manufacturing sector, its' principles are applicable in other industries as well.

Lean is primarily derived from the Toyota Production System (TPS). TPS was developed within Toyota over the second half of the twentieth century. Under the visionary guidance of inspirational leaders such as Taiichi Ohno and others, TPS transformed Toyota into a leading automaker first in Japan and later globally as well. The term "lean" was coined in the U.S. in the 1990s. The lean movement gained momentum after the publication of "The Machine that changed the World" (Womack, Jones, Roos, 1990) and "Lean Thinking" (Womack, Jones, 1996).

1.1 OVERVIEW OF LEAN PHILOSOPHY

There are numerous activities involved in the production of a good or service. Often very few of these activities add value to the final product from the customers' point of view. Typically customers want to pay for only those activities that have added value to the good or service. These activities that add value are considered as value adding (VA) activities. Those that do not add value to the final product from the customers' point of view are considered as non-value adding (NVA) activities. Sometimes there are activities which are necessary in the production process but do not exactly add value to the final product such as inspection, transportation, and storage. In lean, these activities are considered as necessary but non-value adding. There is a single basic idea underlying the lean philosophy which is to identify wastes or NVA and continuously work towards eliminating or reducing them. Lean identifies seven major types of wastes that can be present in a system (Liker 2004) including:

1. Overproduction: producing more than that is required or earlier than it is required.
2. Transportation: all the movement of the products or work in process (WIP) inventory to and from storage. WIP refers to all the unfinished goods in the production process which are waiting in queue before a machine or being stored in the warehouse from where they can be later retrieved for further processing.
3. Motion: movements performed by operators and machines before, during, and after the process.
4. Waiting: holding time for WIP or waiting in queue in front of machines as well as idle times for operators and machines.
5. Over processing: non-value added processing and use of materials, tools, and equipment.
6. Inventory: accumulation of raw materials, WIP, and finished goods.
7. Defects: reworked and scrapped products.

Traditionally, the manufacturing sector believed in maximizing the usage of machinery and manpower. This approach manufactured goods irrespective of customer demand. It is known as the make to stock (MTS) philosophy. It is based on Henry Ford’s push scheduling system wherein manufacturing is carried out irrespective of the actual needs of the downstream operation. Inventory of goods, finished or unfinished, which if not sold ties up valuable revenue for the organization.

It is the biggest evil in a manufacturing system for followers of lean. MTS leads to stocking up of unacceptable levels of inventory. To avoid this lean emphasizes manufacturing to customer demand. This manufacturing philosophy is known as make to order (MTO). It is based on Toyota's pull scheduling system in which the key is to produce only as much quantity and at the precise time as needed by the downstream activity (Liker 2004). Lean suggests various techniques to transform an organization into a profitable and less wasteful one. These techniques include just in time (JIT), kanban systems, single minute exchange of dies (SMED), cellular manufacturing, 5S systems, Kaizen, line balancing, and standardized work procedures. The successful implementation of lean techniques leads to lead-time reduction, inventory reduction, defects reduction, cost per unit reduction, and an increase in productivity.

Some key terms in lean philosophy include:

1. Batch size: the number of units, which are often of similar kind, that move through the system together. Lean strives to reduce the batch size to a minimize WIP.
2. Bottleneck: this is the slowest operation in the process. A system's pace is driven by the bottleneck.
3. Cellular manufacturing: it is the workplace design in which a group of machines or resources are arranged so similar products or product families can be manufactured efficiently. Generally, it is u-shaped and tries to accommodate one-piece flow. This type of facility layout is often used in lean operations.
4. Flow: movement of products through the system. The measuring and managing of flow is key in lean.

5. Group technology: grouping of products with similar design and manufacturing needs into families to save time and effort.
6. Just-in-time (JIT): making resources and material available at the right time, in the right quantity, and at the right place. It is related to MTO.
7. Kaizen: a focused effort on the elimination of wastes and continuous improvement. It is a tool used for continuous improvement events in processes.
8. Kanban: a visual signaling system, usually a card or a bin, which is used to trigger an action such as material withdrawal or parts manufacture in a pull/JIT production system. It is a tool used to manage processes in the MTO environment.
9. Lead time: it is the time from when customers place an order to the time they receive it. In a manufacturing operation, it can be defined as the time between making a product to delivering it.
10. One-piece flow: the flow of only one part from workstation to workstation in a production system. It is a production system with a batch size of one. This is a goal of lean.
11. Pull system: producing parts and withdrawing material from upstream operations or storage only when it is needed. This is also known as MTO.
12. Push system: producing irrespective of the demand to maximize machine and material utilization. This is also known as MTS.
13. Setup time: time taken to switch the production system to manufacture a different product or product family. These operations are NVA and should be reduced in lean.

14. Takt time: ratio of the total daily operating time to the total daily customer demand.
15. Value: what the customer is willing to pay for in a service or a product.
16. Value added: those activities that contribute towards creating value in a product or a service.
17. Value chain: the elements of the system that manufacture a service or product.
18. Value stream map: a graphical representation of a value chain.
19. Waste (Muda): all the resources and efforts of employees in a process which do not add value to the service or product.
20. WIP (work-in-process) inventory: the unfinished goods at different stages in the value chain.

1.1.1 Value Stream Mapping (VSM). VSM is the critical first step in the lean conversion process. The lean initiatives should start with the creation of the current VSM of the system. The current state map helps recognize the wastes in the system and identify its causes. VSM focuses on the value from the point of view of the customer. VSM gathers and helps visualize a broad range of information related to the flow of the product through the system from receiving raw material to finished goods delivery. It provides critical flow and performance measures.

VSM charts the actions, activities, stages, and operations that are applied to transform the material from its raw form to its delivery to the customer in the required amount and mix and on time. Starting from the supplier warehouse the VSM includes activities involved with product flow such as ordering materials, shipping from warehouse, receiving, processing and passing through the various manufacturing stages, storing of finished goods, preparing for shipping and, finally, shipping to the customer. Key performance measures including cycle time, productivity, lead time, capacity, inventory levels and availability are included in the VSM. The transfer activities are described by distance and time travelled, storage and buffer levels, and time delay or wait time. Hence, VSM is able to point out activities and delays in the flow which are wastes and non-value adding.

The next step then is to design the future state map. However, this requires much more engineering, strategy, and planning. The efforts mainly focus on reducing lead time, scrap, and rework. Opportunities to improve equipment and space utilization are explored. The work load is rescheduled with a focus on reducing finished goods and WIP inventory and establishing a flow on individual items in the system. An effort is made to reduce direct and indirect material and labor costs.

1.1.2 JIT/Pull Production System. Just-in-time is a philosophy that has evolved from the Toyota Production System which was developed by Taiichi Ohno. JIT is focused on reducing sources of wastes by trying to produce the right parts in the right place and at the right time. The idea is to produce or order only that what is needed to complete the process and time their shipping to the customer at the exact moment so as to avoid stocking product and building inventory levels. Inventory (both finished and unfinished) can be the biggest waste in an organization. It occupies space on the shop floor and in the warehouse and ties up valuable revenue. JIT improves return on investment by reducing inventory levels. It also reduces production and delivery lead times. JIT is best suited for repetitive manufacturing processes.

To successfully establish JIT, the workload has to be balanced across all workstations. To achieve this detailed demand forecasting system, reduced setup and changeover times and small batch sizes are required. JIT increases system efficiency by increasing productivity, decreasing cost, and reducing wasted materials, time, and effort.

1.1.3 Kanban. Kanban is a key tool of the JIT system. It helps to realize the goal of keeping the WIP inventory low and establishing just-in-time in the value stream. It ensures that materials flow efficiently through the value stream. The term kanban is derived from the Japanese terms Kan which means “card” and Ban which means “signal”.

Simply put kanban is a visual signaling system, which is used to trigger an action such as material withdrawal or parts manufacture in a pull/JIT production system. The basic idea of kanban is that an upstream operation or supplier or a warehouse should supply to the next downstream operation only as and when it is required and without any excess production or inventory. Whenever there is a demand for a part at a downstream operation it sends a signal or a card to the upstream operation. This signal is an authorization for the upstream operation of the value chain to start producing or order that part in exactly the same number as requisitioned by the kanban.

1.1.4 Single Minute Exchange of Dies (SMED). Since lean manufacturing emphasizes on producing according to the customer demand, the batch sizes are bound to reduce. This is because the customer demand is variable, and there will always be demand for different types of products. But as batch sizes become smaller there will be a more frequent need of changing machine setup. The time spent during this setup change is known as the changeover time. It is the time between completing the last good piece of one product/product family to the first good piece of the next product/product family. Clearly, changeover is a necessary activity for the process, but it is not adding any value to the product. Hence, there is a need to minimize this changeover time. The single minute in SMED actually means changeover time of single digit or reducing the changeover to less than ten minutes. This method was developed by Shigeo Shingo in Japan (Quick Changeover for Operators, 1996). SMED helps reduce units, time, and quality losses due to changeover.

The main components of changeover are preparation for setup, removal or installation, measuring/setting/calibration, and making trial pieces. Preparation includes paperwork, operator change, cleanup of the machine area, preparing required materials, dies, and tools, among others. Installation will include mounting of tools, fixtures, parts, dies, and machine configuration. Setup time reduction is done by observing and analyzing these components of the existing changeover process and looking for ways to reduce them. The various tools and means that are usually used to achieve this goal are designing special setup carts, overhang tools, quick fasteners and clamping tools, standardized dies, stoppers, and locating pins.

1.1.5 Cellular Manufacturing. Traditional manufacturing typically followed a functional manufacturing approach. In this philosophy machines of similar kind were grouped together in separate departments. Products would travel from one department to another as per their processing requirements. This meant a lot of material handling and travelling time for the products on the shop floor and additional waiting time in front of the machines depending on their availability and workload. This clearly adds significant amount of waste since transportation is NVA.

In lean manufacturing, cells are formed to minimize travel and material handling and to facilitate flow on the shop floor. A cell is a group of workstations which are equipped with all the machines, tools, and other resources to produce a certain product/product family. Cellular layouts can accommodate one piece flow very easily. Cells can take many different types of configurations (Womack et al., 1990). They can be S-shaped, W-shaped, or U-shaped. Cellular manufacturing has become very popular in industry mainly because it helps reduce costs by reducing transport and delay, shortening production lead times, and clearing up factory space. Also, it helps establish one piece flow. This gives organizations additional flexibility to implement JIT, as they can produce the right product at the right time and in the right mix.

1.1.6 5S. 5S is a housekeeping methodology which can be applied to the office as well as the shop floor workstations. It is directed towards organization, cleanliness, and standardization (Liker, 2006). The five Ss are derived from five Japanese words which are Seiri (Sort), Seiton (Straighten), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain).

1. Seiri (Sort): Clean the work area by discarding all that is not needed and keep only those tools, fixtures, and other resources required only for that particular operation.
2. Seiton (Straighten): The goal here is to eliminate search times and delays. The resources at the workstation are to be so arranged that they are readily and easily available and then easy to return to their designated area. Principles of workstation design and motion economics are to be followed.
3. Seiso (Shine): The tools and equipment are to be cleaned and maintained regularly. This may include inspection, lubrication, calibration, and other preventive maintenance.
4. Seiketsu (Standardize): All the work areas in the organization are to be made similar. Standard signs, marks, colors, and shapes are to be used to recognize the different workstations.

5. Shitsuke (Sustain): The 5S practices should become an organizational culture. Employees should be trained in the 5S techniques and regular 5S audits should be conducted.

The benefits of 5S are reduction in material waste, space, and time. It also improves quality, reduces defects, improves productivity, and reduces changeover time. 5S builds a clear understanding among employees as to how work should be done. It also installs a sense of ownership of the process among employees. Housekeeping has long been a key objective of safety. It can reduce tripping and fire hazards. Thus, if 5S is properly planned and executed it should inherently improve safety and lean operations at the workplace at the same time.

1.1.7 Kaizen. Kaizen is a Japanese term which means continuous improvement. The improvement is in relation to quality, technology, processes, culture, safety, and leadership. Deploying a Kaizen effort in an organization means working continuously towards improvement of all facets of the designated operation. Kaizen can be best implemented by following the PDCA (plan-do-check-act) cycle (Liker, 2006).

1.2 OVERVIEW OF ERGONOMICS PRINCIPLES

Human factors engineering or human centered design simply refers to designing for human use. The related field of ergonomics involves designing work systems (which include machines, materials, tools, interfaces, and environment) with a consideration of human capabilities. Ergonomics improves the system while reducing injuries and fatigue. If ergonomics principles and guidelines are not applied properly, it can lead to operator fatigue and stress which in turn often leads to work-related musculoskeletal and neurovascular disorders (MSDs).

Some of the key ergonomics principles for sound workplace design include (Walder et al. 2007):

- Avoiding prolonged, static postures,
- Promoting use of neutral joint postures,
- Locating work, parts, tools, and controls at optimal anthropometric locations,
- Providing adjustable workstations and a variety of tool sizes,
- When appropriate, providing adjustable seating, arm rests, back rests, and foot rests,
- Utilizing feet and legs, in addition to hands and arms,
- Using gravity,
- Conserving momentum in body motions,
- Providing strategic location (in the power zone, see Figure 1) for lifting, lowering, and releasing loads, and
- Accommodating for a broad variety of operators with respect to size, strength, and cognitive abilities.

Various techniques such as redesigning work and work standardization can be used to meet these ergonomic principles and the potential risk factors can be reduced or eliminated. To adhere to these ergonomics design principles, many types of assist devices can be utilized. The devices include carts, lift devices (scissor lifts and lift tables, etc.), adjustable operator elevation platforms, tool balancers, manipulators, vacuum assist devices, workstation cranes, adjustable workstations and seating, conveyors, stackers, container tilters, pallet invertors and rotators, and vibration dampening devices.

High force, awkward posture, and excessive repetition are three main risk factors which are responsible for MSDs (Walder et al., 2007). These are work related physical risk factors. Other potential risk factors are vibration, cold stress, lack of rest, and non-occupational factors such as sports, home chores, driving, and sleep issues. Personal risk factors such as age, health history, and fitness level can increase MSD risks. Even psychosocial factors including work culture in the organization, job satisfaction, personality traits, and personal problems are also ergonomic risk problems. It is possible to reduce or completely eliminate most of the occupational risk factors, especially the physical risk factors, by complying with proper workplace design principles and appropriate use of assist devices.

There is a “power zone” on the body which is the lifting region that is considered optimal by ergonomists (Walder et al., 2007). This is the area which extends from approximately standing elbow height to standing knuckle height and as close to the body as possible (see Figure 1.1). In the power zone, the arms and back of the operators produce maximum leverage. Working in this range optimizes the operator’s strength, endurance, and comfort. Often, lifting and lowering in a workplace occurs outside the power zone. The lifting and lowering tasks can be moved to an employee’s power zone by providing the right kind of material handling assist devices. Working in the power zone improves ergonomics and decreases the risk of MSDs.

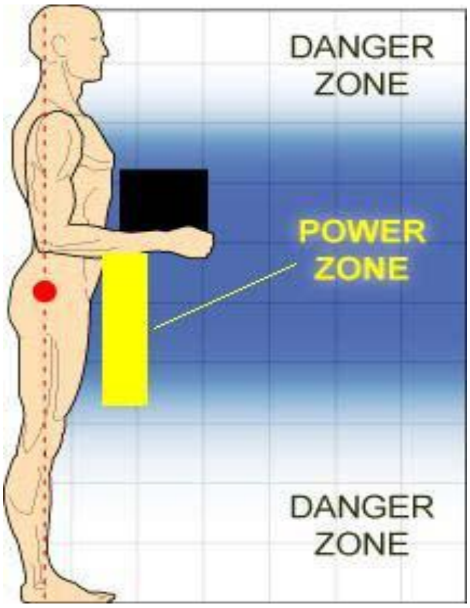

Figure 1.1 POWER ZONE (Walder et al., 2007)

MSDs are serious injuries. They sometimes require costly surgical procedures. MSD claims requiring surgery can, in total, cost approximately $15,000 for a wrist disorder, $20,000 for a shoulder injury, and $40,000 for a back injury (Walder et al., 2007). Thus, if ergonomic design principles are not followed, it can result in costly compensation claims for the organization. Apart from this direct cost of compensation, there is also the indirect cost of lost earnings associated with it. Proper ergonomics design principles are helpful in decreasing fatigue, a symptom that is often a precursor to injury.

2. LITERATURE REVIEW

Main et al. (2008) have provided a brief overview of lean concepts and discussed the importance of implementing lean and safety concurrently. They think that to be on the forefront of machine safeguarding and to help U.S. manufacturers avoid risk and associated costs, it is necessary for manufacturers to recognize the degree to which lean methodologies are driving change. Change will either increase risk or reduce risk. Very rarely will change on the plant floor or even in a service industry have zero net effect on risk. Organization's efforts to become lean by eliminating waste can be derailed if safety is not properly considered. If safety concerns in lean changes are not handled properly, waste will be inadvertently introduced into the system. Hence, unacceptable risks must be corrected. It is not possible to get truly lean without safety.

Manuele (2007) states, as accidents and their consequences are so fundamentally wasteful, preventing them should be an integral part of lean applications. Always during the initial phases, when an organization starts discussion of adopting lean concepts, safety professionals should step forward to be lean team members. This will present them opportunities to identify and address hazards that arise during the lean process design and help to reduce risk levels. However, to do so, safety professionals must become familiar with lean concepts.

Wilson (2005) states that sometimes lean changes come with some disadvantages such as making jobs highly repetitive or eliminating critical rest time for employees. If ergonomics is not integrated into the change process, repetitive jobs can have an adverse effect on employees due to stressful postures and high forces being repeated continuously throughout the day. In the long run, the financial savings from the productivity gains and quality improvements may be lost due to the higher cost of operator compensation claims. The integration of ergonomics into a lean process should begin in the planning stages itself. Ergonomics provides additional tools for lean teams to reduce waste and create value in the process. Ergonomics should not be considered as another step, but as a part of the process. With ergonomics, lean processes can achieve cost savings goals and reduce operators' compensation costs.

Furst (2007) states that there is tremendous possibility and potential for applying Lean Six Sigma thinking to safety. Lean Six Sigma provides a framework for integrating safety into operations. It addresses the needs of all the organizational stakeholders and creates a holistic and integrated approach to managing safety. The result is that the process creates innovative solutions that not only meet but also exceed the organizational and business expectations.

Abdul (2007) stated that when it comes to modern manufacturing practices, leaner does not always have to be meaner. Effective and up-to-date workplace health and safety policies will simultaneously help organizations protect their operators and reduce their overhead costs. Lean manufacturing's 5S program, which is a basic systematic approach for organizing the work place, should be used to develop safety support tools and safety programs (Kempfer, 2007). 5S focuses on establishing visual order, organization, cleanliness, and standardization, all of which leads to improved efficiency, service, and safety.

Often the managers who face problems with improving their bottom lines, blame rising health care costs or the operators’ compensation costs for their poor performance. Huge gains can be made in productivity by employing ergonomic devices such as manipulators and lift tables. Savasta (2003) stated that for organizations to move beyond survival and to achieve growth they must eliminate as much waste as possible. But, generally the health and safety function is not considered as one that contributes to a company’s revenue. Minimizing wasteful practices by employing sound health and safety practices along with the lean manufacturing initiatives will prove critical in acquiring that competitive edge for organizations.

Walder et al. (2007) stated that for lean thinking to be implemented correctly it will require effective ergonomics. Effective ergonomics is a necessary part to sustain the lean efforts of any organization. Neither concepts of lean and ergonomics is really new, but appropriate application of both is vital to short and long-term success. The successful implementation of lean thinking and ergonomics includes the redesign of work, standardizing work, and reduction or elimination of MSD risk factors. Successful implementation often includes utilization of material handling assist devices. Potential ergonomics challenges become visible during lean analysis which helps for these correct issues. Making processes more flexible allows the company to better position itself for a competitive advantage. Operator fatigue, which has a negative impact on productivity, can be significantly reduced through the application of sound ergonomics principles. All of these tools, techniques, and philosophies are just as useful in the office and the service sector as they are in the manufacturing environment in satisfying rising customer expectations.

LaMarsh (2008) found that monetary losses due to employee injuries are significant for organizations. Manufacturing companies should include safety as part of a holistic approach to improving efficiency, productivity, and profitability. Improving safety does not directly lead to profits similar to those associated with the introduction of new products or services; however, improvements in safety can result in increased profitability by eliminating needless waste.

For the transformation into a lean organization, Brown et al. (2006) presented a family of measures focusing on critical performance metrics and an adaptive performance measurement system was proposed. The kaizen methodology and the lean transformation have four measurement areas: quality, cost, delivery, and safety. As a result of the transformation process, organizations experience increased productivity, lower setup times, and require less space for manufacturing.

Veltri et al. (2007) stated that occupational safety performance has the potential of influencing operating performance. Occupational safety and operating performance concerns have often been viewed as separate independent fields, sometimes in opposition to one another. Safety and operating performance measures should be viewed as being in concert with each rather than as competing entities. Veltri et al. recommend that industry should recognize occupational safety performance as an economic opportunity, not as an annoying cost or inevitable regulatory threat.

Herrero et al. (2006) stated that safety and health have undergone significant changes mainly because of the use of new production technology and the proliferation of legislation and regulations in this area. Managers are realizing that a safe working environment increases productivity.

Roughton (1993) recommended that the scope of the jobs of safety, health, and quality managers in the U.S. be expanded to include more supervision of suppliers' product quality, employee training, and participation in concurrent engineering. They should also take part more extensively in product design, process planning, and identification of wasteful practices.

Weinstein (1998) has explained the relationship between behavior based safety and total quality management (TQM). Combining the two produces a quality and safety based management system that involves all levels of an organization. In such a system the root causes of accidents get addressed by all employees and management personnel involved. The corrective actions taken in this system ensure long-term continuous improvement.

Petersen (1994) stated that TQM and safety fit hand-in-hand. He has proposed Deming's "Obligations of Management", which is the best description of TQM philosophy in safety jargon. For the marriage of TQM and safety to be successful, a new organizational culture has to be created in which safety is perceived as a key value. Safety professionals must be trained to use the different problem solving tools of TQM such as flow diagrams and fishbone diagrams. Behavioral sampling and perception surveys must be used to reveal the statistical reliability of new processes.

Vincoli (1991) believes every concept of TQM can be applied to the practice of safety and health professionals. To survive in the present competitive industrial and technological atmosphere everyone at every level in an organization regardless of its size should implement TQM principles. The safety and health professional is not excluded from this recipe.

In the 21st century manufacturing environment, to maintain international competitiveness and bring about continuous improvement there will be increasing demands for safety and efficiency and the safety and health professional will play an important role (McGlothlin, 2006). Therefore, it is necessary to identify the key requirements for the occupational safety and health professional in the manufacturing environment for this intensely competitive international marketplace. To meet these requirements a cooperative effort is required between industry and universities to move towards higher education excellence.

American National Standard Institute (ANSI) Report: In May 2007 an important study addressing the integration of lean and safety was released by ANSI. The report, ANSI B11 Technical Report 7 (B11.TR7), was released by Association for Manufacturing Technology (AMT), a society that promotes the interests of the American manufacturing community. AMT was established in 1902 and develops and implements programs to benefit its membership. Professionals from the Boeing Company, Deere & Company, General Motors Corp., Liberty Mutual Group, Design Safety Engineering Inc., and Tenneco Inc. among others were involved in creation of this report. The main aim of releasing this report is to provide guidelines to industry who wish to concurrently address lean and safety concerns when using machinery. The report proposes a risk assessment framework to address lean and safety concerns. It also provides design guidelines to meet lean objectives without compromising safety. The report can be used by professionals from all sectors who wish to implement lean in their organizations. Its scope is not limited to the manufacturing industry.

The report summarizes basics ideas of lean philosophy including the elimination of wastes, balancing work flow, establishing pull, standardization, reduction of changeover time, cellular layouts, kanban (WIP inventory buffers), kaizen (continuous improvement), and 5S (organization of workplace). There is an overview of the seven major types of wastes in a production system. Wastes or non-value added activities are categorized in two ways: necessary and unnecessary. Often safety concerns in the organization are considered in the “necessary non-value added” category according to ANSI B11.TR7.

The report discusses examples of lean and safety conflicts. The lean initiatives in these examples had led to a violation of OSHA norms. In the event of a conflict of interest between a lean and safety issue, often lean will get the preference because of the gains in productivity and throughput at the cell level. Unfortunately, this leads to a sub-optimal performance at the organizational level. Safety officials should be involved in lean initiatives and trained in lean principles so that they can anticipate problems. This will help the team design the right kind of tools and equipments for the operators.

ANSI B11.TR7 has put forth a process model for the leadership of organizations to help foster a culture of continuous improvement. It is based on the Six Sigma DMAIC (define, measure, analyze, improve and control) model for continuous improvement. A risk assessment process has also been proposed in the report. It is based on identifying hazards, assessing risk, reducing risk to an identifiable level, and documenting the results. This is an iterative process which is to be continued until a predetermined tolerable risk level is attained. The risk assessment process does not address exact risk reduction methods, but the report cites some methods with examples which would be effective in controlling risk.

The ANSI report has also given some actual examples of safety and lean successes. Finally, several considerations are provided in the appendices of the report which can be helpful to lean teams in implementing their initiatives without compromising safety. These are:

- Considerations for Planning – minimize the seven wastes, maximize utilization and establish flow.
- Considerations for Process Design – for the design of the cell or work station and work place handling equipment.

- Considerations for Planning and Layout – for the compliance of anthropometric and ergonomic requirements.
- Considerations for Tool and Equipment Design – creation of the least stressful work conditions for the operator.
- Considerations for Workplace Handling Equipment – guidelines and principles of material handling equipment.

The ANSI report is a significant step towards the integration of lean and safety. This thesis will explore whether industry is implementing the actions recommended in the report.

PAPER

I. RELATIONSHIP BETWEEN LEAN AND SAFETY

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Abstract

To remain profitable, organizations today, have to work at the lowest cost and yet maintain quality and pace in their activities. The lean philosophy helps in achieving this goal. The basic principle of lean is to identify and eliminate wastes of all forms. Implementation of lean may sometimes lead to non-compliance of health and safety

issues. The relationship between lean and safety is not clearly established. If during lean implementation hazards are introduced in the system, it will lead to accidents. Money and time spent on compensation claims is a waste for the organization. Clearly both lean and safety are against hazards and accidents. Lean and safety do not have conflicting goals. If both lean and safety are simultaneously addressed, it would lead to more productive and safe environment in organizations. An online survey was conducted to gauge the effects of lean initiatives on safety and to understand the level of integration of the two.

INTRODUCTION

The manufacturing sector has seen unprecedented change in the past three decades. Each decade had an underlying theme for change. The decade of the 80s was about “quality”. To sustain and increase their market share companies had to make a reputation for themselves of producing quality goods. Then in the 90s, the theme was to manufacture “fast”. Due to the tremendous amount of R&D taking place everywhere, rapid product changes were common. In such an atmosphere, companies had to enhance their production systems to manufacture at faster rates and launch their new products in the market speedily while maintaining the quality theme from the previous decade. In the past decade, there has been an emergence of a few newer developing economies. These economies had the advantage of lower labor costs and government backed subsidies which enabled them to compete at the global level with cheaper products. Therefore, this past decade has been about “cost”. It has become necessary for companies to manufacture at lowest possible cost and yet maintain high quality and pace. To achieve this goal and remain competitive, companies have turned towards lean manufacturing. Lean has been the preferred management philosophy for companies all over the world in the past decade.

The present day lean philosophy is derived from the Toyota Production System (TPS) which was developed by leaders at Toyota including Taiichi Ohno, Shigeo Shingo, and Eiji Toyoda during Toyota's formative years as an automobile company. Toyota practiced and perfected a production system which involved manufacturing the right thing at the right time and in the right quantity, also known as just-in-time (JIT). This production system helped Toyota achieve high levels of productivity and became one of the most profitable automobile companies. The central premise of lean is to identify wastes, also known as non-value adding (NVA) activities and then eliminate or reduce them. Waste is anything that consumes time, money, and resources and does not add value to the final product or service. Lean defines seven major types of wastes that can exist in a system including transport or unnecessary movement of material; excessive inventory which includes raw material as well as semi-finished work in process inventory; unnecessary motion or the activities done by employees due to improper workspace layout; overproduction which leads to creation of work-in-process (WIP) or finished goods which are not going to be sold immediately; and defects in production. Lean is a collection of ideas, tools, techniques, and initiatives such as value stream mapping (VSM), kanban, kaizen, pull systems, 5S, one-piece flow, poke yoke, just-in-time, and others. A summary of lean techniques is given in table 1.

CONFLICTS BETWEEN LEAN AND SAFETY

When there is a passionate effort to lean processes, there is a danger that lean facilitators might overlook health and safety issues or even introduce new hazards. For example, it is possible that during an attempt to minimize cycle times that a redesigning of a process or workplace could result in protective machine guards being removed. This would compromise safety and potentially lead to an accident.

Accidents bring with them the indirect costs including compensation claims as well as forced shut down of machines and processes. These are counter to the fundamental principle of lean, minimizing wastes in addition to everyone's general disdain of accidents. Lean and safety should not be viewed as having conflicting goals but should be addressed simultaneously. The integration of lean and safety can help companies achieve a competitive edge that is critical while providing a safe workplace. Despite the synergistic nature of lean and safety, researchers have found conflict or at least neglect to consider safety in lean implementation.

The process changes associated with lean have an effect on safety whether related or not. Main et al. (2008) have discussed this effect. They stated, "Change can have the net effect of increasing risk or reducing risk. Seldom does change on the plant floor or even in a service industry have zero net effect on risk. Lean efforts can and will at times be implemented in ways which fail to adequately consider safety".

Lean focuses on the seven wastes in the system. All lean efforts are channeled towards reducing wastes in the manufacturing process. At times, it is the machines and materials that receive the attention when changes are made. The emphasis should be to optimize all the assets of the manufacturing system, but those implementing lean at times fail to recognize that the operators are also asset. During the lean evaluation process, the contribution of the operators should not be just looked at from a value-added or non-value-added point of view, but also from a health and safety perspective. During lean implementation, managers need to look at the product flow and the operator's well being. Unfortunately, this is not always done.

A California based automobile manufacturer had implemented lean during the changeover of one of its assembly line on its shop floor. It experienced a 100% increase in its cumulative trauma disorder (CTD) cases. The manufacturer received a citation from the California Division of Occupational safety and Health for the same (Wilson 2005). In 2004, a lean project was initiated at Roger Corp. The lean changes were made at a rapid pace to improve efficiencies. In the process they failed to take into account the ergonomic risks associated with their lean changes. This resulted in a sharp increase of 38% in their safety related recordable rates over the previous year. (Edwards 2008).

LaMarsh (2008) found that monetary losses due to employee injuries are significant for organizations. Manufacturing companies should include safety as part of a holistic approach to improving efficiency, productivity, and profitability. Improving safety does not directly lead to profits similar to those associated with the introduction of new products or services, improvements in safety can result in increased profitability by eliminating needless waste. Walder et al. (2007) stated that for lean thinking to be implemented correctly it will require effective ergonomics. Effective ergonomics is a necessary part to sustain the lean efforts of any organization. Neither concepts of lean nor ergonomics are really new, but appropriate application of both is vital to short and long term success.

Lean manufacturing's 5S program which is a basic systematic approach for organizing the work place should be used to develop safety support tools and safety programs (Kempfer, 2007). 5S focuses on establishing visual order, organization, cleanliness, and standardization, all of which leads to improved efficiency, service, and safety.

When there is conflict of interest between a lean and safety issue, there is a very high probability that lean will get the preference due to the obvious instant and tangible gains in productivity and throughput. Lean aims to eliminate wastes in the system; safety aims to eliminate risk in the system. However, considering only one of the two will lead to a sub-optimal performance. Hence, the challenge lies in developing improvements by concurrently addressing lean and safety.

AMERICAN NATIONAL STANDARD INSTITUTE (ANSI) REPORT - DESIGNING FOR SAFETY AND LEAN MANUFACTURING

There is literature on lean as well as on safety; however, there is not much that addresses both lean and safety simultaneously. Some researchers have reported successfully incorporating lean and safety in case studies (Ikuma et al., 2010 and Correia et al., 2010). The most comprehensive work on this topic is the ANSI B11TR7 – 2007 technical report which was released in May 2007. The study addressed the integration of lean and safety.

The ANSI report was developed based on input provided by The Boeing Company, Deere & Company, General Motors Corp., Liberty Mutual Group, Design Safety Engineering Inc. and Tenneco Inc. This report concurrently addresses lean and safety concerns when using machinery. The report includes a risk assessment framework to address lean and safety concerns. It also provides design guidelines to meet lean objectives without compromising safety. Though this report was initially developed for the machine tool industry, it can be used by many other industries.

The report begins with a brief overview of lean concepts including the elimination of wastes, balancing work flow, establishing pull, standardization, reduction of changeover time, cellular layouts, kanban (WIP inventory buffers), kaizen (continuous improvement), and 5S (organization of workplace), among others. Two examples of lean and safety conflict involving a pneumatic punch press and a robotic cell are presented to demonstrate the issue. Perimeter fencing around the robotic cell and machine safeguards on the pneumatic press were removed during a lean re-designing process. The goal was to facilitate operator access to the machines to reduce set-up time during machine change over. These lean initiatives led to a violation of OSHA standards and increased workplace hazards.

The report recommends a process model for leadership to foster a culture of continuous improvement. It is based on the Six Sigma DMAIC (define, measure, analyze, improve, and control) process of continuous improvement. A risk assessment process is also proposed in the report. It is based on identifying hazards, assessing risk, reducing risk to an identifiable level, and documenting the results. It is an iterative process which is to be repeated until a predetermined tolerable risk level is attained. The risk assessment process does not address exact risk reduction methods, but the report cites some methods with examples that would be effective in controlling risk. Finally, several considerations are provided in the appendices of the report which can be helpful to lean teams in implementing their initiatives without compromising safety.

RESEARCH METHODOLOGY

A survey of industry professionals with lean expertise was conducted to understand the current practices of integrating of lean and safety. A 39 question survey was posted using an online survey software tool for three weeks. Members of professional groups with an emphasis on lean were invited to take the survey. Participants were also encouraged to invite others to take the online survey. There are several areas where the implementation of lean can have a negative impact on safety; the survey examined these specifically. Questions explored the application of the lean and safety integration principles as proposed in the ANSI report. The survey consisted of four distinct types of questions:

1) Demographic questions – related to both the individual and the employer,

2) Generic lean questions – questions to determine the level of lean initiatives within the organizations,
3) Generic health and safety questions – exploring the health and safety culture of the organizations, and
4) Lean and safety questions – to determine if the recommendations of the ANSI report are being incorporated.

The survey had 27 usable responses; 67% of the respondents were from the United States, the others completing the survey were from Europe, India, and Australia. The industries represented included engineering, healthcare, pharmaceutical/chemical, retail, transportation/distribution, and other. The largest represented sectors were manufacturing (44%) and aerospace (22%). To verify the respondents' familiarity with lean concepts, they were asked which tools they had applied at their organizations. The respondents reported applying the popular lean tools including VSM, pull system, 5S, standardized work, poke-yoke, kanban, and others.

VALUE STREAM MAPPING

Value stream mapping (VSM) is a method of identifying which steps in a process are value adding and which are not. It helps to visualize the whole process with the help of a sophisticated flow chart which uses symbols, metrics, and arrows. Usually VSM is the first step in the lean implementation initiative. VSM tracks the performance of the whole process from the raw material stage till it is delivered to the customer. Traditionally, the motive in the VSM stage is to identify wastes related to excessive movement of material, overproduction, waiting time, and inventory buildup. Lean practitioners use value stream mapping to identify major sources of non-value-added time in a value stream, envision a less-wasteful future state, and develop an implementation plan for future lean activities.

However, if metrics related to safety concerns are added to the VSM process, the wastes related to it will be tracked in the very first stage of lean implementation. This will further help to integrate the initiatives of safety and productivity. If ergonomics risk assessments and quality metrics are incorporated into the VSM process, it will provide a structured method for prioritizing Lean opportunities" (Wilson 2005). 73% of our survey responders said that during the value stream mapping process waste related to safety issues was considered and 27% said waste related to safety was not considered.

LAYOUT DESIGN TO ESTABLISH ONE-PIECE FLOW

The most important concept of lean is to maintain a steady flow of parts on the shop floor. It is popularly referred to in lean as "one-piece-flow". The products or services should flow through the organization uninterrupted. To avoid build up of WIP inventory, the product should be pulled by the downstream operation rather than pushed by the upstream operation. This requires for the upstream operation to produce only when the next operation requires the product. The downstream operation will generate a signal or kanban, which will be the cue for the upstream operation to produce. However, there is always a bottleneck operation which becomes the cycle time of the whole line or assembly. Hence, it is recommended to maintain a specific minimum size of WIP inventory between operations so that there is optimum utilization of the system.

To establish flow, lean efforts often involve redesigning a workplace layout or process. This activity can impact both productivity and safety. In these kinds of projects there are opportunities for lean and safety professionals to concurrently identify risks and suggest improvements to develop a safe and productive process.

Any kind of stoppage or delay in a process due to lack of immediate availability of tools, gauges, fixtures, or other equipment necessary is a waste. To minimize such wastes the work cell should be designed such that all the required materials and equipment are strategically placed along the actual path of the flow of product. However, if human limitations and capabilities including long reaches or excessive lifting are not taken into account, it might lead to hazardous and strenuous operations for the operators.

There is a chance that organizations might end up correcting hazards and retrofitting while pursuing lean. The expenses and loss of production time associated with these activities is another factor of waste. Applying ergonomic principles - both human and engineering – will be the correct policy while trying to minimize material handling and reducing WIP during lean implementation (Manuel 2007).

When ergonomics are not integrated into the process, the repetitive jobs take their toll on employees as stressful postures and high forces are repeated continuously throughout the day (Wilson, 2005).

The ANSI standard states that anthropometric considerations should be taken into account while designing a new work cell. Providing the right kind of illumination, displays, and control panels are also key. Factors such as noise, vibration, temperature, and air quality also play a role in designing a stress free and safe working environment. Multi tasking and sharing equipment and utilities among and within processes and operators will result in faster completion of work and lesser movement and travel time for the operators.

64% of our survey responders said that during the work cell design process they had investigated the location of tools, gauges, jigs, and fixtures. 56% investigated opportunities for material handling devices and 56% investigated easy and fast pickup/set down equipment. Whereas, a lower percentage of respondents said that they had investigated considerations other than those related to anthropometry, including environmental factors such as displays and control panels, illumination, noise, vibration, and air contamination. Sharing of personnel, equipment, and utilities is also not being adequately considered during the designing of lean work cells as shown in Figure 1.

SMED (SINGLE MINUTE EXCHANGE OF DIES)

According to the just-in-time philosophy, manufacturers should produce in response to a customer order. This prevents finished goods inventory from building to disproportionate levels. Hence, companies are required to manufacture products at a faster pace and in smaller batches. To achieve this, the manufacturing processes should be flexible enough to accommodate these rapid product changes. This demands that changeover times be as small as possible.

Changeover time is the time required to convert the setup on a machine/sequence of machines from one process/operation to another. It is the time from the last good piece of one product until the first good part of the next product. It may typically include switching fixtures, tools, programming, and other aspects of a manufacturing process/operation. Although changeover is necessary, it is not adding any value to the product. Hence, it is still a non-value added activity.

Single minute exchange of die (SMED) in lean refers to single digit changeover time and it is a key goal to lean manufacturing. While designing for SMEDs, care has to be taken that the process does not violate safety requirements. As in the areas previously discussed, anthropometric considerations should be taken into account to avoid overburden and unsafe working conditions for the operator. SMED events often result in more frequent changes in the setup configuration which can translate to a drastic increase in the frequency of lifts performed by the operator. The ANSI report suggests various considerations that can be incorporated during designing for SMED. These include the provision of lockout-tag out devices for mistake proofing.

48% of the survey respondents said that they had implemented SMED successfully in their organization. Of them, only 57% of the respondents surveyed said that lockout devices such as switches and valves were incorporated while designing for SMED. 52% said that care was taken so that the switches would be placed at points that were easily accessible, whereas 39% said that they had considered placing the switches away from any hazardous area as shown in Figure 2. These numbers are positive but higher percentages would likely translate into improved safety.

MATERIAL HANDLING PROCESSES

During the process of becoming lean, material handling is an area that is often changed to improve productivity. Changes in material handling can have an impact on ergonomics and safety. Selecting the right material handling equipment can improve movement of raw material and WIP on the manufacturing floor. It can eliminate wasted motions, eliminate manual lifting, decrease floor space usage and improve quality. Minimizing operator handling of materials during a process can often benefit both lean and safety by increasing productivity and reducing ergonomic risks.

In manual material handling, the power zone is the lifting region that is considered optimal by ergonomists. This area extends from approximately standing elbow height to standing knuckle height and as close to the body as possible. The power zone optimizes operator strength and durability with the most comfort by providing the arms and back with maximum leverage. Often, workplace lifting and lowering occurs in locations that are out of the power zone (Walder et al., 2007).

Sound ergonomic practices will result in a less strenuous work environment for the operators which in turn should result in less time lost in accidents or injuries and lower medical compensation and insurance costs. The injuries or illnesses that result from incorrect ergonomic practices are known as musculoskeletal disorders (MSD). They are a group of disorders that affect the human musculoskeletal system. Every activity that has repetitive manual or mechanically assisted handling should be carefully analyzed to determine how MSD risks are minimized and productivity improved.

The best design for material handling will depend on the situation. Lean will strive to reduce the frequency and distance of move since by definition moving material is a non-value adding activity. Safety, on the other hand, is concerned with frequency, operator posture, and load involved in the operation. Depending upon the application the various material handling equipment used in the industry are scissor lifts, stackers, elevating platforms, container tilters, balancers for hand tools, small workstation cranes, vacuum hoists, self-leveling turntables, and anti-fatigue matting. Well designed tasks optimize the work height and keep the operator in neutral position. It also minimizes the amount of handling required to transfer parts. According to our survey responses, 39% had provided scissor lifts, 9% had provided stackers, 48% had provided elevating platforms, 17% had provided container tilters, 35% had provided balancers for hand tools, 30% had provided small workstation cranes, 35% had provided vacuum hoists, 9% had provided self leveling turntables, 61% had provided anti-fatigue matting while 17% of the respondents had not provided any kind of material handling equipment in their new lean processes as shown in Figure 3. While we cannot comment directly on the quality of the lean improvements in material handling with respect to safety, it is very encouraging that a high percentage of ergonomically related products were added during the lean redesign process.

CROSS FUNCTIONAL TRAINING

In most organizations the efforts related to lean and safety is tackled by completely different groups. Continuous improvement is handled by the lean teams while risk management is handled by health and safety and production (Wynn, 2008). For the improvements in safety and productivity to occur simultaneously the lean facilitators and health and safety officials should work together. This would necessitate basic knowledge of each others' area of expertise. The lean facilitators should be given training in safety principles and ergonomics and the health and safety officials should be trained in the underlying philosophies of lean. When safety officials involved in lean initiatives are trained in lean principles they can anticipate potential safety and ergonomic problems. This will help the team design the right kind of layout, tools, and equipment for the operators. Cross functional training will lead to a better appreciation of the each others' point of view. It will create a better understanding of demands and limitations of the other department and help in the exchange of ideas. It will create a better team environment and lead towards the goal of improved safety and productivity.

88% of the survey respondents said that they had observed a positive impact of their lean activities on the health and safety performance of their operators while 12% said that they experienced neither a positive or negative impact on the health and safety performance. None of the respondents had observed a negative impact on the health and safety performance on their operators because of their lean activities. 73.9% who said they had a positive impact on the health and safety because of their lean activities had health and safety personnel on their lean teams and 13% said they did not have any health and safety personnel on their lean teams. 100% of those who had seen neither a positive or negative impact on the health and safety performance said they did not have any health and safety personnel on their lean teams as shown in Table 4. 77.3% who had seen a positive impact on health and safety performance said their health and safety personnel were given some kind of training on lean methods and concepts and 10% said no such training was given. 75% of those who had seen either a positive or negative impact said their health and safety personnel were not given any kind of training on lean methods and concepts as shown in Table 2.5. 72.70% who said they had a positive impact on the health and safety said their lean facilitators were given training in safety principles and 18.20% said their lean facilitators were not given any training in safety principles. 25% who had seen neither a positive or negative impact said their health and safety said their lean facilitators were given training in safety principles and 75% said their lean facilitators were not given any training in safety principles as shown in Table 2.6.

SYNERGIES BETWEEN LEAN AND SAFETY

As lean is based on the core idea of removing wastes from the system, lean initiatives implemented by those who fully understand production operations will have some form of safety and ergonomic analysis in the process. Non-compliance of safety regulations is a waste in the system; it increases the likelihood of OSHA fines and accidents. It is common that safety issues will be missed while identifying wastes in the system. The 5S tool used for workplace organization can also be the basis for creating a safe and ergonomically sound workplace. Thus, 5S can be said to be the foundation of integration of lean and safety. Professionals with formal training in lean are of the opinion that safety is an integral part of the 5S process of lean, which is related to housekeeping. It would be inconsistent with lean concepts to exclude these safety concerns. Also, professionals with formal training in safety concepts say that their concerns related to minimizing risk also address productivity concerns (Main et. al. 2008).

If the lean implementation teams keep operator safety and ergonomics at the heart of the lean initiatives, it would help assure that while removing waste in the process they do not create new wastes of overburden and unsafe conditions for the operators. There are many examples of lean initiatives that have concurrently addressed lean and safety issues. In these instances the lean teams ensured that the cause of lean and safety received equal consideration. These initiatives led to the creation of more productive and safe processes.

An example of simplification, combination, and elimination in the same process is the West Virginia National Guard hanger responsible for repairing Army Black Hawk helicopters (Walder, 2007). They installed a vertical lift module to use in their hanger to remove waste from their processes. In the hanger an industrial vertical carousel was being used to store parts needed to fix the helicopters. The new vertical lift module replaced several storage spaces and cabinets within the hanger that were five feet high each. These units included nuts and bolts and other small repair parts. By simplifying the process through standard part locations within the carousels, it was much easier for the repair technicians to locate the parts they needed. By combining the many cabinets into two vertical carousels the West Virginia National Guard removed unnecessary walking for the operators. Eliminating the bending and twisting necessary to lift heavy parts off the ground significantly improved their ergonomics. The parts could be brought into position by moving the lift itself. These helicopters cost about $17 million each and parts to fix them are expensive as well as critical to the helicopter operations. The parts must be kept secure and a vertical carousel equipped with a lockout system provided them with the necessary security. Overall, the benefits that were seen by the West Virginia National Guard in this example were safety, security, time savings, space savings, and ergonomics.

The ANSI B11TR7 report has also given examples of safety and lean successes. The lean initiatives in these cases were concurrently addressed with safety concerns. This approach helped the organizations achieve best throughput with the lowest risk and wastes. One example discusses a machine with two hand controls. The location of these controls had created a conflict between safety issues and lean philosophies. The optimal location of the controls created difficulties in material movement and housekeeping, while placing the controls on or near the machines would put them out of an ergonomically safe reaching distance. To meet both objectives the controls were converted to a rotating arrangement which swiveled on a pivot. The controls could now be adjusted to accommodate other tasks that needed to be performed. Also, the pivot does not let the controls swivel beyond the horizontal position which would bring them closer than the permissible safe distance. Thus, both lean and safety concepts were addressed in this case. If either of lean and safety had been preferred over the other, it would have led to sub optimal performance.

CONCLUSION

Lean is built on the central idea of reducing or eliminating wastes from the system. Since accidents are fundamentally a waste, lean inherently includes safety concerns within its scope. Ergonomics, health and safety, and continuous improvement activities in lean should be integrated to achieve higher efficiencies and better working conditions.

Wastes related to safety issues should be considered by lean practitioners form the beginning, VSM stage, which is the most primary step of any lean project. When continuous improvement activities take place on the shop floor, people are already trying to identify and act on improvement opportunities. Giving them an added perspective of recognizing ergonomic issues will add a whole new dimension to the improvement activities. Consideration of safety aspects from the elementary stages will help in the thought process trickling down the whole system.

Designing lean processes to anthropometric specifications and human limitations will help limit accidents related to human limitations to a large extent and create a favorable work environment. The survey trends indicate there has been an effort to add ergonomically better material handling equipment during the lean redesign effort. Also, there have been efforts to investigate positioning of tools, gauges, and fixtures to facilitate operator movements. Imparting basic cross-functional training to lean facilitators and health and safety officials in each others' areas will help achieve the goal of integrating lean and safety.

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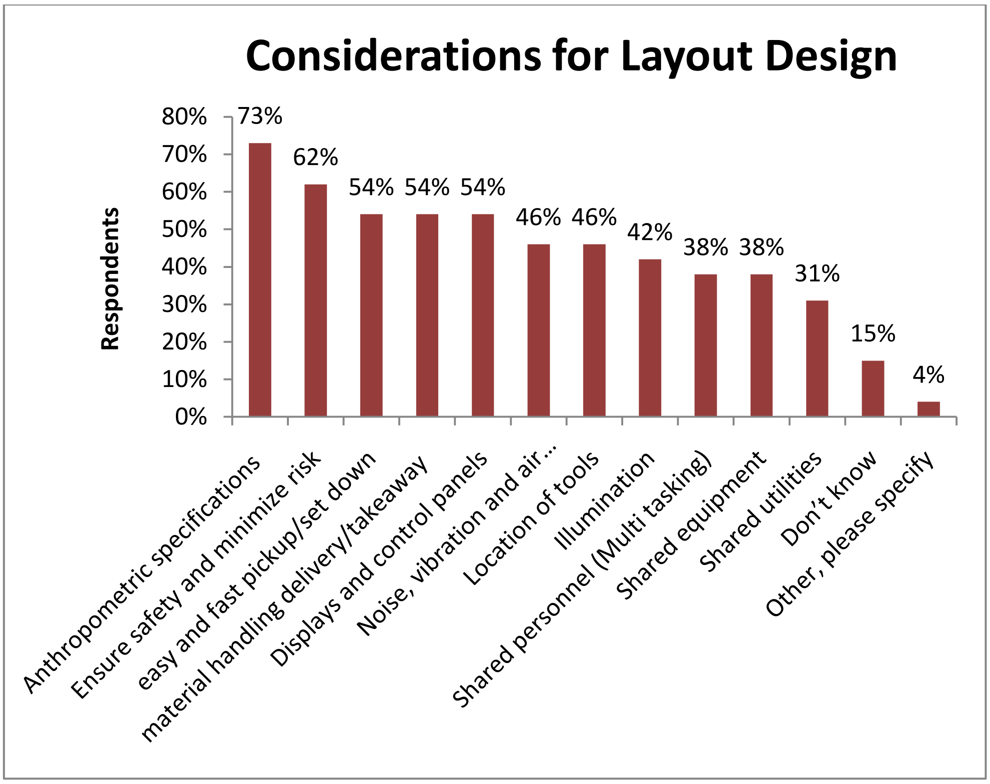

FIGURE 1: CONSIDERATIONS FOR LAYOUT DESIGN

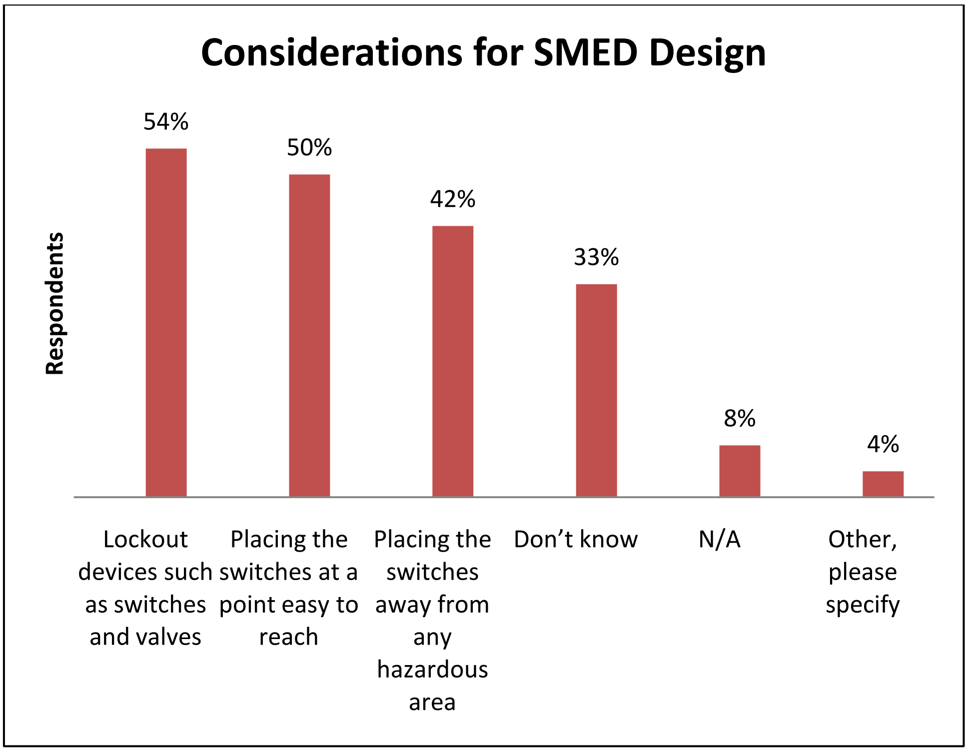

FIGURE 2: CONSIDERATIONS FOR SMED DESIGN

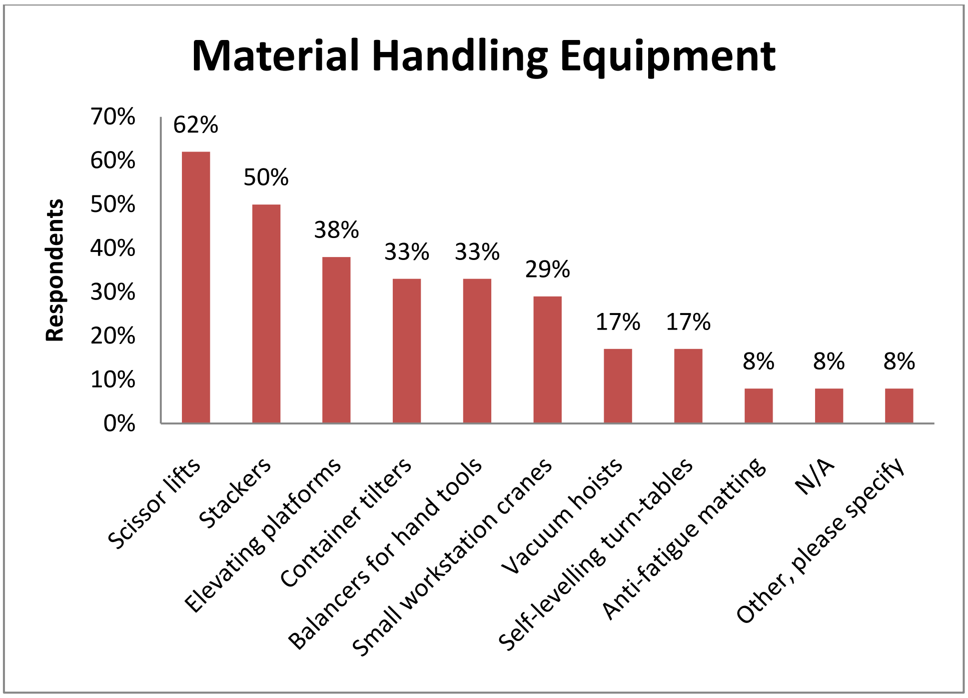

FIGURE 3: MATERIAL HANDLING EQUIPMENT BEING USED IN THE INDUSTRY

TABLE 1: SUMMARY OF LEAN TECHNIQUES

Value Stream Mapping (VSM)	VSM is a pictorial representation of each step in the system which identifies the sequence of activities and information flow that happen in the system as products are manufactured or a service is delivered. It provides opportunity for identifying the value added and non-value added activities in the system.
Pull System	It is a production system in which parts are manufactured at workstations only when they are needed. This is done to prevent work-in-process inventory which is a waste according to lean.
Push System	It is a production system where workstations manufacture irrespective of the demand. It is mainly done to maximize utilization of machines and other resources. It is the exact opposite of the pull system and was idealized by Henry Ford.
Kanbans	It is a device used to alert a workstation of new demands so that it can start producing. Kanban in Japanese means a kind of signal which will trigger action
Poka Yoke	Poka yoke means mistake-proofing or fool proofing. The purpose is to design such processes where it will be impossible for people to commit mistakes. This is to ensure quality products are manufactured in the first pass and no time is lost producing defective products.
5S	5-S refers to the first letters of five words or phrases used to describe a repeatable process used to identify and eliminate all forms of waste. The five S's are Japanese terms which have been explained in table 2

TABLE 2: THE FIVE S'S OF 5S

Sort	Remove unneeded materials from the workplace, eliminate distractions and confusion.
Set-in-order (straighten)	Make it easy to visually find things that are needed including parts, tools, information, etc.
Shine	Introduce a regular system for cleaning the work area, also focusing on inspecting the workplace for equipment needing preventive maintenance
Standardize	Establish methods to maintain cleanliness.
Sustain (self-discipline)	Implement methods to sustain the process, including continuous improvements.

TABLE 3: COMPARATIVE ANALYSIS OF IMPACT OF LEAN ACTIVITIES AGAINST THE CONSIDERATION OF WASTES RELATED TO ERGONOMIC PROBLEMS DURING VSM.

During the value stream mapping process was any waste relating to ergonomic problems in design or safety considered?				
	Total*	What kind of impact (from your lean activities) have you observed on the health and safety performance of the operators?		
		Positive impact	Negative impact	No impact
	21	17	0	4
Yes	11 52.40%	11 64.70%	0 0.00%	0 0.00%
No	10 47.60%	6 35.30%	0 0.00%	4 100.00%

TABLE 4: COMPARATIVE ANALYSIS OF IMPACT OF LEAN ACTIVITIES AGAINST THE INCLUSION OF HEALTH AND SAFETY PERSONNEL ON LEAN TEAMS.

Did the lean teams have any Health Safety and Environmental personnel on it?				
	Total*	What kind of impact (from your lean activities) have you observed on the health and safety performance of the operators?		
		Positive impact	Negative impact	No impact
	26	23	0	3
Yes	17 65.40%	17 73.90%	0 0.00%	0 0.00%
No	6 23.10%	3 13.00%	0 0.00%	3 100.00%
Don’t know	3 11.50%	3 13.00%	0 0.00%	0 0.00%

TABLE 5: COMPARATIVE ANALYSIS OF IMPACT OF LEAN ACTIVITIES AGAINST THE TRAINING OF HEALTH AND SAFETY PERSONNEL IN LEAN METHODS.

Were the Health Safety and Environment personnel given any training on Lean methods/concepts?				
	Total*	What kind of impact (from your lean activities) have you observed on the health and safety performance of the operators?		
		Positive impact	Negative impact	No impact
	26	22	0	4
Yes	17 65.40%	17 77.30%	0 0.00%	0 0.00%
No	5 19.20%	2 9.10%	0 0.00%	3 75.00%
Don’t know	4 15.40%	3 13.60%	0 0.00%	1 25.00%

TABLE 6: COMPARATIVE ANALYSIS OF IMPACT OF LEAN ACTIVITIES AGAINST TRAINING OF LEAN FACILITATORS IN SAFETY CONCEPTS.

Does your company offer any safety/ergonomics training to the lean facilitators?				
	Total*	What kind of impact (from your lean activities) have you observed on the health and safety performance of the operators?		
		Positive impact	Negative impact	No impact
	26	22	0	4
Yes	17 65.40%	16 72.70%	0 0.00%	1 25.00%
No	7 26.90%	4 18.20%	0 0.00%	3 75.00%
Don’t know	2 7.70%	2 9.10%	0 0.00%	0 0.00%

SECTION

3. CONCLUSION

The survey had respondents from a good cross section of industry. They represented industries including manufacturing, aerospace, engineering, healthcare, chemical, transportation, and retail, among others. All the respondents had some experience with the popular lean tools such as VSM, kanban, 5S, and others. Although it was a small sample, it still covered a large spectrum of the industry.

5S can be said to be the foundation of the integration of lean and safety. Implementation of 5S leads to the standardization of processes, placement of tools, and equipment at designated places and optimal space utilization. This is the basis for creating a safe and ergonomically sound workplace.

The metrics used to evaluate the system in a VSM are cycle time, productivity, lead time, capacity, inventory levels, and availability of material. VSM covers all the activities in the system such as ordering, shipping, receiving, warehousing, and processing. Thus, VSM tracks all the non-value adding activities responsible for delays and stoppages in the first stage of lean implementation itself. If along with the original lean metrics some measures relating to ergonomics risk assessments are included in the value stream mapping process, it will help to detect the losses occurring due to improper ergonomic designs and non-compliance of safety regulations in the first stage along with other losses. Thus, when designing the future state map these losses will be taken into account. It is encouraging that 73% of the survey responders are considering wastes related to safety issues during the value stream mapping process.

Lean aims to avoid interruptions in flow and excessive storing of materials to avoid the wastes related to transportation and motion. To this end, work cells are redesigned with a goal to place all materials and equipment strategically along the path of the flow of products. To avoid hazardous and strenuous operations for operators these redesign attempts should be done by applying ergonomic principles. Most of the considerations relating to the layout design listed in the survey are being investigated by the survey participants during their lean efforts. There is a higher percentage that looked into anthropometric considerations such as locating tools and fast pickup/set down rather than other environmental factors such as displays, illumination, noise, vibration, and air contamination.

Almost half of the survey respondents said that they had implemented SMED successfully in their organization. Implementing SMEDs usually results in an increased frequency of setup changes. This in turn results in increased strenuous actions such as lifting for the operators. The ANSI report has various considerations that can be incorporated during designing for SMEDs including provision of lockout-tag out devices and placement of switches away from hazardous areas and at points easy to reach for the operators. A fair percentage of the respondents surveyed said they were incorporating these considerations in their SMED design process. However, higher percentages would result in an improved safety culture in lean environments.

Lean will strive to reduce the frequency and distance of movement of materials as it is a non-value adding activity. Hence, to improve productivity material, handling is an area that is largely worked upon in lean initiatives. Changes in material handling can have an impact on ergonomics and safety. The ANSI report suggests the use of various ergonomically related material handling devices such as scissor lifts, elevating platforms, and vacuum hoists, among others. All these products are being used by most of the respondents of the survey.

To achieve better safety through the implementation of lean principles, there has to be an integrated effort from the lean facilitators and the health and safety officials. For this reason there has to be some basic knowledge of each others' area of expertise. Hence, there should be cross-functional training in the organization for the lean facilitators and the health and safety officials. If the lean facilitators have an understanding of operator safety and consider ergonomics metrics while implementing lean, it would help assure that wastes in the system are not removed in exchange of creating new wastes of overburden on the operators. Cross-functional training will result in the creation of a more productive and safe process.

Ultimately, both lean and ergonomics aim to minimize wastes and add value. Hence, there will be natural opportunities for the integration of lean and safety or ergonomics. However, as the drive to get lean is pursued sometimes, there might arise a conflict between lean and safety. In such circumstances there is every probability that lean might get the preference. For the goal of becoming lean and safe simultaneously ergonomics should be included as another tool in the lean kit.

Future Research. The amount of cost savings that would be achieved by integration of lean and safety is not clearly known. An area of research would be to categorically quantify the exact cost savings to the organizations which try and integrate their lean efforts with safety. Cost savings would occur from reduced accidents and compensation claims. Also when the processes are redesigned for lean and safety simultaneously there will lesser chances of retrofitting later. This will also be a cost saving. Most of the cost savings from the integration of lean and safety will be indirect. The research purpose can be focused on quantifying these costs.

Another area of research can be establishing a system to measure the efforts of integration of lean and safety. The lean – safety metrics would help lean teams set goals for projects and measure their progress.

Integrated training programs can be developed for the lean and safety professionals. These programs would help deploy the expertise gained through research and experience in the field of integration of lean and safety at a faster pace. The lean teams will be better equipped to tackle challenges and implement their programs if they are put through well devised training programs.

APPENDIX

SURVEY QUESTIONS, REPONSES AND RESULTS:

1. Please indicate your gender		
Male	22	81%
Female	5	19%
Total	27	100%

2. Please select the category that includes your age.		
18-24	1	4%
25-34	6	22%
35-44	6	22%
45-54	7	26%
55 and above	7	26%
Total	27	100%

3. What is the highest education that you have achieved?		
High School	4	15%
BS	13	48%
MS	8	30%
PhD	0	0%
Other, please specify	2	7%
Total	27	100%

4. In which country/region do you work?		
USA	18	67%
Canada	0	0%
India	3	11%
China	0	0%
Europe	4	15%
South America	0	0%
Other, please specify	2	7%
Total	27	100%

5. In which industry do you work?		
Aerospace/Aviation/Automotive	6	22%
Computer Hardware/Software/Internet	0	0%
Consulting	1	4%
Engineering/Architecture	1	4%
Finance/Banking/Insurance	1	4%
Food/ Beverage industry	1	4%
Healthcare/Medical	3	11%
Manufacturing	12	44%
Mining	0	0%
Pharmaceutical/Chemical	1	4%
Retail/Wholesale Trade	0	0%
Utilities	0	0%
Wholesale	0	0%
Transportation/Distribution	0	0%
Don't work	1	4%
Other, please specify	3	11%

6. How many total employees in your company (all branches)?		
Under 49	4	15%
50 to 499	5	19%
500 to 4999	7	26%
5000 or more	11	41%
Total	27	100%

7. What are the annual revenues of your company/organization?		
Under $ 500 Million	6	22%
Over $ 500 Million	12	44%
Don't know	5	19%
Don't work	1	4%
Prefer not to answer	3	11%
Total	27	100%

8. Which of the following most accurately describes your primary functional work area?		
Account Management	0	0%

Administrative	1	4%
Health Services	0	0%
Business Development	1	4%
Clerical, Processing	0	0%
Creative, Design	0	0%
Consulting	2	7%
Customer Service, Support	0	0%
Distribution	0	0%
Education	2	7%
Engineering	10	37%
Executive Management	2	7%
Finance	0	0%
Human Resources	2	7%
Information Systems, Information	1	4%
Operations/Production	9	33%
Purchasing	0	0%
R&D/Scientific	1	4%
Sales	0	0%
Don't work	0	0%
Other, please specify	3	11%

9. Has your company implemented any lean programs?		
Yes, attempted successfully	21	78%
Yes, attempted unsuccessfully	3	11%
No, not attempted	3	11%
Total	27	100%

10. How long has your company worked with lean?		
No experience with lean	2	7%
Less than 6 months	2	7%
7 months to 2 years	7	26%
3 to 5 years	7	26%
6 to 10 years	9	33%
Don't know	0	0%
Total	27	100%

11. Which programs have been successfully implemented? (Check all that apply)		
Value Stream Mapping	18	69%
Pull System	13	50%
5S/Visual Factory	19	73%
Standardized Work	14	54%
SMED (Single Minute Exchange of Dies - quick changeover)	12	46%
Poke-Yoke (mistake proofing)	15	58%
Kanban (production signaling system)	12	46%
Heijunka (production leveling)	10	38%
Other, please specify	5	19%

12. Do the Lean facilitators in the organization have any kind of certification?		
SME Lean certificate	2	8%
ASME Black belt	3	12%
ASME Green belt	5	21%
Other, please specify	18	75%

13. How many operators' compensation claims did you have in your organization within the last year?		
0 incidents/month	8	31%
1 to 2 incidents/month	5	19%
3 to 4 incidents/month	2	8%
More than 5 incidents/month	1	4%
Don’t know	10	38%
Total	26	100%

16. Does your company follow any risk assessment process (FMEA, PDCA, Safety Checklist) for existing process or the newly designed lean process?		
Yes	18	75%
No	6	25%
Total	24	100%

17. Is the risk assessment process documented?		
Yes	18	75%
No	6	25%
Total	24	100%

18. How often is it updated or reviewed?		
Weekly	4	19%
Monthly	7	33%
Quarterly	1	5%
Half yearly	1	5%
Yearly	3	14%
Never	5	24%
Total	21	100%

19. Does your company emphasize on		
Lean over safety	0	0%
Safety over lean	12	44%
Both equally important	12	44%
Neither emphasized	3	11%
Total	27	100%

20. What kind of impact (from your lean activities) have you observed on the health and safety performance of the operators?		
Positive impact	23	85%
Negative impact	0	0%
No impact	4	15%
Total	27	100%

21. Did the lean teams have any Health Safety and Environmental personnel on it?		
Yes	17	65%
No	6	23%
Don't know	3	12%
Total	26	100%

22. Were the Health Safety and Environment personnel given any training on Lean methods/concepts?		
Yes	17	65%
No	5	19%
Don't know	4	15%
Total	26	100%

23. Does your company offer any safety/ergonomics training to the lean facilitators?		
Yes	17	65%
No	7	27%
Don’t know	2	8%
Total	26	100%

26. During the value stream mapping process was any waste relating to ergonomic problems in design or safety considered?		
Yes	11	52%
No	10	48%
Total	21	100%

27. During the design of a new process or work cell (during lean implementation) which of the following considerations were investigated? (Check all that apply)		
Anthropometric specifications (i.e. Human size)	10	38%
Ensure safety and minimize risk	19	73%
Facilitate safety, easy and fast pickup / set down	14	54%
Facilitate material handling delivery and takeaway (lifts, cranes,)	14	54%
Displays and control panels	12	46%
Noise, vibration and air contamination	14	54%
Location of tools, gauges, jigs/ fixtures for the operation	16	62%
Illumination	11	42%
Shared personnel (Multi tasking)	10	38%
Shared equipment	12	46%
Shared utilities	8	31%
Don’t know	4	15%

Other, please specify	1	4%

28. What kinds of material handling equipment were provided in the new layout during lean implementation? (Check all that apply)		
Scissor lifts	9	38%
Stackers	2	8%
Elevating platforms	12	50%
Container tilters	4	17%
Balancers for hand tools	8	33%
Small workstation cranes	7	29%
Vacuum hoists	8	33%
Self-levelling turn-tables	2	8%
Anti-fatigue matting	15	62%
N/A	4	17%
Other, please specify	2	8%

29. Were following issues considered while designing for quick part changeover (SMED)?		
Lockout devices such as switches and valves	13	54%
Placing the switches at a point easy to reach	12	50%
Placing the switches away from any hazardous area	10	42%
Don’t know	1	4%
N/A	8	33%
Other, please specify	2	8%

Rate the following criterions (questions 29 to 37) on a scale of 1 to 6 based on their influence on the success of your lean programs

30. Safety concerns addressed		
Don't Know	4	16%
Not Sccessful	0	0%
Slightly Successful	3	12%
Moderately Successful	5	20%
Successful	6	24%
Very Successful	7	28%
Total	25	100%

31. Documenting the financial impact/savings		
Don't know	5	20%
Not Successful	2	8%
Slightly Successful	2	8%
Moderately Successful	7	28%
Successful	6	24%
Very Successful	3	12%
Total	25	100%

32. Commitment from leadership		
Don't Know	2	8%
Not Successful	2	8%
Slightly Successful	5	20%
Moderarely Successful	3	12%
Successful	9	36%
Very Successful	4	16%
Total	25	100%

33. Flexible scheduling techniques		
Don't Know	3	12%
Not Successful	2	8%
Slightly Successful	3	12%
Moderately Successful	8	31%
Successful	6	23%
Very Successful	4	15%
Total	26	100%

34. Handling of work force issues		
Don't Know	2	8%
Not Successful	2	8%
Slightly Successful	3	12%
Moderaely Successful	8	31%
Successful	7	27%
Very Successful	4	15%
Total	26	100%

35. Attention to root causes in mistake proofing		
Don't Know	2	8%
Not Successful	1	4%
Slightly Successful	4	15%
Moderately Successful	8	31%
Successful	6	23%
Very Successful	5	19%
Total	26	100%

36. Expanding lean beyond manufacturing into all areas		
Don't Know	3	12%
Not Successful	2	8%
Slightly Successful	8	31%
Moderately Successful	4	15%
Successful	7	27%
Very Successful	2	8%
Total	26	100%

37. Taking advantage of beneficial new technology		
Don't Know	3	12%
Not Successful	3	12%
Slightly Successful	7	27%
Moderately Successful	5	19%
Successful	5	19%
Very Successful	3	12%
Total	26	100%

38. Receptiveness to outside input		
Don't Know	3	12%
Not Successful	2	8%
Slightly Successful	3	12%
Moderately Successful	9	35%
Successful	3	12%
Very Successful	6	23%
Total	26	100%

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