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## The impact of 5S on the safety climate of manufacturing workers

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# **THE IMPACT OF 5S ON THE SAFETY CLIMATE OF MANUFACTURING WORKERS**

A Thesis

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Master of Science

in

Industrial Engineering

by

Siddarth Srinivasan  
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To my parents

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## **ABSTRACT**

The occupational injury rate in the manufacturing sector is higher than the average of all private industries, necessitating safety studies. Occupational safety can be measured through different approaches. Safety climate, a predictive measure of safety, studies the workers' perceptions of safety of the workplace. This measure includes several dimensions of safety like management commitment, involvement and work place hazard evaluation and was chosen as a method of evaluation in this study.

Even though occupational safety is an important concern, management often prioritizes reducing waste and cost. So, there is a necessity for some technique which reduces waste and simultaneously improves safety. Lean has been effective in reducing waste and costs. Researchers have shown that lean might improve occupational safety too. Nevertheless, empirical evidence to prove the relationship between the two is insufficient. In this study, 5S, a lean technique, was implemented in a manufacturing company and its impact on safety climate of the workers was studied to show the relationship between lean and safety climate of the workers.

Case and control groups took the Safety Climate Assessment Toolkit, a safety climate questionnaire, both before and after the 5S event. The effectiveness of the 5S event was determined through three productivity measures (cycle time, floor space utilized, ratio between inventory and units produced). Statistical analysis showed that the safety climate of the manufacturing workers increased after the 5S event ( $p$  value = 0.0085). The 5S event was also shown to be effective. The cycle time was reduced by 16.6% and floor space utilization decreased by 22.2%. 5S not only improved the processes by reducing waste and costs, but also improved the safety climate of workers.

# 1 INTRODUCTION

## 1.1 Motivation

Occupational safety is a critical issue. In 2011, an estimated 39 million workers had a nonfatal occupational injury or illness in the US (Bureau of Labor Statistics). Compensation cost to employers due to injured workers was \$73.9 billion in 2009 (National Academy of Social Insurance, 2011). In 2006, OSHA reported that lost productivity from workplace injuries and illness had cost companies \$60 billion. Manufacturing accounted for nearly 20% of all musculoskeletal injuries (Bureau of Labor Statistics).

The safety of employees in manufacturing is adverse. According to the Bureau of Labor Statistics, in 2011, manufacturing industries had a non-fatal occupational injury rate of 4.4 per 100 employees, compared to 3.9 in construction and 3.8 overall (Figure 1). In 2010, the specialized manufacturing sector in this study, the fabricated metal product manufacturing sector, had an incidence rate of 5.6 per 100 (Bureau of Labor Statistics). Even though the rate is better compared to other adverse industries like nursing, which had a rate of 7.8 cases per 100 employees (Bureau of Labor Statistics), this rate is considered high.

There are two different approaches to safety, reactive and proactive. Usual safety measures like safety incidents, workplace injuries, and absenteeism due to injuries are reactive measures of safety. They determine the safety of the workplace after the incident. Proactive measures of safety, such as workplace hazards and safety risk factors, predict the safety of a workplace. Safety climate also includes management commitment to safety, workplace

risks, and employee involvement in safe practices. This results in integrating various dimensions of the workplace and the people in measuring safety, thereby making safety climate a reasonable safety measurement. This study utilizes safety climate as a safety measure.

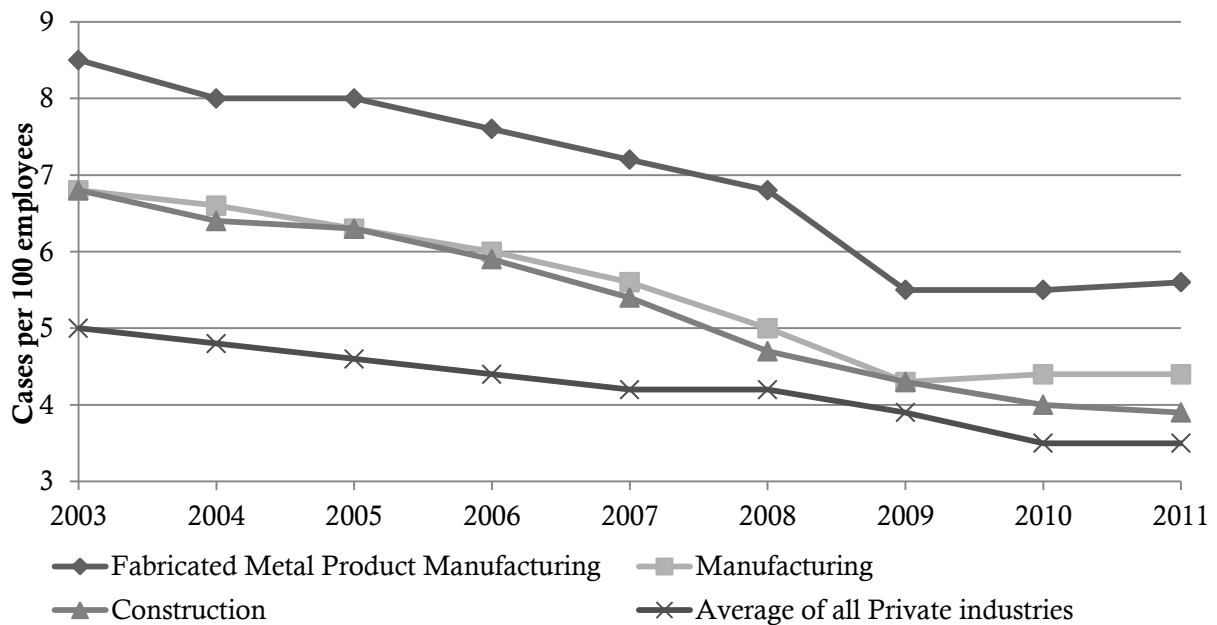


Figure 1: Non-fatal occupational injuries & illnesses – trend for private industries

## 1.2 Improving manufacturing challenges and safety through lean

Manufacturers address different challenges like rising manufacturing costs, inefficiencies, and lack of quality and safety by implementing process improvement techniques. Lean is a well-established set of principles which aim at reducing waste. It is used prominently due to its effectiveness and simplicity. Lean works in manufacturing by decreasing lead time, reducing inventory and reducing waste (Melton, 2005). However, there is a dire need to improve worker safety. Lean, in theory, is supposed to improve the working conditions of the employees and eliminate the hazards in the workplace as well (Ohno, 1978). There are even a few instances where researchers have shown improvements

in occupational safety through lean, but they are limited (Rahman, Khamis, Zain, Deros, & Mahmood, 2010). Primarily due to other critical issues in a manufacturing company like on time delivery, quality and customer satisfaction, occupational safety is lost in the lean process. Improving sales volume is critical to any manufacturing company and thereby making it the first goal. So with lean being well established in optimizing manufacturing processes and potentially improving occupational safety, it is important to further analyze the effects of lean. Concrete evidence of lean affecting occupational safety is required. Given the current need in the competitive manufacturing industry to reduce cost and waste, a whole system overhaul needs to be in place, which affects all aspects of manufacturing including occupational safety. Standalone safety initiatives are not sufficient due to a couple of reasons. One, they concentrate on following a set of regulations drawn by federal organizations which may or may not necessarily improve occupational safety. Another reason is, with lean, the employee involvement is very high and this gives the employees a better perception of targeting the problem area safety-wise and attacking them which the safety initiatives do not provide. So, this relationship between lean and safety, specifically safety climate, needs to be understood.

### **1.3 Objective**

Ultimately two different research areas in manufacturing, the different techniques to improve process and safety simultaneously along with proactive measures of safety like safety climate vs. reactive measures of safety have focused the current research to understanding the potential impact of lean on safety climate of assembly workers (Figure 2).

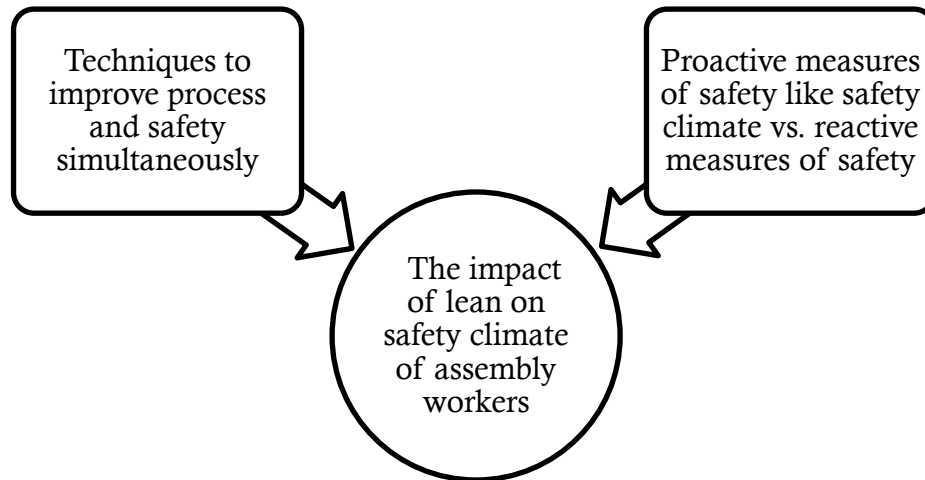


Figure 2: Understanding the impact of lean on safety climate of assembly workers

The objective of this study is to examine the potential relationship between lean and safety climate of assembly workers. 5S is the lean technique implemented in this study. The subject location is the assembly department at a manufacturing facility at Baton Rouge.

#### 1.4 Research scope and limitations

The scope of this thesis included measuring safety climate of the assembly workers, quality inspectors, supervisors, other manufacturing workers and employees in the assembly department at the manufacturing facility. Other safety measures were not considered. 5S was implemented in the assembly department at the manufacturing facility. Other lean tools were not implemented. Only 3 assembly workers, one quality inspector and one supervisor were involved in the implementation of the 5S event as a part of the 5S team. The safety climate of the 5S team was not measured due to bias. The workers, whose safety climate was measured, did not participate in the actual 5S implementation; however, their workplace was modified due to 5S. The productivity metrics used to measure the effectiveness of the 5S event were cycle time, the available floor space and inventory.

## **2 LITERATURE REVIEW**

This research concentrates on determining the effects of lean on safety climate of assembly workers. This section reviews the literature and current research gaps on lean in manufacturing, 5S in manufacturing, safety climate in manufacturing, different surveys measuring safety climate in manufacturing and finally how lean and safety climate in manufacturing relate to each other.

### **2.1 Lean manufacturing**

Lean was developed by the Japanese automobile industry after World War II, but its roots can be traced back to the early days of Ford Motor Company. Lean manufacturing as introduced by Toyota is a management philosophy with a set of tools which aims at decreasing waste, optimizing workflow, reducing cost and improving quality (de Koning, Verver, van den Heuvel, Bisgaard, & Does, 2006). Lean techniques also ensure timely service or delivery. By identifying and eliminating waste, lean focuses on improving value as perceived by customers. Hines and Taylor (2000) presented the seven wastes which were originally extracted from the Toyota Production System (TPS) (Table 1).

Over the years, the application of lean has evolved from the original Toyota Production System principles to a more customer value orientation. Value is defined as the capability to deliver the product or service a customer wants with minimal time. In this respect, process steps can be identified as value-added and non-value added. Value-added are the steps which are critical in delivering a service or a product to a customer whereas non-value added should be eliminated (Womack & Jones, 2003). This results in placing customer value and waste reduction at the center of lean (Al-Araidah, Momani, Khasawneh, & Momani, 2010).

Table 1: Seven wastes in manufacturing from TPS

<b>Wastes</b>	<b>Description</b>
Overproduction	Producing too much or too soon, resulting in poor flow of information or goods and excess inventory
Inventory	Excessive storage and delay of information or products, resulting in excess inventory and costs, leading to poor customer service
Motion	Poor workplace organization, resulting in poor ergonomics, e.g., excessive bending or stretching and frequently lost items
Transportation	Excessive movement of people, information or goods, resulting in wasted time and cost
Inappropriate processing	Going about work processes using the wrong set of tools, procedures or systems, often when a simpler approach may be more effective
Defects	Frequent errors in paperwork or material/product quality problems resulting in scrap and/or rework
Waiting	Long periods of inactivity for people, information or goods, resulting in poor flow and long lead-times

Lean in manufacturing focuses on improving the throughput of a facility, reducing the lead time, inventory, defects, rework and process wastes and ultimately improving financial savings and customer satisfaction (Melton, 2005). Lean has helped streamline operations and increase value as perceived by customers (Al-Araidah et al., 2010). Recent research has shown that organizations have attained significant achievements due to implementing lean practices. Bayo-Moriones, Bello-Pintado, and Merino-Díaz de Cerio (2010) reported that applying lean techniques in a manufacturing unit resulted in improved performance in terms of productivity and quality. This presents the potential of improving quality while simultaneously decreasing cost in manufacturing facilities.

## **2.2 5S in manufacturing**

There are several common tools within lean like 5S and kaizen which are used to achieve a lean workplace and improve housekeeping practices. Good housekeeping is an

essential quality in a workplace that can reduce safety concerns, retain visual order, improve employee morale, and increase efficiency and effectiveness (Becker, 2001). In Japan, housekeeping was first introduced as 5S which stands for 5 Japanese words: *Seiri* (Sort), *Seiton* (Set in order), *Seiso* (Shine), *Seiketsu* (Standardize) and *Shitsuke* (Sustain). These principles emerged in the post-World War II era to eliminate obstacles for efficient production (Becker, 2001). According to Bayo-Moriones et al. (2010) 5S is a system where waste is reduced and productivity and quality are optimized through observing an orderly work area. The first phase *sort* eliminates unnecessary, broken and expired items from the work area by “red tagging” and removal. The second phase *set in order* focuses on providing efficient storage areas for the remaining items. Items are labeled and put in place where it is very easy to locate them. *Shine*, the third phase, is to thoroughly clean the work area. Daily schedules to clean the area are created to sustain these changes. Once the first three phases have been implemented, the next phase is to *standardize* the best practices in the work area. Standard operating procedures (SOP) are created or enforced if already available. The newly developed practices are integrated into the SOP and they become the standard way of performing actions. The final phase, *sustain*, often considered the most difficult, is to create habits of maintaining the changes and properly communicating them to the organization.

The 5S technique includes the whole organization for complete involvement and systematic implementation at all levels and establishes effective quality processes (Ho, 1999). 5S has been implemented in diverse fields due to its simplicity and immediate results. Instant return on investment and its applicability to a variety of scenarios are the reasons for 5S's immense popularity (Kilpatrick, 2003).



5S is one of the most commonly applied lean techniques in the manufacturing sector. According to Wilson (2009), 5S along with Kaizen forms the base foundation for lean implementation in a manufacturing organization (Figure 3).

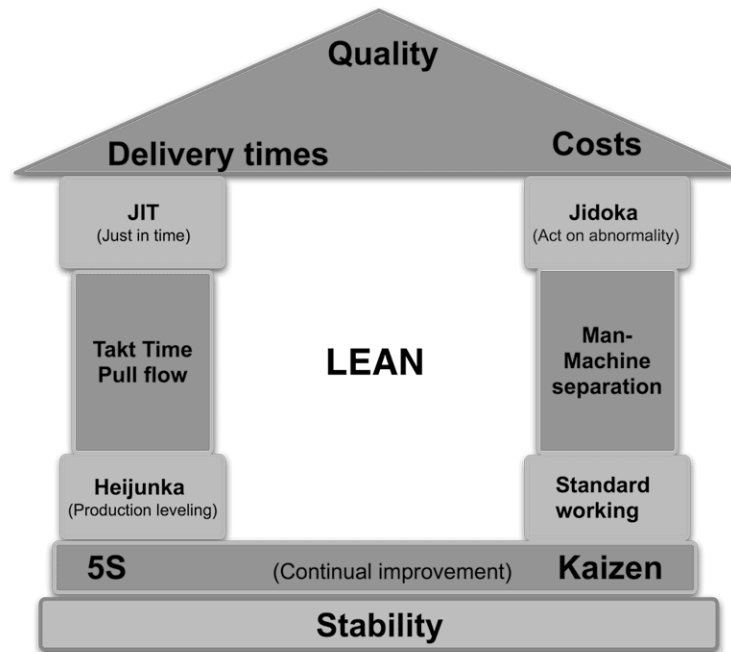


Figure 3: House of lean

In manufacturing, 5S is viewed at from different angles. Some researchers view 5S as a philosophy that encourages workers to think differently, while others look at it as an organization tool (Bayo-Moriones et al., 2010). However, all agree that 5S is one of the best known methodologies for improving processes (Ho, 1999). 5S is applied in a variety of areas in a manufacturing facility. Rahman et al. (2010) reported applying 5S in the offices, the production line, inventory area, final assembly and the surrounding areas as well.

Results from 5S programs are instant and tangible. 5S in an assembly area reduced the processing time from 278 minutes to 164 minutes in a manufacturing plant (Perera & Kulasooriya, 2011). In another study, it reduced the total lead time from 2252 minutes to just 687 minutes (69% reduction) (Perera & Kulasooriya, 2011). Narain, Yadav, and

Antony (2004) reported that 5S along with other lean tools achieved several improvements in a manufacturing facility like production set up time (74%), production space (17% - 45%), scrap reduction (75%), machine down time (60% - 100%) and delivery against schedule (21%). Veza, Gjeldum, and Celent (2011) reported that 5S as a part of a lean initiative in an assembly area of a manufacturing facility was able to improve several metrics like startup time, shutdown time, changeover time, maintenance time. 5S along with Pareto analysis identified and solved 80% of the storage space problems in an equipment storage area (Ballé & Régnier, 2007).

Apart from statistics and values, many other areas were improved due to 5S implementation. After the implementation of 5S, employee morale was improved, financial resources increased by selling unused, old or unnecessary equipment, efficient coordination at all levels in the organization and increased resource utilization (Veza et al., 2011). In another example, a better relationship with suppliers was created, workers at all levels were trained and empowered, awareness was created and ultimately brought a cultural change throughout the organization through 5S (Ferdousi, 2009).

Although sufficient researchers reporting the advantages of implementing 5S in manufacturing, most previous research does not mention worker safety as a goal or an outcome of 5S. The current research addresses this gap by looking at a component of worker safety. According to Kilpatrick (2003), the primary objective of 5S is to maximize the level of workplace health and safety in conjunction with increased productivity. Rahman et al. (2010) agreed that 5S improves health and safety standards in the workplace. However in most cases, safety is often overlooked when implementing lean. Improved employee safety is usually just an extra benefit of the 5S program and is not the actual reason for

implementation. This makes it difficult to analyze the real relationship between worker safety and 5S implementation. Concentrating on the limitations of the available literature, this thesis will examine the relationship between lean and safety climate.

### **2.3 Safety climate**

High risk industries such as aviation, construction, and manufacturing pay considerable attention to assessing safety (Colla, Bracken, Kinney, & Weeks, 2005). Traditionally, safety measures have been based on reviewing data of employee fatalities and injuries. These are the reactive measures of safety. However, organizational, managerial and human factors are involved in causing workplace incidents. So, nowadays industry is focusing on predictive measures of safety. One specific emphasis is the assessment of safety climate (Colla et al., 2005). Safety climate is a predictive measure of safety (Clarke, 2006) compared to conventional safety measures (work related injuries, safety incidents) which are reactive.

Safety climate is defined in terms of attitudes towards safety by different researchers; Donald and Canter (1993) defined safety climate as the workers' attitudes towards safety in an organization. Safety climate, according to Neal and Griffin (2004), is more clearly defined as, "perceptions of procedures and practices relating to safety", which reflect, "employee perceptions about the value of safety in an organization" (p. 18).

S.J. Cox and Cox (1991) investigated attitudes towards a number of safety-related objects and activities, including safety software, people and risk. Safety climate is either related to unconstructive or constructive beliefs of safety or to evaluations of the workplace. Griffin and Neal (2000) pointed out that safety climate should be understood in terms of the employees' perceptions of safety in the work environment while other elements like

attitudes towards safety and workplace hazards should be treated as influences on safety climate.

The term safety culture has often been used interchangeably with safety climate, although both have a different history and have been studied independently (Clarke, 2006). While safety culture refers to the overall beliefs existing in an organization, safety climate has a more passive implication relating to attitudes and perceptions of the members to both internal and external influences (Glendon, 2005). Mearns, Whitaker, and Flin (2001) stated that safety climate is a more appropriate term for the output from the questionnaires.

Safety climate is often measured by questionnaires which might include several dimensions like management commitment, supervisor competence, work pressure, risk perception and regard for procedures (Mearns et al., 2001). Different surveys measuring safety climate have been developed for manufacturing (Zohar, 2002), construction (Gillen, Baltz, Gassel, Kirsch, & Vaccaro, 2002), service (Barling, Loughlin, & Kelloway, 2002), nuclear (Lee & Harrison, 2000) and telecommunications industries (Hayes, Perander, Smecko, & Trask, 1998).

## **2.4 Safety climate in manufacturing**

Safety climate is considered the most effective measure for measuring workplace safety in manufacturing facilities (Baek, Bae, Ham, & Singh, 2008). In manufacturing industries, researchers argue that given the increase in occupational injuries and accident rates, the workers' perceptions of safety of their workplace might be a reason (Oliver, Cheyne, Tomás, & Cox, 2002). Johnson (2007) explains that the explanatory power of the conventional methods of measuring safety, i.e. reactive, is incomplete and several other factors are required to truly understand the safety in a workplace. Employees' attitudes

toward safety, safe practices, management commitment to safety and potential risks are vital parts to be understood to realize the overall importance of safety in the manufacturing sector. Measuring safety climate, which includes all these components, is therefore of great importance.

Safety climate questionnaires were initially developed for measuring the perceptions of safety of employees. Several researchers identified key dimensions in their surveys like management commitment, co-worker safety, perceived risk in the workplace, organization support and so on; however there is no particular safety survey which is considered the most effective (Gillen et al., 2002; Hayes et al., 1998; Lee & Harrison, 2000; Zohar, 2002). Particularly pertaining to this study, several questionnaires were rejected due to their irrelevant models. Certain dimensions like personal risks, safety rules and procedures and work environment were not available in these surveys (Gillen et al., 2002; Hayes et al., 1998; Lee & Harrison, 2000; Zohar, 2002). These dimensions are extremely relevant to this study due to the fact that they may be impacted by implementing 5S.

Therefore, given the prerequisites, the safety climate survey used in this research is the Safety Climate Assessment Toolkit (SCAT) which was developed by the UK Health and Safety Executive (HSE) (S. J. Cox & Cheyne, 2000). This was originally developed for oil extraction companies, but later on became one of the most commonly applied questionnaires in the manufacturing industries as well (Tomás, Cheyne, & Oliver, 2011). This questionnaire contains 43 items from 8 dimensions which are; Management Commitment, Communication, Priority of Safety, Supportive Environment, Involvement, Personal Priorities and Need for Safety, Personal Appreciation of Risk and Work Environment.

The SCAT uses a 5point Likert type scale with 1 being “strongly disagree” to 5 being “strongly agree”. This survey was developed from a variety of established safety climate questionnaires (Donald & Canter, 1993; Lee & Harrison, 2000; Zohar, 2002). This instrument has shown adequate validity. The survey had a minimum Cronbach’s  $\alpha$  value of 0.64 for the different dimensions (S. J. Cox & Cheyne, 2000). Tomás et al. (2011) applied this survey tool in several industries in Spain and reported a minimum Cronbach’s  $\alpha$  score of 0.78 for the different dimensions. Kao, Stewart, and Lee (2009) implemented the SCAT along with a few other surveys to measure the safety climate in an airline setting and reported that the different dimensions were valid with a Cronbach’s  $\alpha$  score of 0.89. Antonsen (2009) compared the SCAT with several other questionnaires and reported that they measured similar dimensions of safety. Even though the Cronbach’s  $\alpha$  scores are less than 0.8 in most of the applications, according to Nunnally (1978), the range could be 0.75 to 0.83 with at least one dimension claiming a value above 0.90, which the mentioned applications all had, thus making the SCAT reliable.

The suitability of this survey (SCAT) to this thesis is due to the relationship between the dimensions of the survey to the lean implementation. Several dimensions of SCAT are going to be potentially affected by the 5S event. Work Environment, Management commitment, and communication, for example, will be potentially changed as a part of the 5S event. So, with the confirmed validity of SCAT, it is hypothesized to be effective in capturing safety dimensions that change as a result of 5S.

## **2.5 Safety & lean**

Concepts of lean like reducing waste, optimizing work flow, and increasing quality often leads to reducing unwanted motions and resources which may reduce workplace

hazards and improve safety (Ikuma, Nahmens, & James, 2011). Several researchers presented cases where implementing lean has improved safety. Safety personnel in an automobile industry in Brazil, where lean techniques were applied, reported that the most significant improvement was in the employees' perceptions of safety (Saurin & Ferreira, 2009). In manufacturing, Brown and O'Rourke (2007) presented that the best way to promote worker safety is through lean production by training the workers with the knowledge, skills and presence of mind to identify and eliminate hazards in the workplace. They reported that several hazards like noise, heat, ergonomic, machine guarding and radiation exposure were deeply reduced due to lean operations. However, no empirical results were presented by Brown and O'Rourke (2007). Jamian, Rahman, Ismail, and Ismail (2012) similarly reported that 5S generated benefits for the workers in terms of safety, health and discipline in addition to optimizing the on time delivery and reducing cost in a midsize manufacturing company. No quantifiable results on worker safety were reported by Jamian et al. (2012) either. The available literature showcasing the potential benefits of lean on worker safety are insufficient as empirical results in terms of worker safety were not reported. These results are required to quantify safety improvements. This ultimately fails in substantiating the real relationship between lean and worker safety.

Summarizing the available literature, lean is potentially an efficient tool to improve the work flow and safety and to reduce waste in manufacturing. Given the need to improve sales and reduce cost in manufacturing, lean is the most commonly applied tool. 5S, an important tool of lean, concentrates on improving the layout of the workplace and reducing cost and waste. Moreover, 5S is simple, effective, easy to implement, and produces quick results. This makes 5S favorable over other lean tools which may take longer to realize

benefits. However, occupational safety needs to be stressed. With lean already being implemented to optimize processes, its impact on improving occupational safety needs to be verified. Predictive measures of occupational safety are critical here as lean has a potential chance of affecting them. Lean initiatives or implementations directly affect the employees' perceptions of the workplace and thereby safety too. So, this bridge which connects lean and the employee's perceptions of safety needs to be explored. This has ultimately directed the scope of this research to one particular question: What is the impact of the implementation of 5S on the safety climate of manufacturing workers?



### **3 METHODS**

#### **3.1 Purpose of research**

The purpose of this research was to explore the effects of 5S on safety climate of assembly workers in a manufacturing facility. This research was performed in the assembly area at the manufacturing facility in Baton Rouge, LA. A 5S event was implemented and safety climate and productivity of the workers were measured before and after the 5S event. Safety climate was compared with a control group at the same company that did not undertake any lean events during the same time period.

#### **3.2 Research question and hypotheses**

The research question in this study was: Did the 5S event influence the safety climate of the assembly workers?

The question analyzed the impact of 5S on the safety climate of the assembly workers. This study used the safety climate survey Safety Climate Assessment Tool (SCAT) to understand the changes in employees' perceptions of safety before and after the implementation of the 5S event.

Hypotheses were defined at the beginning of the study to confine the statistical analysis to the specific research questions.

a. Ha – Case vs. control group

- Null Hypothesis,  $H_{a0}$ : There is no significant difference in the initial total safety climate between the case and the control groups.
- Alternate Hypothesis,  $H_{a1}$ : There is a significant difference in the initial total safety climate between the case and the control groups.

b. Hb – Safety climate & its components

- Null Hypothesis,  $H_{b0}$ : There is no significant impact on the total safety climate and its different components after the 5S event.
- Alternate Hypothesis,  $H_{b1}$ : There is a significant impact on the total safety climate and its different components after the 5S event.

c. Hc – Cycle time

- Null Hypothesis,  $H_{c0}$ : There is no significant change in the cycle time after the 5S event.
- Alternate Hypothesis,  $H_{c1}$ : There is a significant change in the cycle time after the 5S event.

d. Hd – Floor area

- Null Hypothesis,  $H_{d0}$ : There are no changes in the floor area after the 5S event.
- Alternate Hypothesis,  $H_{d1}$ : There are changes in the floor area after the 5S event.

e. He – Inventory held up

- Null Hypothesis,  $H_{e0}$ : There are no significant changes in the inventory after the 5S event.
- Alternate Hypothesis,  $H_{e1}$ : There are significant changes in the inventory after the 5S event.

### 3.3 Participants

Around 15 employees worked in or around the assembly area. These workers were directly affected by the 5S. They included assembly workers, quality inspectors, and supervisors. These employees formed the case group of this study. The participants in the 5S implementation were three assembly workers, one quality inspector, one supervisor, one lean organizer and the researcher. The rest of the participants (~10) took part in the survey as they were affected by the 5S.

The control group was used to determine if the potential changes in the safety climate are due to the 5S event or some other confounding factor. Employees from different departments (welding, scales, machining, inventory and shipping) in the shop floor formed the control group by taking the safety climate questionnaire at the same time as the case group.

### 3.4 Safety climate survey

The safety climate survey (Appendix 1) used in this study was the Safety Climate Assessment Tool (SCAT) developed by S. J. Cox and Cheyne (2000). The SCAT measured the perceptions of safety on a Likert – type 5 point scale (Table 2).

Table 2: Safety Climate Survey Scale

Rating	Scale
Strongly Disagree	1
Disagree	2
Neither Agree nor Disagree	3
Agree	4
Strongly Agree	5

The SCAT included a total of 43 questions with 8 different components (Table 3). The final score and the section wise scores was obtained by adding the points as per the Likert scale. The maximum score that could be obtained was 215 and the minimum score that could be obtained was 43. Higher scores indicated better safety climate. A meaningful change in safety climate of the employees could be observed in three to five months (Cooper & Phillips, 2004). Due to the extensive changes in the work environment and introduction of standards through 5S, a change in safety climate of employees was potentially observable.

Table 3: Different components of SCAT

Components	# of Questions
Management Commitment	7
Communication	5
Priority of Safety	7
Supportive Environment	6
Involvement	3
Personal Priorities and Need for Safety	5
Personal Appreciation of Risk	4
Work Environment	6

### 3.5 5S productivity measures

The effectiveness of the 5S event was tested using three productivity measures.

i. **Cycle time:** The cycle time in this study was defined as the time it takes the assembly worker to assemble a unit with all the parts. In the assembly area at the company, assembly of each unit was done by one specific worker. The worker obtained the parts required for assembly and starts the assembly. Once, the worker finished the assembly, the worker placed it in the crating area and started on the next unit. Sometimes, due to high load, the assembly worker worked on two or more units and then sent them to shipping at the same

time. The cycle time was measured by time study; which involved measuring the continuous time, using a stop watch (or a phone), for predetermined events. This entire process was already performed by the manufacturing engineer at the facility as part of the lean initiatives in the company. The cycle time for each part in the assembly was already available. These times were used as Pre - 5S Cycle times as they are recent. No changes in the layout or the standard operating procedures were made after the time study. The cycle time of the assembly of different parts after 5S was measured. This was done by visual observation on the assembly workers. Using the available data, the actual number of cycles to be measured was calculated as;

$$N = \left( \frac{(Z) (S)}{E} \right)^2$$

$$N = \left( \frac{(1.96) (3)}{35 \times 0.05} \right)^2$$

$$N = (3.36)^2$$

$$N = 11.3 \sim 12$$

Where,

N = Final number of cycles to be observed

Z = Value from the Z table (Z = 1.96 for 95% confidence interval)

E = Accuracy ( $\pm 5\%$ ) x Average cycle time (35 minutes for the initial five observations)

s = Standard Deviation of the cycle time (three minutes for the initial five observations)

This was done one week before and one month after the implementation of the 5S event.

**ii. Floor space:** A successful 5S event usually frees the available floor space previously held up by unnecessary items. Increased floor space is one of the visual indicators of a successful 5S event. The available floor space was measured both before and after the 5S implementation.

**iii. Inventory:** Inventory (parts ready to be assembled) in the assembly area, in terms of dollars, was measured both before and after the 5S implementation. A ratio between the inventory available in dollars and number of units produced in the particular day was calculated.

### **3.6 5S implementation**

5S is a lean housekeeping technique to improve visual order that uses five standard steps. Each of these steps was implemented over a span of two weeks. The 5S was initiated by the company as a part of the lean strategy. The 5 steps were:

- i. **Sort:** In the first step, all the unnecessary tools, items and parts was eliminated. Only the essential items were retained. This was be done by red tagging all the unwanted items and prioritizing the required items based on the necessity. The frequently used items were made more accessible than the others. The supervisor verified the red tagged items and discarded them.
- ii. **Set in order:** The step involved assigning places for all the retained items. They were clearly labeled. Foamed toolkits were utilized to assign a set of tools to every assembly worker. Colored bands were inserted on the tools to identify the toolbox and the area. Physical marking on the floor was done with special colored tape. Each worker was assigned two tables which will be his work cell. This phase made sure that there was a specific location for each worker, item and equipment.

- iii. Shine: This step involved cleaning the workplace. An activity task list was established to make sure that the workplace was regularly maintained. At the end of every shift, the worker cleaned his work cell. The assembly area floor was cleaned on a turn-by-turn basis as per the schedules.
- iv. Standardize: This step involved standardizing the work practices. Standards were established so that using the tools, obtaining the parts, cleaning the area and standard operating procedures were followed. The assembly workers were educated on their responsibilities.
- v. Sustain: The final phase made sure that the changes were sustained. The results of the 5S event were communicated to everyone who had access to the implemented area. A checklist which was developed by the manufacturing engineer was utilized as a part of this phase to audit the 5S. It included 50 items with 5 sections and 10 questions in each section. Each section denoted the different steps in 5S. Each question included a “findings” section which had a “YES” or a “NO” option. The total number of “NO” options or non-conformances was the final rating of the 5S event at that instance. A lower rating meant more effective sustainment of the 5S event. This checklist was filled out by one of the assembly workers once a week after the 5S implementation. This was a continuously improving process and so should be maintained forever. A notice board was put up which included all the changes made, the results of the checklist and area for future changes made by the assembly worker. Employees were asked to come up with better suggestions to improve the workplace.

### **3.7 Experimental design**

#### **3.7.1 Dependent variables**

The dependent variables in this study were the different components of the safety survey (SCAT in this case) and the productivity measures. The dependent variables were:

- i. Safety Climate (total score)
  - a. Management Commitment
  - b. Communication
  - c. Priority of Safety
  - d. Supportive Environment
  - e. Involvement
  - f. Personal Priorities and Need for Safety
  - g. Personal Appreciation of Risk
  - h. Work Environment.

The total score of the questionnaire and the scores for each section were considered.

- ii. Cycle time (minutes)
- iii. Floor space (square feet)
- iv. Inventory (inventory held up vs. number of units)

Statistical analysis evaluated the relationship between safety climate and 5S. The effectiveness of the 5S was tested through these different metrics. This helped determine if the changes in the safety climate were due to the 5S event.



### **3.7.2 Independent variables**

The independent variables in this study were time and case vs. control group analysis. The dependent variables were measured at two different points in time. The productivity metrics were measured one week before the 5S and 4 weeks after the 5S in the assembly area. The safety climate questionnaires were administered to both the case and control groups before and after the 5S.

### **3.8 Procedure**

The procedure was approved by the Institutional Review Board of the university and the organization with the informed consent form (Appendix 2).

- i. Pre – 5S Safety Climate Surveys was conducted on the participants involved in the study 1 week before the 5S event. The participant pool did not include any member from the 5S team. Informed consent forms (Appendix 2) were provided to the participants explaining the procedure, risks, benefits and the privacy information.
- ii. The control group took the safety climate questionnaire at the same time as the case group.
- iii. The cycle time was measured by time studies (Pre – 5S Productivity Measures) one week before the implementation of the 5S event.
- iv. The 5S event was a company initiated event and so all the training and audits were conducted by the in-house manufacturing engineers. All the resources required for the 5S was predetermined by the manufacturing engineers.
- v. The 5S event was implemented which involved the 5 standard steps (3.6 5S Implementation). The first 4 phases will completed over a period of 4 days. Each of these steps took 2 to 3 hours. The last phase, sustain would go on forever.

- vi. The cycle time was measured by time studies (Post – 5S Productivity Measures) 1 month after the implementation of the 5S event.
- vii. Post – 5S Safety Climate questionnaire was conducted 1 month after the 5S implementation on the participants involved in the study and the control group.
- viii. Periodic audits of the implemented 5S event with checklists to sustain the changes implemented were performed with an interval of 1 week. This was done by the assembly workers.

### **3.9 Statistical analysis**

The data collected from the productivity measures (cycle time, floor, inventory) and the safety climate questionnaires were statistically analyzed to test the hypotheses.

Independent two sample t - test was performed on the initial total safety climate scores of the case and the control group at a 0.05 level of significance. If the p – value from the two sample t – test was less than 0.05, the null hypothesis  $H_0$ , will be rejected meaning there was a significant difference in the initial total safety climate scores between the case and the control groups and so they could not be compared. However, if the null hypothesis was not rejected, then the initial safety climate scores were statistically not different and they could be compared. The questionnaires obtained from the control group were used to find out if the potential changes in the safety climate of the case group are due to the 5S. If the safety climate of the control group remained unchanged, then the potential changes in the safety climate of the case group could be assumed to have been developed due to the 5S.

Paired t – tests with a difference in the SCAT scores (total score and individual section scores) from the pre and the post 5S implementation safety climate questionnaires

were performed with a 0.05 level of significance. If the p – value from the paired t – test was less than 0.05, then the null hypothesis  $H_0$  would be rejected meaning there was a significant impact on the safety climate due to the 5S event. If not, the null hypothesis would be retained meaning no significant impact on the safety climate of the workers.

The cycle time for assembly were measured before and after the 5S and an independent t test was performed with a 0.05 level of significance. This helped find out if the cycle time would decrease significantly after the 5S event.

The area available in the floor in the assembly area before and after the 5S was compared. As it was just one value, it was compared to see if it reduced after the 5S. If the area available was reduced, then it was assumed that the 5S event enabled the reduction. This also helped in determining if the 5S event is effective.

A ratio between the inventory held up and units produced would be calculated. Lower ratio equaled to better productivity. An independent t test was performed with a 0.05 level of significance on the ratios. This helped find out if the inventory held would decrease significantly after the 5S event.

Ultimately, these statistical analyses helped answer the research questions as mentioned in the beginning of the section.

## **4 RESULTS**

The present research was carried out in the assembly area in the manufacturing facility. This section presents the results obtained from the Safety Climate Assessment Toolkit questionnaires and the different productivity measures.

### **4.1 Outcomes of 5S**

The 5S event was a part of the lean initiative at the manufacturing facility. Several changes were made to the layout, operating procedures, tool organization, material handling and cleaning schedules.

The first phase, sort, resulted in removing unwanted items, broken tools and cabinets, unused parts and scrap materials. Unused inventory was returned to purchasing, rarely used tools and items were assigned a new location and scrap items were discarded.

The second phase, set in order, resulted in several changes in the organization of the workplace. Each of the four workstations received their own set of tools in foam cut outs and new toolkits. All the tools were color coded to their respective workstation. All equipment had specific locations. Trashcans and other items on the floor had floor markers to indicate their locations. All tools and hoses were removed from the floor and were placed on clamps. Commonly used parts were placed in bins on every workstation.

The third phase, shine, resulted in removing scrap, dust and other unwanted items from each workstation. This initial clean-up helped to visualize other issues clearly.

The fourth phase, standardize, resulted in developing standard operating procedures for the employees in the assembly area. Some of the standards developed were:

1. Each worker should use the tools assigned to him and put back the tools in their allocated location after use.
2. No units should be placed on the floor.
3. Any time a tool is missing, it should be immediately reported to the supervisor.
4. Once a unit is assembled, it should be moved to a “Ready to be shipped” area.

The fifth phase, sustain, resulted in the assembly employees conducting periodic audits to monitor the changes made through 5S in the assembly area. Once a week, the activities needed for continuous improvement and the audit results were put up on an electronic notice board.

## **4.2 Data analysis**

### **4.2.1 Safety Climate Assessment Toolkit**

Out of 24 participants approached, 18 complete sets of questionnaires (Safety Climate Assessment Toolkit) were obtained (9 participants from the case group and 9 participants from the control group). Demographics of both groups were collected. Mean age was 32.3 (8.73) years for the case group and 39.9 (6.62) years for the control group. Mean experience for the case group was 2.28 (1.48) years and 3.56 (1.76) years for the control group.

An independent 2-sample t test was performed to determine if the case and control groups could be compared. Safety climate scores for both groups were similar ( $p$  value = 0.708) before 5S and thus were useful in finding out if 5S was the only contributing factor to any potential increase in the safety climate of the case group. This supports hypothesis 1.

Mean and standard deviation of the total score and the scores of the individual dimensions of the questionnaire of the case group are presented in Table 4. The mean total score improved from 136 to 153 in the case group. Paired t-test with the pre and post 5S questionnaires were performed on total scores and scores for eight individual dimensions of the questionnaire for the case group. The p-values are presented in Table 4.

Table 4: Safety climate questionnaire mean, standard deviation and t-test results of the case group

Dimensions of SCAT	Pre 5S Mean (SD)	Post 5S Mean (SD)	p-value
Management Commitment	21 (2.3)	25 (2.8)	0.0016
Communication	18 (2.9)	19 (3.0)	0.2897
Priority of Safety	25 (3.0)	28 (3.2)	0.0455
Supportive Environment	19 (3.3)	20 (3.1)	0.1837
Involvement	7 (2.3)	10 (2.3)	0.0102
Personal Priorities and Need for Safety	18 (2.0)	18 (2.6)	0.8805
Personal Appreciation of Risk	12 (3.8)	14 (3.4)	0.0755
Work Environment	16 (4.7)	19 (5.1)	0.0071
Total Score	136 (12)	153 (14)	0.0002

Four individual dimensions' scores, Management Commitment, Priority of Safety, Involvement and Work Environment, and the total score had p values less than 0.05 and so these dimensions of safety climate improved after 5S. This supports hypothesis 2.

Paired t-test with the pre and post 5S questionnaires were performed for the control group. The mean total score improved from 134 to 136 in the control group. The p-values are presented in Table 5. The p value of the total score was 0.3003 and so, the null hypothesis was retained and there was no significant change in the total score after the 5S event for the control group. Two individual dimensions' scores, supportive environment and involvement had p values less than 0.05 and so these dimensions increased significantly.

Table 5: Safety climate questionnaire mean, standard deviation and t-test results of the control group

Dimensions of SCAT	Pre 5S Mean (SD)	Post 5S Mean (SD)	p-value
Management Commitment	22 (2.3)	22 (2)	0.8487
Communication	20 (4)	18 (4.6)	0.2995
Priority of Safety	24 (2.8)	25 (3.6)	0.0960
Supportive Environment	18 (3.3)	20 (3.6)	0.0207
Involvement	6 (2.3)	8 (2.5)	0.0353
Personal Priorities and Need for Safety	17 (2.7)	16 (2.3)	0.5596
Personal Appreciation of Risk	13 (3.2)	13 (2.5)	0.7245
Work Environment	16 (4.2)	14 (1.7)	0.3122
Total Score	134 (9.1)	136 (7.8)	0.3003

Figure 4 shows the increase in the mean total scores for both the groups after 5S. In conclusion, the total safety climate improved after 5S for the case group, whereas there was no difference for the control group.

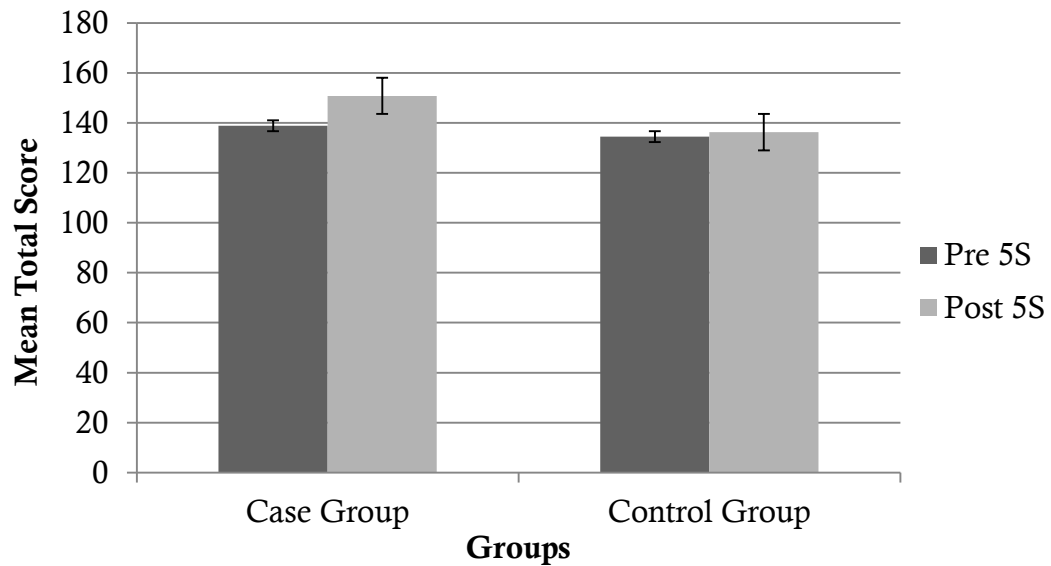


Figure 4: Change in mean total safety climate scores of the case and the control groups due to 5S

#### **4.2.2 Productivity measures**

##### **i. Cycle time**

The cycle time was predefined as the time it takes the assembly worker to assemble a unit with all the parts. Initially, the cycle time to assemble a unit with the following parts was calculated before the 5S event.

- Flange – 2 (8 studs each)
- Scale – 1 (150 cm)
- Gate Valve – 1
- Electronic Comp – 1
- QC Electronic Comp – 1
- Name tag – 1

This was done by using a video camera, a stop watch and a computer.

All the parts were readily available on the workstation. The average total time to assemble all these parts was 33 (4.6) minutes, as measured with 12 samples. One month after the 5S event, the cycle time was again calculated with the same conditions to assemble the same parts with 12 samples. The total time to assemble was 27.5 (2.94) minutes. An independent t test showed the cycle time after the 5S decreased significantly (p value = 0.002). This showed that the 5S event effectively reduced the cycle time of assembling a unit. This supports hypothesis 3.

##### **ii. Floor space utilization**

The floor space utilized by assembly for material storage, handling and aisles were measured both before and after the 5S event. Before the 5S, the area utilized by assembly was 52.2 m<sup>2</sup>. The first phase of 5S, sort, resulted in removing unnecessary equipment and



parts which took up space in the workplace. The fourth phase, standardize, led to implementation of a pull concept as opposed to the traditional push concept. This resulted in moving the units to the next step immediately after completion, which was crating in this case. So, the units were never placed on the floor, which freed up space. The floor space utilized by final assembly after 5S was 42.7 m<sup>2</sup>, which is a 22.2% decrease. This supports hypothesis 4.

### **iii. Inventory held up**

The inventory held up in the racks allocated for assembly included finished parts from other departments ready for assembly. This measure was monitored along with units produced on that particular day. These parameters were observed for 6 days before the 5S and for 6 days one month after the 5S.

A ratio (inventory held up to the number of units finished) was developed. Lower ratio equaled to better inventory management. A mean ratio of \$ 5.79 per unit (0.62) (\$144,866 in inventory held up to 25 units finished) was calculated before the 5S event. One month after the 5S, the mean ratio was reduced to \$ 3.67 per unit (0.43) (\$113,833 in inventory held up to 31 units finished). The ratio decreased by 36.6% after 5S. An independent t test showed ratio after the 5S decreased significantly (p value = 0.0085). This showed that the 5S event effectively reduced the inventory held up in the assembly area. This supports hypothesis 5.

## 5 DISCUSSION

The objective of this study was to study the impact of 5S on the safety climate of manufacturing workers. The safety climate of the manufacturing workers increased significantly due to the 5S. The 5S event was also effective in reducing waste, eliminating costs, and increasing value, as shown by the improvement in the productivity measures.

1. Cycle time was reduced by 16.6% due to the 5S event. Toolkit organization, scrap and unwanted items removal, efficient material storage and well developed set of standards attributed to this decrease in the cycle time. This decrease ultimately reduced the lead time of the whole manufacturing process.
2. Floor space utilization decreased by 22.2% after implementing 5S. Standards were created which prevented workers from placing units on the floor. Several unused tools, items and racks were removed. Two workstations were shifted to another department. These changes decreased the floor space utilized by assembly.
3. Inventory held up was measured as a ratio of inventory available to units produced to account in for the variability. Kanban concepts, extra bins on the workstations for common parts, removal of excess parts from racks and ultimately a few racks themselves helped reduce the inventory by 36.6%. In addition, the number of units produced increased due to the improvement in the cycle time. This led to a lower ratio of inventory to units produced.

These improvements due to 5S positively affected the safety climate of the manufacturing workers. Table 6 shows how the changes made in each phase of the 5S impacted safety in the work area, which may have led to an increase in the safety climate.

Table 6: Possible impact on safety due to changes made in the different phases of 5S

Phase	Changes made	Possible impact on safety
Sort	Unnecessary tools, machines were removed. Broken items were removed. Floor area was cleared.	Risk of using a broken/rusted tool or machine was eliminated. No clutter resulted in lower chance of tripping hazard.
Set in order	Every workstation had its own set of tools in a toolbox. All tools were color coded and had a specific location. Search and travel times were reduced.	Work environment was more visible and organized making potential ergonomic risks and hazards transparent. Motion waste was reduced resulting in reduced musculoskeletal disorder risks.
Shine	The workstations were cleaned and maintenance schedules were created.	No significant impact of this phase on safety.
Standardize	Rules were created to reduce the cycle time. Standard operating procedures were implemented.	Lesser units on the table and floor made the workplace less prone to slip and trip hazards. The workers were no longer prone to risks of heavier units falling from racks.
Sustain	Weekly audits are made to sustain the changes. The workers were more involved in making changes in the workplace.	The workplace was continuously monitored for safety hazards. Solutions to reduce safety hazards were put forth by different workers rather than the management alone. This enabled a thorough impact on reducing hazards from several perspectives.

Four out of eight dimensions of safety climate were increased. Three of them, management commitment, priority of safety and involvement were directly affected by the standards which were setup as a part of the standardize phase. Employees were responsible for reporting hazards and eliminating them. Employees perceived these changes made by the management to be positive and safer.

The final dimension, work environment, was directly influenced by the physical changes made to the workplace. Removal of units from the floor, setting standards which restricted the workers from placing more than one unit on the table at a time, removing large parts from top shelves, purchasing new tools, utilizing carts instead of moving a unit by hand and so on helped reduce the safety hazards like falling objects, tripping hazards and muscle strain. The employees in turn perceived these changes to be safer when compared to the situation before 5S. This helped increase the score for the “work environment” dimension of the safety climate questionnaire. Overall, the total safety climate was significantly increased with positive changes in these four dimensions due to these improvements.

Communication, supportive environment, personal priorities and need for safety and personal appreciation of risk are the four other dimensions whose scores increased after the 5S, but not significantly. This could be attributed to the fact that, in theory, these dimensions are not directly affected 5S. As opposed to the first four dimensions, these four emphasize on personal and interpersonal safety and not management interaction or work environment.

Due to bias, the safety climate questionnaires were not administered on the 5S team. However, personal interviews made with the 5S team on their safety climate provided valuable insights. The workers reported that as they were personally involved in making decisions about their workplace, they felt that they were in more control of their surroundings and thus felt safer. In addition, some of the changes related to removing and reporting hazards were made by these workers.

Scores of two dimensions, supportive environment and involvement increased significantly for the control group. One reason might be that the administration of the questionnaires might have increased the perceptions of involvement and supportive work environment of the workers with respect to safety.

Main, Taubitz, and Wood (2008) reported that lean and safety go along concurrently. They also reported that any changes through lean in a manufacturing facility would definitely have an impact on the safety risks, positive or negative. Extreme care should be taken to make sure that the lean events support occupational safety. The 5S in the study addressed this concern by making sure that any change made impacted the risks and hazards positively. This was shown through the increase in the work environment dimension of the questionnaire.

These results obtained in the study support the available literature. These results confirm Brown and O'Rourke (2007), who stated that employee engagement through training and involvement are required to identify and reduce the hazards. This was specifically observed when two dimensions management commitment and involvement increased significantly after 5S.

Safety was improved in two key categories; physical work environment and management involvement. This supports Varonen and Mattila (2000), who reported that safety level of the work place and the safety practices of the management were driving factors for the improvement in safety climate.

The 5S event in the assembly area improved the relationship between the supervisors and the workers through active communication. Every time a tool or equipment was

missing, the worker notified the supervisor. If a safety hazard was spotted by the worker, the supervisor was notified. If a required part was not available, the worker would report it to the supervisor. The 5S also resulted in creating standard operating procedures which the workers were trained on. These improvements brought a change in the day to day operations of the assembly area as predicted by Ferdousi (2009).

The 5S event in the study increased workplace safety along with increased productivity which coincides with what other researchers proposed. (Kilpatrick, 2003; Rahman et al., 2010). The 5S event in the study also generated benefits in terms of workers' health along with reducing costs and wastes. However, the lack of statistical evidence showcasing the relationship between lean and worker safety, which was the limitation of Jamian et al. (2012) was considered and overcome by providing quantifiable statistical analysis to show the impact of 5S on the worker safety.

As presented in the literature section, empirical data to help relate 5S to occupational safety was potentially insufficient. Moreover, predictive measures of safety were not studied in relation to lean. This study answered these concerns and provided statistical evidence that 5S increases the safety climate of the manufacturing workers.

Ultimately, the research shows that 5S increases the safety climate of the manufacturing workers through two results:

- i. The total safety climate score and four other dimensions significantly increased while the total score for the control group did not differ significantly after the 5S event.
- ii. All the productivity measures (cycle time, floor area utilized and the inventory held up) significantly improved due to 5S, thus proving the event to be effective.

## **5.1 Limitations**

The results of the study cannot be generalized to the whole manufacturing industry as the 5S was observed in one area. The facility was a job shop which manufactured highly customizable, made to order items. 5S might have a different impact on safety climate in high volume manufacturing industries. Moreover, different areas of a factory like inventory, testing, machining, etc. might have different results due to lean. The post 5S questionnaires and measures were obtained one month after the 5S event. Total Safety climate and four of its dimensions did increase significantly; however, it would be interesting to see what kind of change would happen to the safety climate over a longer time period (Cooper & Phillips, 2004). A small fraction of the increase in the safety climate of the workers might be attributed to the bias developed due to the lean training and the anticipation of change due to lean. Steps were taken to avoid this situation by not including the members of the 5S team in the participant pool, but there is always a chance of other participants being influenced.

## **5.2 Future research**

A longitudinal study to understand the changes in safety climate due to lean could be performed to realize the long term effects due to 5S. Other tools like kaizen, poka yoke could be implemented to find out if they too have a similar effect of safety climate. Applying 5S in different areas of a factory would be beneficial to understand how other departments' safety climates are affected. 5S with an overall emphasis on safety in every phase could be implemented to analyze if the relationship between the two changes significantly.

### **5.3 Conclusion**

The 5S implemented in this study successfully improved the safety climate of the workers. It also improved the cycle time, floor area utilization and inventory held up.

This study ultimately helped in understanding the impact of 5S on the safety climate of the manufacturing workers in an assembly area. Some dimensions of safety climate weren't significantly improved, but overall safety climate improved. It is evident that 5S is effective in improving the perceptions of safety of the workers.

In conclusion, 5S not only improves the processes by reducing waste and costs, but also improves the safety climate of workers. This technique may be implemented in other sectors to realize these benefits.



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## **APPENDIX 1: SAFETY CLIMATE ASSESSMENT TOOLKIT**

### **Cover Sheet**

*(To be filled by Researchers)*

**Name:** \_\_\_\_\_

**Employee Job title:** \_\_\_\_\_

**Participant ID#:** \_\_\_\_\_

### Safety Climate Assessment Toolkit

Q No.	Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
<b>Management Commitment</b>						
1	Management acts decisively when a safety concern is raised					
2	Management acts only after accidents have occurred					
3	Corrective actions are always taken when management is told about unsafe practices					
4	In my workplace management acts quickly to correct safety problems					
5	In my workplace management turn a blind eye to safety issues					
6	In my workplace managers/supervisors show interest in my safety					
7	Managers and supervisors express concern if safety procedures are not adhered to					
<b>Communication</b>						
8	Management operates an open door policy on safety issues					
9	My supervisor does not always inform me of current concerns and issues					
10	I do not receive praise for working safely					
11	Safety information is always brought to my attention by my line manager/supervisor					
12	There is good communication here about safety issues which affect me					
<b>Priority of Safety</b>						
13	I believe that safety issues are not assigned a high priority					
14	Management clearly considers the safety of employees of great importance					
15	Safety rules and procedures are carefully followed					
16	Management considers safety to be equally as important as production Safety Rules and Procedures					
17	Sometimes it is necessary to depart from safety requirements for production's sake					
18	Some health and safety rules and procedures are not really practical					
19	Some safety rules and procedures do not need to be followed to get the job done safely					

Q No.	Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
<b>Supportive Environment</b>						
20	Employees are not encouraged to raise safety concerns					
21	Co-workers often give tips to each other on how to work safely					
22	I am strongly encouraged to report unsafe conditions					
23	When people ignore safety procedures here, I feel it is none of my business					
24	A no-blame approach is used to persuade people acting unsafely that their behavior is inappropriate					
25	I can influence health and safety performance here					
<b>Involvement</b>						
26	I am involved in informing management of important safety issues					
27	I am never involved in the ongoing review of safety					
28	I am involved with safety issues at work					
<b>Personal Priorities and Need for Safety</b>						
29	Safety is the number one priority in my mind when completing a job					
30	Personally I feel that safety issues are not the most important aspect of my job					
31	I understand the safety rules for my job					
32	It is important to me that there is a continuing emphasis on safety					
33	A safe place to work has a lot of personal meaning to me					
<b>Personal Appreciation of Risk</b>						
34	I am rarely worried about being injured on the job					
35	In my workplace the chances of being involved in an accident are large					
36	I am sure it is only a matter of time before I am involved in an accident					
37	I am clear about what my responsibilities are for health and safety					
<b>Work Environment</b>						
38	I cannot always get the equipment I need to do the job safely					
39	Operational targets often conflict with safety measures					
40	Sometimes conditions here hinder my ability to work safely					
41	Sometimes I am not given enough time to get the job done safely					
42	There are always enough people available to get the job done safely					
43	This is a safer place to work than other companies I have worked for					

## APPENDIX 2: INFORMED CONSENT FORM

**Title**

The impact of 5S on the safety climate of the manufacturing workers

**Location**

Baton Rouge, LA

**Participants**

Assembly workers, Quality Inspectors, Supervisors and workers from other departments

**Number of Participants**

~ 30

**Description**

A questionnaire (Safety Climate Assessment Toolkit) will be provided which measures your perceptions of safety in the workplace. It has 43 questions with a possible rating of 1 to 5 for each question. This process will take about 15 minutes. The questionnaire has to be taken twice; both before and after 1 month following the 5S event. This questionnaire will be administered to both the control group and the case group. All the information obtained will be kept confidential.

**Benefits**

Participating in this study will contribute to understanding the impact of lean on your perceptions of safety in manufacturing industry.

**Subject's Right to Refuse to Participate or Withdraw**

Participation is voluntary. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled and you may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

**Financial Information**

You will not be paid for the participation.

**Privacy Information**

Results of the study may be published, but no names or identifying information will be included in the publication. Your identity will remain confidential unless disclosure is required by law.

By signing below, you agree to have read and understood the purpose of this questionnaire.

---

Signature of Subject

---

Date

---

Printed Name of Subject



---

Consent Administered by

---

Date

---

Printed Name

If you have questions you may contact:

**Primary Investigator**

Laura Hughes Ikuma, Ph. D

Assistant Professor, Construction Management & Industrial Engineering

Louisiana State University

likuma@lsu.edu

(225) 578-5364

**Study Coordinator**

Siddarth Srinivasan

Graduate Student, Construction Management & Industrial Engineering

Louisiana State University

ssrini@lsu.edu

(225) 361-5876

**LSU Institutional Review Board (IRB)**

Dr. Robert Mathews, Chair

131 David Boyd Hall, Baton Rouge, LA

Phone: (225) 578-8692

Fax: (225) 578-5983

irb@lsu.edu

## APPENDIX 3: IRB APPROVAL FORM

### Application for Exemption from Institutional Oversight

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/ projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.



Institutional Review Board  
Dr. Robert Mathews, Chair  
131 David Boyd Hall  
Baton Rouge, LA 70803  
P: 225.578.8692  
F: 225.578.5983  
irb@lsu.edu  
lsu.edu/irb

-- Applicant, Please fill out the application in its entirety and include the completed application as well as parts A-F, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at <http://research.lsu.edu/CompliancePoliciesProcedures/InstitutionalReviewBoard%28IRB%29/Item24737.html>

-- A Complete Application Includes All of the Following:

- (A) Two copies of this completed form and two copies of parts B thru F.
- (B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
- (C) Copies of all instruments to be used.

\*If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.

- (D) The consent form that you will use in the study (see part 3 for more information.)

- (E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (<http://phrp.nihtraining.com/users/login.php>)

- (F) IRB Security of Data Agreement: (<http://research.lsu.edu/files/item26774.pdf>)

1) Principal Investigator: Dr. Laura Ikuma

Rank: Assistant Professor

Dept: Mechanical & Industrial Engine

Ph: (225) 578 - 5364

E-mail: likuma@lsu.edu

2) Co Investigator(s): please include department, rank, phone and e-mail for each

\*If student, please identify and name supervising professor in this space

Siddarth Srinivasan  
Student, Department of Mechanical & Industrial Engineering  
(225) 364 - 6939, [ssrin14@lsu.edu](mailto:ssrin14@lsu.edu)  
Supervising Professor: Dr. Laura Ikuma

IRB# E6056 LSU Proposal #

☒ Complete Application

☒ Human Subjects Training

3) Project Title:

The Impact of SS on the safety climate of Manufacturing Workers

Study Exempted By:  
Dr. Robert C. Mathews, Chairman  
Institutional Review Board  
Louisiana State University  
203 B-1 David Boyd Hall  
225-578-8692 | [www.lsu.edu/irb](http://www.lsu.edu/irb)  
Exemption Expires: 7/26/2015

4) Proposal? (yes or no) NO

If Yes, LSU Proposal Number

Also, If YES, either

☐ This application completely matches the scope of work in the grant

OR

☐ More IRB Applications will be filed later

5) Subject pool (e.g. Psychology students)

Manufacturing Workers

\*Circle any "vulnerable populations" to be used: (children <18; the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature

Laura Ikuma

Date

7/18/12

(no per signatures)

\*\* I certify my responses are accurate and complete. If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted ☒ Not Exempted

Category/Paragraph 2

Signed Consent Waived?: Yes / No

Reviewer Mathews

Signature

Robert Mathews

Date

7/27/12

## **VITA**

Siddarth Srinivasan was born in Salem, Tamil Nadu, India. He graduated with a Bachelor of Engineering degree in Mechanical Engineering from Anna University in May 2010. He joined the Department of Mechanical and Industrial Engineering at Louisiana State University in August 2010. He plans to graduate with a Master of Science in Industrial Engineering degree in Fall 2012.