LEAN SAFETY: USING LEADING INDICATORS OF SAFETY INCIDENTS TO IMPROVE CONSTRUCTION SAFETY

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ABSTRACT

Safety and organization of a construction site were improved with the application of safety leading indicators and a 5-S assessment tool on a project managed using Lean principles. Safety related data collected on safety walks on a daily basis was organized for each specialty contractor and normalized for worker hours. The implementation of the 5-S assessment rated the site organization from zero to five for each contractor by a variety of key stakeholders. The observation of safety leading indicators provided a measure of safety risk on the construction site and a measure and mechanism for continuous learning. As a result, safety continually over the life of the project. Early results of the 5-S program clustered at the low end of the scale at the beginning of the project and significantly improved over time and reached almost 5 as the project approached completion.

The paper will reflect on related conceptual foundations and propose follow up investigations aimed at exploring leading indicators and other assessment tools related to safety and quality of work. The paper will also explore challenges faced by a general contractor in the on going efforts to implement the leading indicators principles on a company-wide basis.

KEYWORDS

Safety, Leading Indicators, Lean Construction, Visual Management, 5-S.

INTRODUCTION

Safety and organization of a construction site were improved with the application of safety leading indicators and a 5-S program assessment tool (Sort, Set in Order, Shine, Standardize, Sustain) on a project managed on Lean principles (Liker 2004 pp149). A description of the project, the companies involved, the application of various lean construction practices, and overall project outcomes will be followed by a more detailed report on the innovative safety practices and 5-S process employed.

BACKGROUND

XL Construction was hired by Johnson & Johnson as the general contractor to construct its West Coast Consolidation facility in Fremont, California. The overall objective of the project was to modify an existing facility to co-locate Johnson & Johnson's affiliate companies on the west coast at one campus.

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The construction project consisted of three major phases; and included the construction of ISO 8 clean room spaces, general research and development laboratories, and other general support use spaces. Total construction square footage was approximately 60,000 square feet; construction budget was approximately $14,000,000 and the total construction duration, which included 3 phases was 11 months. Johnson & Johnson had used Lean concepts on other construction projects; however, this was the first successful implementation of Lean principles on a Johnson & Johnson project and was XL Construction's first attempt to implement Lean principles. Following the completion of the Johnson & Johnson project, XL Construction has extended the process of tracking leading indicators of safety incidents on all its construction projects.

NEW SAFETY PRACTICES

OVERVIEW

Johnson & Johnson's standard safety reporting matrix, which was presented to the project team at the beginning of the project, requested that the general contractor track "leading indicators" of safety incidents. Without providing a formal definition for the request, the matrix simply defined a "leading indicator" as a "preventive or proactive measure that is taken in order to decrease the possibility of an incident". At first, this approach might appear to another attempt to improve safety through motivating and training the workforce. While these aspects are present, deeper reflection suggests that this the results achieved by approach occurred because 5-S actions both improved resilience and reduced likelihood of irrevocable loss of control. Resilience, the ability to absorb a dangerous variation from the norm, improved as the site became more neat and orderly. There was less to trip over and less to fall on if a worker did trip. Significant improvement in the use of fall protection by the most exposed trade decreased the likelihood that a loss of balance, trip or slip would result in an unstoppable fall.

The construction team implemented a program to collect, categorize, and report data regarding safety violations (corrections) as they occurred on the jobsite as a measure of the requested leading indicators. Each observed occurrence of non-compliance with either the California Division of Occupational Safety and Health (Cal/OSHA) regulations, or with the general contractor's site-specific safety program was recorded – including date, firm of individual in non-compliance, nature of required correction, and implemented correctional measure. Data were then sorted and displayed visually by category, firm, across time, and versus repetitive construction scope cycles. Safety education on the overall jobsite, as well as individual trade/firm safety education, was tailored to address trends in safety correction data.

Traditional and industry standard measurements of safety performance in the construction industry focus on incident rate. Measurements such as Cal/OSHA's Recordable Incident Rate compare the quantity of accidents or incidents to the number of hours worked. The approach of this project was to track leading indicators of safety incidents, or those behaviors or jobsite conditions that could potentially lead to an injury or incident. The project team applied Lean principles, particularly learning based on the "Plan, Do, Check, Act (PDCA) cycle, to this program by implementing aspects of goal setting, measurement, performance analysis, and accountability to tracking of safety leading indicators.

In addition, common 5-S construction programs provide generic criteria for each of the 5-S categories (Sort, Set in Order, Shine, Standardize, Sustain), but do not provide specific criteria relevant to the idiosyncrasies of each construction project nor provide a method for evaluation, measurement, and reporting of performance (Sowards 2004). This project team created a 5-S program that identified specific measureable criteria within each of the 5-S categories, and created a system for goal setting, measurement and performance reporting for each category.

The safety leading indicators and 5-S data were formatted into various reporting tools as described below. These tools were distributed to personnel on the jobsite, distributed to offsite management personnel and posted publically in the common lunch area. The tools were also reviewed at monthly "Safety Leadership" meetings, which were attended by Johnson & Johnson, XL Construction, and multiple major trade partners.

This paper will explore the methods used to track and report safety leading indicators as well as methods used to measure 5-S progress against established goals. The project team tested the hypothesis that the development and measurement of leading indicators of safety incidents would lead to a reduction in the frequency of safety incidents on the construction project. And that the measurement of 5-S performance against pre-determined goals would lead to better overall project conformance with the 5-S principles.

LEADING INDICATORS

Observed leading indicators were categorized into ten general safety program categories ("Personal Protective Equipment", as an example). Each of the ten categories also included multiple more specific sub-categories such as "safety glasses" or "head protection". Each category also included flexibility for additions of new or un-categorized corrections.

Safety compliance was defined by regulations set forth by the California Division of Occupational Safety and Health (Cal/OSHA) (http://www.ca-osha.com/), as well as Johnson & Johnson's project safety requirements, XL Construction's Injury and Illness Prevention Program, XL Construction's Subcontractor Safety Program, and XL Construction and Johnson & Johnson's Site Specific Safety Program. Any observance of non-compliance with any of these project safety regulations was documented as a jobsite safety correction.

Safety correction data were input on a weekly basis into a jobsite database, and multiple the data were published in multiple formats to all personnel on the project site. The most basic data display format is shown in Figure 1 below.

The graph in Figure 1 displays cumulative correction count for all personnel on the jobsite, organized into the ten pre-established correction categories. These graphs show approximately 65% of all corrections occurring within the "Personal Protective Equipment" category. While superficially this may not be particularly alarming (many jobsites experience a high rate of non-compliance within this category), deeper analysis shows a large percentage of the Personal Protective Equipment corrections occurring within the sub-category of "Fall Protection", as seen in Figure 2 below. Non compliance with fall protection requirements was determined to be a leading indicator of a potentially serious safety incident. Thus, jobsite safety education, overall jobsite and firm-specific safety meetings, as well as awareness of onsite safety compliance personnel could be specifically focused on correction of this particularly frequent leading indicator.

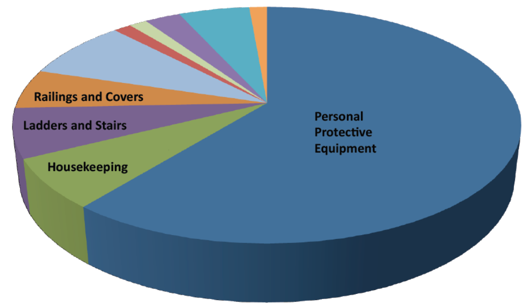

Figure 1: Overall Project Safety Leading Indicators Tracked by Infraction Category

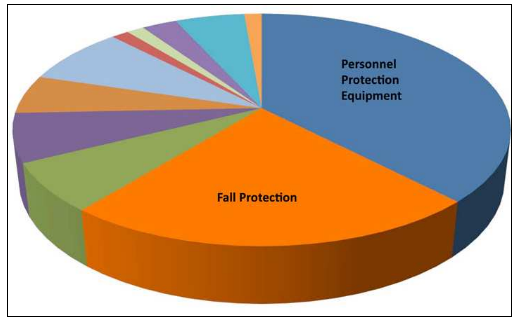

Figure 2: Overall Project Safety Leading Indicators Tracked by Infraction Category, With Personal Protective Equipment Sub-Set Data Broken into Major Sub-Categories.

Correction data were also displayed by trade partner firm as seen in Figure 3 below. Each firm's corrections were also further categorized and displayed by correction category. The benefit of this display format was observed to be two-fold: a sense of accountability by each the multiple firms onsite was created by the public and comparative nature of the data display, and each firm was given individual correction category data specific to their personnel onsite. Similar to the benefits from analysis of overall jobsite corrections sorted by category, each firm was able to focus their individual efforts towards correction of their most frequent or alarming data trends.

The data displayed in Figure 3 above, however, did not adequately gauge the overall safety compliance of each individual firm. The graph in Figure 3 above compares quantity of safety corrections across firms; however, this display format inaccurately implies a correlation between each firm's correction quantity and their overall compliance with the onsite safety regulations, and between each firm's correction quantity and their overall risk for a safety incident. In order to reflect accurately the relative and comparable frequency with which each firm was exhibiting leading indicators of safety incidents, the graph in Figure 4 below was created. This display model compares the number of safety corrections of each firm with the total hours worked by that firm. This "safety correction rate" represents the number of safety corrections observed per 200 man hours worked for each firm. This safety correction rate is an indicator of the likelihood that each firm will experience a safety incident based on the rate that that firm exhibits the defined leading indicators. Based on this data, a pro-active approach to jobsite accidents can be taken by addressing those groups (firms) that most frequently exhibit leading indicators, and based on an observed and measured assessment of risk.

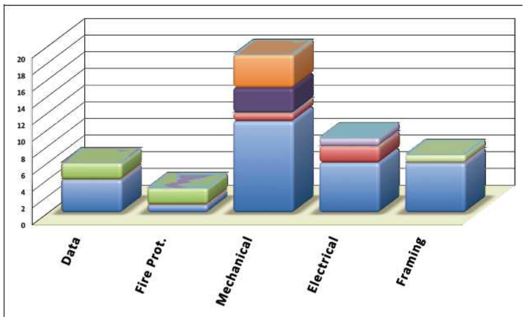

Figure 3: Safety Leading Indicator Tracked by Contractor Firm and Sorted by Infraction Category Within Each Firm.

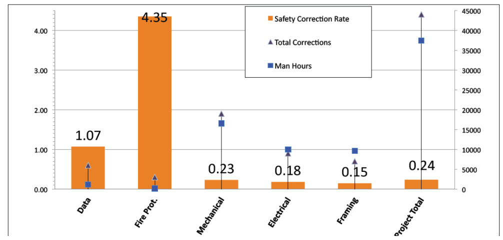

Figure 4: Safety Leading Indicator Rate Per Man Hours Worked, Displayed by Subcontractor Firm and Compared to Overall Project Total Rate

Lastly, safety correction data were tracked and displayed in relation to the project timescale. Figure 5 below shows overall jobsite correction totals, tracked by week throughout the project timeline. This display model was used to gauge the overall safety risk of the project site at any given moment by measuring and observing trends in overall project correction quantities. This display also provided a measured observation of the effect of implemented preventative measures, such as jobsite training of proper use of fall protection systems. The bold yellow line in Figure 5 below tracks the overall project running average number of leading indicators, and provided the team with a good indication of average performance and performance movement trend over time.

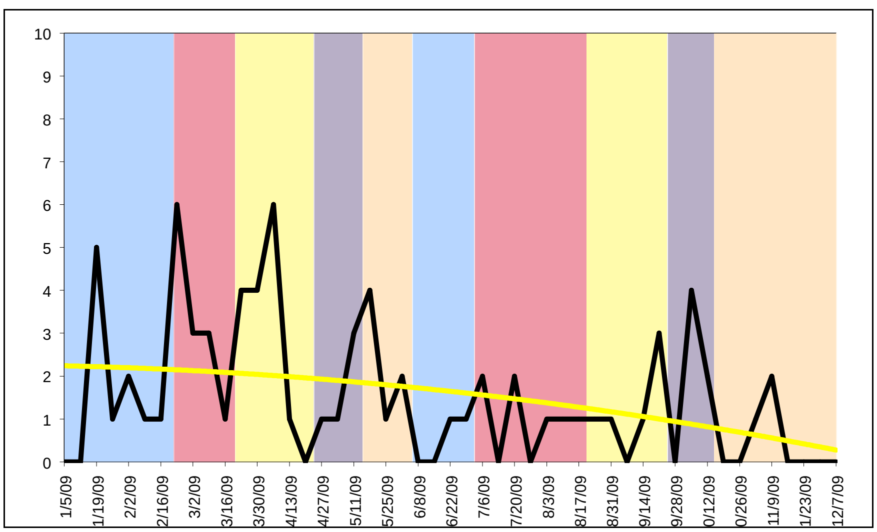

Figure 5: Overall Project Safety Leading Indicator Count Tracked Over Time, and Across Repetitive Project Scope Cycles.

Because the project was constructed in phases, and because the construction scope of each phase was roughly similar, it was also beneficial to augment the display of correction rate across time with an indication of the general construction scope being performed. Figure 5 above also attempts to accomplish this, with the colored vertical bars on the x-axis indicating the general construction activity occurring during each time period. As scope repeated (Phase 1 scope repeated in Phase 2, for example), the team utilized the data model on Figure 5 to review upcoming construction activities, and determine leading indicator trends from similar activities performed in previous phases. This provided the team an earlier opportunity to address potential safety risks based on specific project performance and leading indicators exhibited under near identical circumstances.

5-S ON SITE

The implementation of a 5-S program on this construction site was particularly problematic due to the challenge creating a system that was both practical with respect to the specific scope and jobsite makeup and measureable to the point that relevant feedback was input into the PDCA cycle.

In order to address the first of these challenges, the team created a specific set of criteria for each of the 5-S categories. Each criterion was evaluated to ensure that it was both practically implemented given the scope and execution of the project, and that results were tangible to the point that they could be quantifiably evaluated. Criteria were also created within the "Sustain" category to measure the efficiency and execution of the 5-S program itself (the two criteria for Sustain were: "Are all employees informed of the 5-S goals?" and "Is the weekly 5-S measurement worksheet completed?"). Each criterion was listed on a single-page field evaluation sheet. Measurement was conducted weekly by a variety of key stakeholders. XL Construction's field supervision staff, trade partner foremen, XL Construction management staff, and others, each completed the 5-S Field Evaluation Sheet by assigning a numerical "grade" to the compliance with each listed criterion. 5-S Evaluation Sheets were then collected and compiled, and cumulative averages for each category were calculated and displayed (see figure 6) below. The overall average (across all categories) was also calculated, and is displayed by the bold line in the figure below.

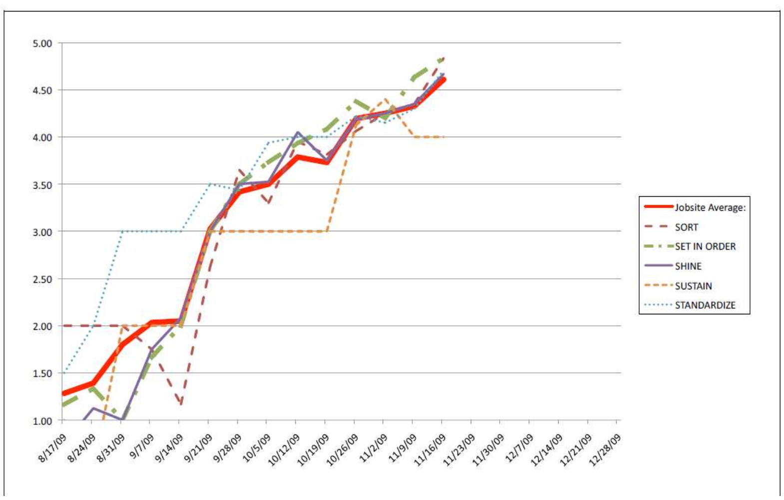

Figure 6: Overall Project 5-S Measurement Reporting by Category, with Project Average, Tracked Across Time

RESULTS

All measured categories of data, both in tracking of leading indicators of safety incidents and in measurement of 5-S performance, showed improvement over time throughout the project.

The overall jobsite frequency of safety leading indicators observed decreased over time throughout the project. During the first four months of the project, an average of 9.75 leading indicators were observed per month overall on the project site. During the second four months of the project, the total leading indicators observed decreased to an average of 5.25 per month. During the final four months of the project, the average number of leading indicators observed decreased to 3.5 per month.

Similarly, although somewhat less dramatically, the total project rate of leading indicator observed (adjusted for man hours worked, per Figure 6 above) decreased over time throughout the project. The rate of total leading indicators observed (per 200 man hours worked) during the first four months of the project was 1.29. This rate decreased to 0.22 during the second third of the project, and the overall project rate remained at 0.22 during the final four months of the project schedule.

Most subsets of the total count of observed leading indicators decreased over time as well. As an example, the "Fall Protection" subset of the leading indicator category "Personal Protective Equipment" (which was of particular concern to the project team throughout the project given the implied potential for serious injury or fatality should an incident in this category occur), decreased markedly over the course of the project timeline. During the first four months of the project, 12 observances of leading indicators in the Fall Protection category were observed (at a rate of 0.40 observances per 200 man hours worked). During the second third of the project the Fall Protection count reduced to 5 (a rate of 0.05 observances per 200 man hours worked). No Fall Protection leading indicators were observed during the final four months of the project.

The measured criteria in the project's 5-S program also showed improvement throughout the course of measurement. At the outset of measurement, the average project score for all criteria within each of the 5-S's (Sort, Set in Order, Shine, Standardize, Sustain) was 1.80 (on a scale of 1 to 5). This average increased to 3.42 during the second third of measurement, and at the final 5-S program measurement the project average was 4.61.

The dramatic improvement in exhibition of leading indicators of safety incidents on the jobsite was due to a variety of factors. Primarily, the awareness of the individual personnel on the jobsite of the specific behaviors that when exhibited lead to an increase in the likelihood of a safety incident occurring led to more overt and proactive behavioral changes being made to avoid them. The fundamental aspect of simply tracking leading indicators, and the multiple more complex methods that were utilized to assemble and communicate this data, led to a shift in individual mentalities in regards to safety as work was executed. In the absence of an awareness of leading indicators a person's focus while planning and executing a particularly risky task may be on the physical and financial consequences of an accident occurring (e.g. the pain of an injury or the financial loss due to lost working time). The awareness of the leading behavioral indicators of such an incident tended to shift the focus during planning and execution away from the consequences of a potential incident, and towards an avoidance of the leading indicators of such an incident.

Secondly, as leading indicator data were collected and displayed on the jobsite, personnel became aware of quantified performance both for the project as a whole, as well as for individual contractor firms. The program's emphasis on creating a high visibility for goals, progress and results increased the overall project awareness of not only the individual performance criteria, but led to a heightened awareness of the specific criteria being measured as well. As data were publically displayed and distributed, and as both positive and negative performance was highlighted, an overall desire for improvement was observed. This effect – although admittedly reliant on the competitive nature of many workers on the site – effectively accomplished the intended goal of increasing the awareness of leading indicators of safety incidents, and achieving a reduction in the exhibition of these behaviors on the job.

Lastly, the collection of data in the formats shown above allowed the project's management team to better understand the specific safety risks of the project, and to take proactive measures to mitigate those risks. Whereas in the absence of leading indicator data the management team's approach to project safety may have been generic and/or reactive in it's approach, this information provided real-time and project-specific insight into the specific areas of risk on the project at any given time, and allowed the safety education program to be tailored to directly address the project based on a quantified assessment. Throughout the project, as an example, the topics for weekly All Hands Tailgate Safety Meetings were selected to address safety categories in which concerning quantities of leading indicators of safety incidents had been observed in the prior week. Similarly, as an example, when Fall Protection and Equipment Safety leading indicators were measured to be increasing, a safety training expert was hired to provide on-site training in proper use of personnel lifts and forklifts, as well as the correct usage of fall restraint and fall arresting equipment.

The same information that allowed the overall project management team to tailor the project safety program to specific risks on the project as a whole also allowed individual trade contractor foremen to individually address the safety risks of their crews as well. Because the leading indicator data were tracked by contractor firm as well as for the project as a whole, trade foremen had access to cross sections of the overall project data that included leading indicators exhibited by members of their crews only. They were also provided with individualized versions the same display formats as were displayed for the project as a whole. Individual trade crews onsite were then able to address particular risks and concerns for their sub-set of the project whole.

CONCLUSIONS

The application of the Lean principles of planning, measurement, adjustment and improvement ("Plan, Do, Check, Act") was applied to both a 5-S program and a program to track leading indicators of safety incidents on this construction project. Each application demonstrated that communication of goals, measurement of performance in relationship to those goals, and a culture of accountability for measured performance can lead to safer and more efficient execution of construction work.

As the leading indicator program progressed throughout the project, and as the data display formats and tools were developed and refined, it was found that the most efficient tools used to communicate goals, progress, and results were those that were most direct and easy to read and comprehend. The efficiency and success of the program was directly related to the execution of the most active participants – those directly responsible for leading indicators as they physically execute construction work in the field. Therefore, the focus in developing tools for this program was on creating formats that were effective in communicating to that particular group. Future projects and implementations should not lose sight of the fact that the most important and directly responsible persons for the success of any aspect of construction on any site are those that directly execute the end product. This is especially true for safety, and we found that the best results on this project were achieved when tools and reporting were developed a focus on ensuring participation from the target audience in mind.

The program to track safety leading indicators, while to date only executed on this singular project, has an overall potential to augment the existing measured safety performance criteria for construction work. While current measurements (such as OSHA's Injury and Illness Incident Rates) (http://www.osha.gov/) focus on the frequency with which incidents have occurred, the measurement of leading indicators of those incidents provides a more proactive perspective that perhaps more directly reflects safety performance.

The program implemented on this project demonstrated that leading indicators of safety incidents can be quantified on a construction project, and that analysis of that data can be utilized effectively to reduce the frequency that those leading indicators are exhibited.

CONTINUING IMPLEMENTATION

Following the implementation on the Cordis/Johnson & Johnson project, XL Construction proceeded with implementation of tracking leading indicators on all its construction projects. This process is ongoing, but has had several success factors as well as challenges in its initial phase.

As this method of tracking has moved forward on other projects, there have been some challenges and opportunities for improvement that have surfaced. At the start of every new project, some training and education has been observed to be critical with the personnel in the field who will be updating and maintaining this tracking matrix. XL Construction has established a standard protocol for updating and maintaining this matrix. This has allowed for an easy learning curve for new employees to learn how the matrix works and what is involved in its upkeep and maintenance. The spreadsheet itself has seen multiple upgrades and versions that come along with suggestions for improvement. Suggestions to make the matrix more user-friendly and automated have been implemented with each subsequent project. Understanding what information is valuable to each team has helped develop better tracking metrics and visuals that can be used for process improvement by the team. For example, how some of the leading indicators are being tracked along with the associated corrective measures has allowed for some good root cause analysis why certain problems keep recurring and how to address those problems.

Another challenge has been with the collection and display of the information. Many trade contractors onsite have seen this identification of leading indicators by contractor as a personal attack on their employees or organization. The most effective way observed to date to address this issue is through the method of display of the information. It has been observed to be increasingly critical to ensure that this tool is used not to place blame or to point the finger at a struggling trade contractor with multiple violations, but rather it is a mechanism to create collaborative and integrated project. This culture of learning and improvement starts with the field foremen who are leading their respective crews. These foremen need to establish the correct attitude with how they approach the data with their crews. The project superintendent plays a key role in helping create the culture of addressing these potential dangers and resolving them in a way that does not become counter productive to the trust and relationships built onsite among the general contractor, trade contractors, and owner.

It has also been important to get some feedback from the trade contractors on what they notice and how they approach their work in a safe manner. During our weekly safety tailgate meetings, we have allowed different contractors onsite to lead the discussion on what safety means to their trade and how they incorporate safety into their work. This has empowered the trades to get more involved in the safety program and buy into this culture of continuous improvement. It makes safety everyone's responsibility instead of the traditional role of the safety manager/engineer policing the site looking for infractions or non-compliance.

As implementation continues on future projects, the PDCA cycle will be applied to find better ways to gather, analyze, and act on the data collected. Further research will be conducted to measure how each differing method of implementation affects acceptance and willing participation by field personnel, as well as the overall efficacy of the program in reducing the safety risk of construction projects.

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