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Gabrielse, Phillip J. *Application of Lean Strategies to Construction Storage Area (Proposal)*

Abstract

Digger Construction is a large excavating and earth moving construction company located in Wisconsin that specializes in Wisconsin Department of Transportation, municipality, and commercial construction projects. Due to years of improper care and control, Digger Construction's headquarters had become a disorganized laydown area for construction materials and equipment. The 12-acre construction yard was cluttered with excess materials, waste inventory, and broken-down vehicles and equipment. This disorganization and layout of the property created extra costs from employees trying to navigate areas of the property and locating needed items, as well as unknown inventory carrying costs. This study utilized lean and 5S methodologies to develop an improvement plan for the cleanliness and organization of the yard. Spaghetti diagramming and ABC inventory grouping were used to study the existing yard and to create an improved site plan. 5S was used to further organize the yard as a whole and to improve workflow, as well as used to develop example policies and documents that were to be used to standardize and sustain the new layout.

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Chapter I: Introduction

Digger Construction (name changed for privacy purposes) is a large excavating and earth moving construction company located in Wisconsin that specializes in Wisconsin Department of Transportation, municipality, and commercial construction projects. These projects are civil engineering projects and typically include demolition, earthmoving, and grading, as well as project oversight management and design. Digger Construction has approximately 60 employees, comprised of grading crews, utility crews, and office employees, and has numerous bulldozers, excavators, dump trucks, and other large construction equipment. The company headquarters is located on a 12-acre property, which houses an office building and a maintenance building, and is used for temporary and permanent storage as well as a laydown area for equipment and materials.

A construction project for Digger Construction begins when the work is acquired, typically through competitive bidding or through design-build opportunities, where then Digger Construction receives a contract for work. The office staff, consisting of civil engineers, estimators, and project managers, estimate and bid on various construction projects. These projects can be public projects for the State of Wisconsin Department of Transportation, public projects for local municipalities, or private projects for commercial clients. Digger Construction also has design staff that can custom design civil projects for clients and has the capability of acting as a subcontractor or a full general/prime contractor with full project management.

Grading crews for Digger Construction consist of a foreman/site supervisor who leads a small team of equipment operators and laborers who physically perform the required work. Grading crews have access to the various equipment needed, such as hydraulic excavators, graders, bulldozers, dump trucks, and other heavy construction machinery. Utility crews for

Digger Construction are comprised the same way but focus on underground utility work, such as storm sewer piping, sanitary sewer piping, and water main piping. An example of a typical civil project Digger would perform is a municipality wanting to repave a section of road. Digger Construction would manage the project, including Digger crews and other subcontractors. Digger grading crews would demolish the old road, tearing out the old pavement with heavy machinery. After the old road is removed, a utility crew would install new underground piping, such as new storm sewers. With the old road removed and utility work complete, Digger grading crews would fine grade the subgrade with new gravel, providing a base course of gravel that can be paved upon. A subcontractor specializing in paving would then install the new road surface.

The projects that Digger Construction perform occur at different geographic locations throughout the State of Wisconsin. Materials and supplies required for jobs are either supplied by subcontractors or are purchased and shipped directly to the project location itself. Also, many of the materials used for earth moving are naturally occurring at the construction site, such as dirt and gravel. For this reason, there is not a significant number of items that need to be held in inventory, but Digger Construction does keep some items in inventory at their headquarters property. This property is also used as temporary storage for materials when a jobsite is too congested, as well as a storage site for materials that may be left over after a project is complete. These materials include various aggregate materials used in road construction projects, and other construction equipment such as traffic cones, signs and barricades, and miscellaneous items. There are also utility supplies kept in inventory, such as precast concrete manhole structures, concrete and PVC pipe, casting assemblies, and various trench-box shoes that are used for stabilizing utility trenches. The manhole structures, pipe, and castings are typically leftover materials from projects and are kept on hand for use in projects where used or non-new materials

are acceptable. It is also common for custom fabricated materials such as manhole structures to be ordered at the start of a project, then, through change orders or changes in requirements, become unneeded. These manholes are brand new and very costly, so they are kept at the headquarters location in storage.

Many of these leftover items had been accumulating over the years with little or no thought to where items were stored on the property. Because of this, the headquarters property had become disorganized and cluttered. Some of the materials stored onsite were usable but disorganized and were often mixed in with broken or worthless materials that for unknown reasons were kept. Also, old equipment and vehicles which were kept for parts were located throughout the site, often being stored in whatever space was available at the time.

Because of this accumulation of clutter over the years, the Digger Construction headquarters storage site had wasted space, obsolete and unused materials, and little organization. This clutter resulted in wasted time searching for materials, investment tied up in inventory, little knowledge of actual inventory quantities, and a health hazard from tripping due to piles of clutter. There was also no differentiation between good, usable materials and obsolete, waste materials.

Statement of the Problem

Due to years of improper care and control, Digger Construction's headquarters had become an unsafe and disorganized laydown area for construction materials and equipment. The 12-acre construction yard was cluttered with excess materials, waste inventory, and broken-down vehicles and equipment. This disorganization and layout of the property created extra costs from employees trying to navigate areas of the property and locating needed items, as well as unknown inventory carrying costs and environmental concerns from old vehicles and parts.

Purpose of the Study

The purpose of this study was to develop a proposal to implement lean and 5S methodologies at the Digger Construction headquarters property. This proposal outlined the steps required to implement and execute a reorganization project and focused on the safety of employees, reduced inventory investment, and reduction of waste. This proposal was accomplished using 5S methodology, which eliminates waste materials and utilized lean methodologies to reorganize the layout of the yard.

Employee safety was the number-one priority for Digger Construction. With that in mind, this study looked at making the property a safer work area for employees who use the site. Employee safety was jeopardized due to tripping hazards throughout the site, piles of clutter that could fall on an employee, and potential for abrasive injuries from jagged, rusty, broken materials and equipment. This study focused on eliminating waste to help reduce these risks.

The second purpose of this proposal was to reduce the inventory investment contained within the site. While some of the materials kept in inventory were usable materials, some were broken and unneeded, or waste materials. Of the good materials, some were outdated or unlikely to be used. This study looked at eliminating both waste and good materials that were wasting space, as well as offered guides and suggestions for managing the inventory, tools, and equipment that were kept on the site.

The third purpose of this study was to reduce wasted time searching for materials. With little organization at the property, there was wasted time spent searching for usable materials. This study and proposal looked at how materials were stored and proposed a new site layout so that materials were not stacked in front of each other or in a way that hindered access, as well as looked at reorganizing and changing the layout of the yard to become a more efficient work area.

Assumptions of the Study

This study primarily assumed that Digger Construction had no major corporate strategic changes during the duration of the research, such as relocating the property or hiring a third-party consultant to do a lean or 5S study. For example, some companies hire outside/third party consultants to do 5S or lean projects. This could have been simply hiring a company to clean the yard. This project looked at 5S and lean and assumed the work would be done in concurrence with or shortly after the research. Also, it assumed no major changes, such as relocation of the property or changes in the property size/shape. These types of changes would have affected the research due to changes in scope and size of the project. Other strategic changes would have included liquidating inventory, where management decides to sell off all the inventory of materials at the site, reducing the need for 5S and lean, or the purchase of a new division, where the site would have to store and hold more equipment or materials than assumed in this study.

Definition of Terms

The following are common industry, lean, and 5S terms and their definitions.

5S. A methodology used in organizations to clean and organize. Originating in Japan, the five S's stand for Seiri, Seiton, Seiso, Seiketsu, Shitsuke, or Sort, Set In Order, Shine, Standardize, and Sustain (Lewis, 2011).

Kaizen. Incremental continuous improvement (Alarcón, 1997).

Laydown area. A term used to describe a physical area where tools, equipment, and materials are received and stored and/or assembled for projects.

Lean. A methodology for eliminating waste (Muda). Originating in Japan, this methodology is used in manufacturing facilities for reducing waste and improving workflow through a company (Hirano, 1995).

Muda. A Japanese term that means waste, such as in non-value adding activities or materials (Hirano, 1995).

Standard operating procedures. Policies and practices that are consistent throughout an organization.

Limitations of the Study

The following factors limited this study: This study was to develop a proposal to Digger Construction for reorganizing improvements; the results were limited to the property owned by Digger Construction that is used as a headquarters/storage yard; and that the research was completed within a reasonable time frame. Digger Construction had been considering building two new storage buildings to house much of the current inventory of materials, tools, and equipment. Before investing in these buildings, this research was conducted to determine what reorganization and layout improvements could be made the yard to better understand if the buildings were in fact needed and where they would be best located.

The results of this study were limited to Digger construction and the Digger Construction yard and headquarters due to the unique requirements and layout of the property. Many of the individual recommendations and methodologies were universal and could have been applied to other projects, but, because the yard itself was shaped and laid out in a certain way, the individual results were custom and could not be replicated at a different location. This study was further limited to the exact property referenced in this paper, as it would not apply to other properties owned by Digger Construction due to other properties having different requirements, configurations, and layouts.

For this study, the research project was also limited to being completed within a reasonable timeframe. The results of the study could have been implemented either concurrently

during the research or any time after the research is complete, but the information is based on the condition of the property when the research was conducted. If implementation of the results was delayed after the research was complete, there was no guarantee the results will be applicable or as effective.

Some costs were assumed for implementation of this proposal, such as labor expenses for cleanup and landfill charges for waste disposal. These short-term implementation costs would have been offset by long-term cost savings through the benefits of implementing lean and 5S methodologies, but were not measured or calculated. Final execution of results and recommendations was decided by Digger Construction management outside the parameters of this project.

Methodology

The methodology used in this study followed lean manufacturing techniques as well as 5S techniques. Lean manufacturing techniques were used to design a proposed site plan for the overall layout of the yard and to organize the flow of materials and people. 5S was used to propose methods to clean, organize, and polish the individual work areas. Policy and procedural examples were also proposed using 5S techniques.

The lean methodology used in this study focused on using a spaghetti diagram to chart the flow of materials and people through the yard. The spaghetti diagram created a map of the existing site, mapping all the movements and processes with lines. A line was drawn on the existing site map connecting similar tasks and processes. If an employee had to gather parts in one area, then travel to a different location for assembly, then travel to a different location for storage of the completed item, a line was drawn between each area. Once all areas and processes were connected with lines, the map was then used to analyze where improvements to work flows

could be made. Any process that had multiple steps or lines were looked at for possible consolidation. Anywhere that lines crossed was looked at for reorganization. Also, consideration was given to ABC inventory grouping based on priority, with highly used, high priority items and areas relocated to the most accessible locations. The lesser used items and areas were then sorted in order by use. Items or work areas used infrequently were located further back and so forth. The result was an improved proposed yard layout that placed highly used items in the best accessible areas and an organization scheme that placed similar items or processes in the same area.

5S methodologies were utilized extensively throughout this project, with recommendations considering each of the 5S's: sort, set-in-order, shine, standardize, and sustain. The sort phase proposed a method to create an inventory baseline of materials and equipment that needed to stay in the yard by using red-tagging methodologies as well as offered ideas for cleanup. The set-in-order phase proposed using the signboard strategy as well as general organization techniques to establish a method to set in order the materials and equipment that stayed in inventory, as well as temporary lay-down areas. The next phase was shine, which proposed methods to further polish and shine the areas. Next, the standardize phase proposed suggestions to set into practice the rules, regulations, and policies regarding how to maintain the clean state of the project. This was important to ensure the property stayed organized and clean after completion of the initial cleaning. It also outlined cleaning protocol examples and created example standard operating procedures for maintaining the site. Finally, the sustain phase looked at long-term sustainment of the yard and proposed more standard operating procedure examples to ensure long-term success.

Summary

This study focused on proposing lean and 5S methodologies to reorganize and lay out the construction yard, which is Digger Construction's headquarters property. The 12-acre property was cluttered with excess materials, waste inventory, and broken-down vehicles and equipment. This disorganization and layout of the property created extra costs from employees trying to navigate areas of the property and locating needed items, as well as had unknown inventory carrying costs and clutter from old vehicles and parts.

Company management knew about the implications of an unorganized storage yard, and had discussed building two new storage buildings to house the materials and equipment that were kept onsite. This study proposed implementing lean and 5S methodologies prior to construction of buildings to clean and organize the site to determine if buildings were in fact needed, where storage buildings would be best located if built, or if most of the onsite materials were waste and could be discarded. This study was limited to the property referenced in this proposal and was limited by time to the extent that the study was based on current site conditions. Changes in the site or strategic changes within the company could have altered the effectiveness of the results of this study. The next chapter reviews some of the literature pertaining to the methodology and history of 5S and lean.

Chapter II: Literature Review

Digger Construction owns a 12-acre property which is used for the company headquarters office, a maintenance building, and general storage of materials and supplies. Due to years of improper care and control, this property had become an unsafe and disorganized laydown area for construction materials and equipment. The 12-acre construction yard was cluttered with excess materials, waste inventory, and broken-down vehicles and equipment. This disorganization and layout of the property created extra costs from employees trying to navigate areas of the property when locating needed items, as well as unknown inventory carrying costs.

Various sources reinforce the need for efficiency and organization. An article by Lewis (2011) calls to attention the many businesses that have had to close their doors because they could not weather tough economic times. He goes on to state the following: “If you continue to do what you have always done, you will continue to get what you have always gotten” (Lewis, 2011). His point is that, if a company wants to be more successful and efficient and able to weather hard times, lean methodology and 5S will help achieve that goal.

This study proposed using lean methodologies to improve workflow and the overall organization/layout of the Digger Construction yard. This included cleaning up the existing site using 5S methodologies and reorganizing the layout of materials and equipment to offer a more efficient workflow. This chapter reviews literature regarding lean methodology and 5S.

Lean, when used in a business setting, refers to the concept of organizing a company in such a way that it runs at peak efficiency through eliminating waste (Muda). Lean methodology utilizes different tools and is a holistic approach; each of the tools contains a set of lean principles, and, when used together, they contribute to a very effective manufacturing environment (Feld, 2001). Lean is often referred to as lean manufacturing, as it is quite often

used in manufacturing facilities to improve workflows, but it can also be used in any number of industries. For example, lean methodologies have been adopted within the construction industry to eliminate waste and lower the cost of non-value-added items.

Manufacturers of construction components, such as window manufacturers, often utilize lean, but it has also been recently adopted by construction contractors and firms. Lean application for construction contractors and firms have problems, which are the result of irregularities in production due to differing projects and project site locations, as opposed to stationary manufacturing, in which products are typically more consistent and are produced in a controlled environment. Construction projects often have a one-of-a-kind nature, site production, and temporary multi-organization (Alarcón, 1997). Digger Construction is a construction contractor and thus deals with these challenges on projects; however, this study focused on applying a lean manufacturing methodology to a construction company storage yard, which is stationary and consistent, and simulates the consistency of a manufacturing environment.

Spaghetti Diagraming

Spaghetti Diagraming is a lean tool used to analyze movements of assets within an organization for the purpose of eliminating waste time. Extra time spent searching for materials, moving equipment, or simply walking to and from work areas are wasteful activities. An article by Orr & Orr (2014) describes an example where a company was able to reduce the distance walked by employees as much as 40% using a spaghetti diagram! This reduction in wasted time created a more efficient work space (Orr & Orr, 2014).

The advantage of a spaghetti diagram is that it visually documents and shows these movements. The spaghetti diagram shows actual flows of employees or materials in a process.

Since workflows often repeatedly cross each other, a completed spaghetti diagram typically looks similar to a bowl of spaghetti (Bhasin, 2015).

A spaghetti diagram was used to propose an improved physical layout of the construction yard. Using an existing site map, the first step of a process was marked, and an arrow was drawn from that process to where the second process happened. This was continued until all processes were mapped. For any lines and arrows that crisscrossed over each other, processes were studied for possible relocation to reduce the crisscrossing. Lines that continually came to one area were looked at for possible consolidation to eliminate backtracking. The result was a layout with shortened and time-saving paths, thus generating the most efficient and least wasteful work layout.

ABC Inventory Grouping

ABC inventory grouping was used to further refine the construction yard into a usable, efficient layout. The ABC inventory grouping principle was created in the 1950's by General Electric and classifies inventoried items based on their value to the company (Millstein, 2014). Largely used items (A items) are placed in the easiest of access locations, less commonly used items (B) items are placed further back, and least commonly used items (C items) are located with the least priority (Millstein, 2014).

It is often found in an ABC inventory classification system that the A items contribute to most use and value. This concept, defined by the Pareto effect, states that the top 20% of an inventory contains 80% of value or sales (Millstein, 2014). Schreibfeder's (2005) research study found that, for most fastener sales distributors, A ranked items accounted for 80% of sales activity within a 12-month period, B ranked items accounted for 15% of activity, C ranked items accounted for 4%, and D items accounted for 1%. This principle can be applied to various

inventory systems and uses simple principles for analyzing what constitutes A, B, and C items. To determine ABC classification, measuring costs of goods sold compared to the number of times an item is sold can determine an accurate rating (Schreibfeder, 2005).

The ABC Classification system along with the spaghetti diagram were useful tools in creating an efficient worksite layout. The tools created a continuous flow by eliminating wasted time searching for materials and parts, and making the process of accessing materials more efficient.

Implementing 5S

5S is a methodology stemming from five Japanese words— seiri, seiton, seiso, seiketsu, and shitsuke— also known as the 5 pillars of 5S. These words roughly translated to English mean sort, set in order, shine, standardize, and sustain, respectively. 5S is a tool used for workplace organization by eliminating waste (Nyaude, 2013). According to Sarkar (2006), if the workplace is clean and well organized, it is easier to identify and eliminate waste. Sarkar states it is important to begin with the end in mind. Having clear ideas of what is to be done is important for understanding what will be done with 5S and what will not be done. This proposal focused on the following: removing workplace clutter, eliminating waste, creating an efficient and productive workplace, and facilitating faster material retrieval (Sarkar, 2006). Furthermore, implementing a 5S program helped find ways to reduce injuries, which are expected when clutter and equipment is left unorganized in the workplace (Hirano, 1995).

Sort

Seiri, or sort, is the first pillar of 5S. Sorting is the process of organizing, and not just lining things up or stacking them neatly, but going further to include organizing tasks, assignments, and outside influences. The objective is to identify what is needed and should be

kept and what is unneeded and should be discarded (Hirano, 1995), with the primary benefits being a more effective use of space and a large decrease in unnecessary clutter (Graves, 2012).

One tool used in the sorting phase is called red-tagging. The red tag strategy was the first step in eliminating waste, and proposed using red tags placed on non-used items within the work area (Hirano, 1995). Red tags are typically simple pieces of paper that get placed on everything that was waste or appeared to be unused. The concept was having a highly visible way to identify a waste item. Red tags commonly have written on them a category of the item, such as the area of work it was used, the item name, quantity, reasons, and a date. This allows further identification of the items to be discarded. A list of red-tagged items is utilized along with a strategy to get rid of the waste (Hirano, 1995).

The sorting phase also considered inventory requirements when being analyzed. Inventory was kept to help insulate the company from problems, such as unreliable suppliers and improper production control policies; however, excess inventory was extremely wasteful as it tied up capital from moving, tracking, storing, and otherwise managing the unneeded material (Standard & Davis, 1999). It was proposed that unnecessary inventory items were returned to suppliers or thrown away to eliminate this issue. A certain level of safety stock was ok, providing it was carefully monitored and recorded when used. Safety stock is an extra amount of materials that are held in inventory incase future demand for materials exceed what was projected (Thomopoulos & SpringerLink, 2015).

Set-in-Order

Seiton, or set-in-order, is the next pillar of 5S and refers to orderliness. Orderliness coincides with organization, where items that are not needed are eliminated and those items that remain are organized. Furthermore, things that are needed and that are kept are organized in a

way so that anyone can find them easily (Hirano, 1995). It is important to keep items in the same order to streamline processes and to reduce the production cycle. This organization is crucial to minimize time spent searching for items. Typically the items should be easy to find, and it should be obvious when something is missing or out of place. The benefit of this is that it ensures tools are in the locations they are supposed to be (Mezentseva, 2013), and with an organized and efficient workspace, employees can easily locate important items and enjoy a less stressful work environment (Graves, 2012).

This study proposed using the signboard strategy to help set in order the construction yard. The signboard strategy is an organization tool that uses signs to label areas, materials, and important items. Without signboards and signage of one type or another, only trained, knowledgeable employees were able to find items (Hirano, 1995). This study proposed setting items in order and labeling them with obvious signs identifying what the items are, where they are, how they are used, and how many of them there are. This made orderliness a much more visual process. Identification of the best locations for items was done through spaghetti diagramming for the yard as a whole, and focused on placing often-used items as close as possible to the end user through ABC inventory grouping. Then, much like an address, it was proposed that location indicator sign boards were used to identify unique locations for the items as well (Hirano, 1995).

Shine

The next pillar is Seiso/shine, which also translates to cleanliness. This is a very straightforward concept, which is to literally clean up and make the work area shiny. This included sweeping, polishing, painting, and any other form of shining the work area to improve its physical appearance. The benefit of cleaning is that it not only improves working conditions

for employees, but it also makes it easier to identify problems, such as damaged or broken parts and equipment (Hirano, 1995). As an area is shined, safety is improved, as risks of injury decrease from cleaner work areas, such as cleaning slick, oily walking surfaces or removing sharp objects protruding through piles of clutter (Santos, 2014). Employees become more comfortable in a cleaner work environment, often leading to a feeling of personal ownership of the work area, which leads to an increase in personal ownership of the company's goals and vision (Graves, 2012).

Standardize

Seiketsu/standardize is the next pillar and means that the previous steps are being maintained. This study developed standardization techniques to maintain organization, orderliness, and cleanliness, since they were crucial to the long-term success of the 5S program. Cleaning house every few years isn't enough to maintain an efficient system. Hirano states that standardized cleanup should be made into habit, and company policies should reflect this concept. Standard operating procedures needed to be established to maintain the system and needed to be enforced (Hirano, 1995). Essentially, the system as a whole needed to be standardized throughout the company with employees trained in its implementation.

Fabrizio and Tapping (2006) describe systems standardizing each pillar which includes creating checklists for each item. For example, a sort checklist included items such as these: always having red tags available, inspect all items in the area, red tag unneeded items, and perform cleaning while red tagging. An example checklist for set-in-order included items such as the following: always replace the item immediately after using it; the more often an item is used, the closer it should be; avoid storing in piles. For shine a checklist included different items

and areas that need to be maintained, and the user would put a checkmark next to the item cleaned (Fabrizio & Tapping, 2006).

Ultimately, creating a standardized system is crucial for a successful 5S program. “When these new standards and best practices are implemented, the old habits will soon die out and be replaced by the more efficient patterns of behavior” (Graves, 2012). The benefit of this standardized system is that it builds a quality culture and creates a mindset for problem prevention (Sarkar, 2006).

Sustain

The final pillar is Shitsuke/sustain. Sustaining a 5S program comes down to discipline, which refers to always following and sustaining specified and standardized procedures (Hirano, 1995). Sustaining the 5S program was crucial for its long-term success and included everyone involved in the program. Much like standardize, this study developed procedures to sustain the system through standard operating procedures and systems that employees were to follow. This was beneficial because it created a system that ensured employee participation for all employees and built an excellent foundation for high quality workmanship (Sarkar, 2006). Ultimately, the proposed improvements required individual employees and end users to sustain the site. Proper training of the new policies and sustainment ensured everyone knew the policies and that the rules were followed.

Summary

The literature outlined in this chapter covered the concepts used in creating a lean work environment. Spaghetti diagrams and ABC inventory classifications were tools used to propose an organized and continuous flow of materials throughout the yard. A continuous flow where people, materials, and equipment move efficiently throughout the site is a lean work area with

little waste time. 5S methodologies were proposed to the further take those principles and sort, set-in-order, shine, standardize, and sustain those systems. The next chapter goes into further detail on the methodology of lean and 5S and techniques for implementation.

Chapter III: Methodology

This study utilized lean methodologies to develop a proposed layout to improve workflow and organization for the Digger Construction yard. This included utilizing a spaghetti diagram and ABC inventory methodology to reorganize the layout of the yard to offer a more efficient workflow, as well as methodologies and tools for cleaning up the existing site using 5S. This study also utilized 5S methodology to create proposed policies and procedures that ensure standardization and sustainment of the yard.

Spaghetti Diagraming

Spaghetti Diagraming is a lean tool used to analyze movements of assets within an organization for the purpose of eliminating waste time. Extra time spent searching for materials, moving equipment, or simply walking to and from work areas were wasteful activities. This study utilized a spaghetti diagram to map the existing movements of people and materials through the construction yard in order to create a proposed site plan with improved work flows. The spaghetti diagram mapped the movements and processes with lines, with the purpose being to understand how materials and assets were moved around and accessed within the site. Using an existing site map, the first step of a process was marked, and an arrow drawn from that process to where the second process happened. This was continued until all processes were mapped. Along with mapping the movements, the physical distances between areas were measured. Measuring the distances between existing movements tracked the amount of time spent moving between areas and was used as a tool to measure and analyze improvements. Longer distances equaled longer travel time. Reducing the distance an employee walked between work areas reduced wasted time traveling. By comparing the existing distances to improved distance, time saved was measured.

Figure 1 shows an example spaghetti diagram, where assembly movements were mapped in a workspace. Assembly started when a worker gathered raw materials/parts. Next, the worker walked to the Lathe and Drill Press to machine the raw parts. After this, the worker gathered bolts for assembly, then gathered the tools required for assembly. With the machined parts, bolts, and tools, the worker walked to the Work Bench to assemble the materials. Once the product was assembled, the worker walked to the Finished Inventory Storage to store the completed product. In this example spaghetti diagram, the existing workspace was laid out poorly, with the worker having to travel back-and-forth across the workspace multiple times to complete the tasks. The employee traveled a total of 112 feet walking back and forth across the room.

Assembly Route

- Step 1 - Parts Bin to Lathe - 15'
- Step 2 - Lathe to Drill Press - 20'
- Step 3 - Drill Press to Bolt Bin - 28'
- Step 4 - Bolt Bin to Tool Shelf - 9'
- Step 5 - Tool shelf to Work Bench - 8'
- Step 6 - Work Bench to Finished Inventory - 32'

Total distance walked: 112 feet

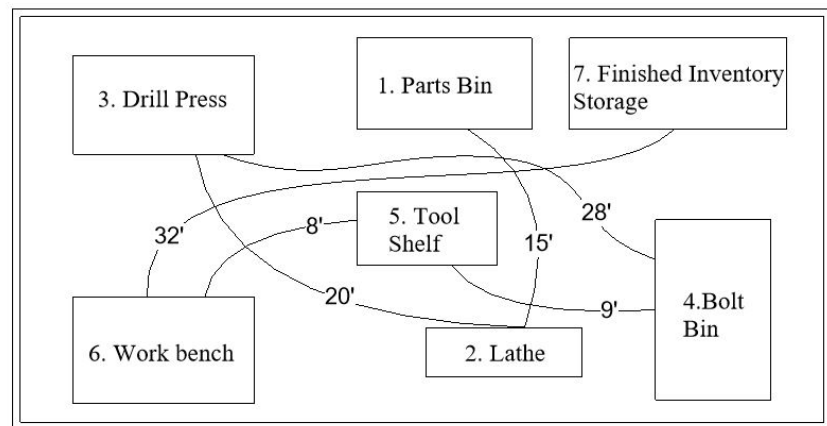


Figure 1. Example spaghetti diagram.

Once all areas and processes were connected with lines, the spaghetti diagram was used to create a proposed site plan. This was done by looking at the lines on the existing map, and anywhere lines crossed was looked at for reorganization to improve flow. Tasks which required walking back and forth multiple times were wasteful movements and were consolidated. Lines that continually came to one area, the processes were combined at that location to eliminate

backtracking. The more movements a person took to perform his or her job, the more time was wasted, reducing value to the company by higher labor costs.

Figure 2 shows an example of an improved layout. The individual work areas have been rearranged to have a continuous flow around the room with reduced distances between work areas. The Lathe and Drill Press work stations were combined so all machining could be completed in one area. This improved layout reduced the walking distance from 112 feet down to 68 feet.

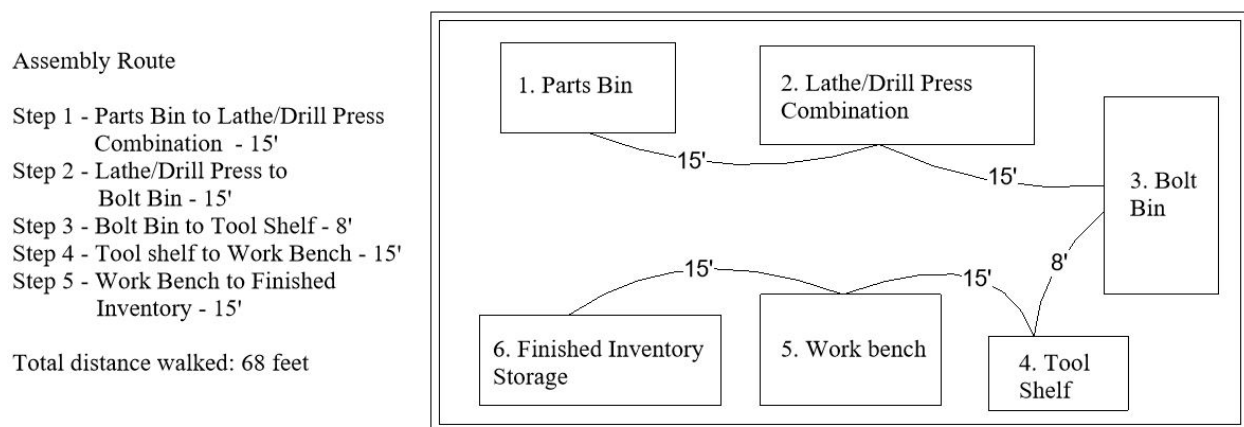


Figure 2. Example improved layout.

This reduction of 44 feet per assembly was used to calculate the time and cost saved. In this example, the employee completed 16 assemblies per day (2 per hour, 8 hours per day), and worked 260 days in a year. When comparing the existing spaghetti diagram to the proposed example work layout, the employee traveled 44 extra feet in the existing layout, multiplied by 16 assemblies per day, multiplied by 260 days per year, giving a total of 183,040 extra feet. 183,040 feet is equal to an additional 34.7 miles the employee walked each year to complete their job. With the employee walking an average of two miles per hour, the company in the example had 17.35 hours, or over two full working days per year, of wasted time spent just walking around the room.

For Digger Construction, inventory was to be categorized by similar type and use. These categories were to be shown on the spaghetti diagram and movements between areas tracked. The distances were to be tracked as well to determine time spent moving between areas. Using these measurements between movements, compared to the improved layout, allowed for similar cost reduction calculations to be completed. A field supervisor/foreman at Digger Construction has an hourly cost to the company of \$73 per hour. This includes the employee's hourly pay, federal and state taxes, and fringe benefits. A general laborer has an hourly cost of \$55 per hour, which includes the employee's hourly pay, federal and state taxes, and fringe benefits. These hourly rates were to be multiplied by the calculated waste time to determine the actual wasted dollar value.

ABC Inventory Grouping

Along with spaghetti mapping, this study utilized a tool called ABC inventory grouping. ABC inventory grouping gives consideration for an item's priority level, which allowed the proposed site plan to be broken down into an efficient and convenient layout by placing highly used, high priority items and work areas in the most accessible locations. Where spaghetti diagramming consolidated unnecessary movements between work areas and categories of inventory, ABC inventory grouping helped determine where the consolidated and improved work areas were to be located within the overall site. The first step was taking the inventory categories as identified in the spaghetti diagram and ranking them by importance. To rank the categories, average unit cost for the items in inventory was multiplied by the number of uses annually. The result was a total annual dollar value that was ranked as a percentage of the total annual dollar value of all categories. The categories that ranked within approximately eighty percent of annual usage were identified as A items, categories within approximately twenty

Implementing 5S

Spaghetti diagraming and ABC inventory grouping developed an improved site plan of the overall construction yard. This study also developed suggestions to complete further organization through 5S methodologies, with focus on each of the 5S's: sort, set-it-order, shine, standardize, and sustain. The sort phase utilized red-tagging to sort the waste items from good items to establish a baseline of materials and equipment that needed to stay in the yard. The set-in-order phase organized the individual categories to set in order the materials and equipment that stayed in inventory and applied the signboard strategy to identify each area.

Next, this study developed techniques to further clean and polish the site in the shine phase, and the standardize phase created suggestions for implementing rules, regulations, and policies regarding how to maintain the clean state of the project. It also created protocol and standard operating procedures for cleaning. Finally, the sustain phase created long-term sustainment policies and standard operating procedures for the long-term success of the 5S and lean project.

Sort

The sorting phase in 5S developed a plan for sorting and sifting through the existing area to identify and remove waste. Waste included broken or damaged items and items that were not used or needed. To identify items as waste, a red-tagging event was to be utilized by management and knowledgeable field staff to red-tag items that were waste. Other items that were to be red-tagged were items that had been in storage for extended periods of time and were not going to be used in the near future. Employees were then to go through the yard to remove the waste items, using hand labor or machinery to sort and dispose of the waste. Consideration was to be given to items that could be recycled, items of hazardous waste, and

items that could be thrown away. Items that were in good condition but unneeded were to be salvaged or returned to manufacturers or sales distributors.

Set-in-Order

The next step was developing a plan to set in order materials at their respective locations and those locations organized and labeled. This ensured that items had a specific location where they belonged and that those locations were always used, and that nothing else was placed in their spot. Each category of items was to be consolidated and relocated within the yard according to the proposed site plan. With the overall site rearranged, these individual categories were to then be organized and set-in-order as well.

The set-in-order phase utilized the signboard strategy to label areas. Each area was to be labeled with signs that were to be durable to withstand outdoor placement and large enough to be legible within a vehicle driving through the yard. Every building and storage area within the site was to be specifically labeled, and individual entrances were to be labeled to differentiate between customer and employee entrances. Areas were to be labeled based on broad categories as well as by specific items. The degree of labeling should have been determined by experienced staff or management and based on frequency of use, with highly used items being labeled with more detail. Decorative signs were to be used for areas that were trafficked by customers, but signs used by employees, vendors, or delivery drivers should have had a high contrast, such as those that are found in the Manual on Uniform Traffic Control Devices (Federal Highway Administration, 2017).

Shine

With clutter and waste items removed and remaining items organized in previous steps, the next was to develop a plan to clean and polish the site to make it shine. The 12-acre parcel

owned by Digger Construction consisted of a primarily gravel surface with asphalt near the office building for parking and landscaping around the property. These areas were to be cleaned and polished along with individual items and individual storage areas. Cleaning and polishing the site helped reduce weeds that crept up through the gravel of non-trafficked areas of the yard as well as improved the overall look of the yard. By removing weeds, sticks, and other debris, tripping hazards were reduced, making the site safer. After the property was shined, the storage areas themselves were to be shined. Storage containers that were old and damaged but still useful were to be repaired as needed and could have been painted to improve their appearance. Stored vehicles were to be parked parallel to each other and in line with each other. Vehicles, equipment, and materials that were muddy or dirty were to be cleaned.

Standardize

The next step was to standardize the system. This was done by developing example policies and procedures for standardizing and keeping the area organized, orderly, and clean. This also included examples for training employees on the new layout so all employees were aware of the new locations of items and categories, as well as on the procedures and frequency of cleaning. These policies were to ensure all current and future employees were well equipped with the knowledge needed to maintain maximum efficiency as well as how to use the facility.

Training programs were to show employees where materials and equipment were located throughout the yard and were to establish policies pertaining to the upkeep of the yard. The training examples were to also lay out procedures for cleaning and what to do if an item became damaged or not needed. To ensure tools and equipment were not removed from their assigned locations unnecessarily, the policies addressed ways to ensure employees return tools and do not misuse them. This helped eliminate tools and equipment from being stolen or not returned to

their locations so other employees could easily find them. Every tool had its own location; a place for everything and everything in its place.

The new policies were to be easily accessible, so employees could access the information at a later time. The policies were to be posted in common areas along with instructions, as well as posted on the individual signboards throughout the yard. Also, red-tagging equipment was to be available for employees to conduct red-tagging events in the future, with a provision that employees could conduct a red tag event without the direct oversight of management. This included empowering employees to make decisions about some waste items without approval. With the creation of policies, simple was better. Implementing solid, easy-to-follow instructions ensured employee support and compliance.

Sustain

To sustain the new system, this study developed example policies to ensure future compliance. The policies addressed issues such as the frequency of cleaning and maintenance, reducing waste from entering the yard, and monitoring and controlling other items entering and leaving the yard. This was to ensure the cleanliness of the yard was not compromised by improper documentation, theft, or others using the yard such as delivery drivers, other contractors, or employees from sister companies. These policies were to be easily accessible and legible so employees could access the information at later times when needed. The policies were to be posted in common areas that employees access along with instructions. The policies were to have included contact information of whom to contact with questions such as management or field supervisors. They should also have included provisions for punishments for failure to comply, and offered a standard operating procedure for filing and documenting compliance.

Summary

In summary, this study utilized lean and 5S methodologies to improve the overall organization and layout of the Digger Construction yard. Spaghetti diagraming was utilized to map the existing flow of materials and people through the yard, with the purpose of eliminating wasted time. ABC inventory methodology was also used to rank inventory and work areas by level of use and importance. This study also used 5S methodology to further organize the yard as a whole and improve workflow. The first 5S, sort, was the first step in organizing the yard, and was utilized to clean up waste. The second 5S, set-in-order, was utilized to organize the non-waste items into a more efficient layout. The third 5S, shine, focused on cleaning and polishing the work area. The fourth 5S, standardize, developed policies and standard operating procedures to standardize the 5S program. The fifth 5S, sustain, developed policies and standard operating procedures that ensured future compliance with the program. The following chapter discusses the results of these methodologies as they apply to Digger Construction.

Chapter IV: Results

This study utilized lean methodologies to develop a proposed layout to improve workflow and organization for the Digger Construction yard. This included utilizing a spaghetti diagram and ABC inventory methodology to reorganize the layout of the yard to offer a more efficient workflow, as well as methodologies and tools for cleaning up the existing site using 5S. With 5S, policies and procedures were created to ensure standardization and sustainment of the yard.

Spaghetti Diagraming

The spaghetti diagram created in this study mapped the general layout of and the movements between existing storage areas. These were the storage areas for supplies and materials that were identified as being able to be relocated feasibly. These included aggregate stockpiles, mechanical and maintenance supply items, utility structure items, utility pipe items, utility incidental items, utility tools, non-utility supplies, and small equipment.

This study did not include areas of the yard that were unfeasible to be moved. This included general parking areas for employees as well as truck and large equipment parking areas. The truck parking and equipment parking areas have an extensive electrical system installed that provides power outlets at each parking stall. These outlets are used for powering engine block heaters for the trucks and equipment during colder weather. This electrical system is located along the west side of the property and at a few locations around the maintenance shop. This electrical system could not easily be moved.

The first category of materials that was mapped on the spaghetti diagram was aggregate storage. Digger Construction has storage onsite for topsoil and other earthen materials, as well as stockpiles of broken concrete and asphalt materials, which are stockpiled throughout the year

and then recycled through crushing at the end of the year. The recycled concrete and asphalt aggregate is then stored in stockpiles onsite for use as gravel on future projects. As trucks leave or enter the yard, they must cross a drive-on scale, which weighs the trucks to determine how much material is coming into or leaving the yard. These materials were located near the rear of the yard and had other supplies stored in between the piles. There was no clear separation between some piles, with the materials becoming mixed where piles met.

The distances traveled for each aggregate pile were as follows: Concrete Pile Route from the main entrance to pile ramp, 827 feet; Asphalt Pile Route from the main entrance to pile ramp, 1,013 feet; Crushed Concrete Route from the main entrance to pile, 700 feet; ¾" Gravel Route from the main entrance to pile, 928 feet; Crushed Asphalt Route from the main entrance to pile, 1,144 feet; Topsoil Route from the main entrance to pile, 1,221 feet.

The next category of items mapped was the storage of mechanic's supplies and the movements between the maintenance shop building and those storage locations. It was found that the mechanics storage areas were located away from the maintenance building, requiring mechanics to waste time moving between storage areas and the shop. The mechanics had four different storage locations, and the travel distance between the locations totaled 2,500 feet when measuring the distance an employee would walk to visit all locations.

The next category of storage that was mapped was utility pipe storage. This included different storage locations for different types of pipe, fittings, and tools required for pipe installation. These materials and tools were typically loaded onto large semi-trailers which often could not navigate the tight spaces of the yard, so the trailers were loaded in central location. An employee would use a fork-lift to gather materials and bring them to the loading location. It was found there were four pipe storage areas and one pipe tool storage area that an employee would

visit to gather pipe and materials needed. To visit each location in search of supplies and return to the loading area, an employee would travel a distance of 2,738 feet.

Next, utility structure and tool storage locations were mapped. An employee would use a fork-lift to gather these materials and load them onto a semi-trailer in a central location in the yard. It was found that an employee would have to visit four structure storage locations and two tool storage locations, traveling a distance of 2,490 feet.

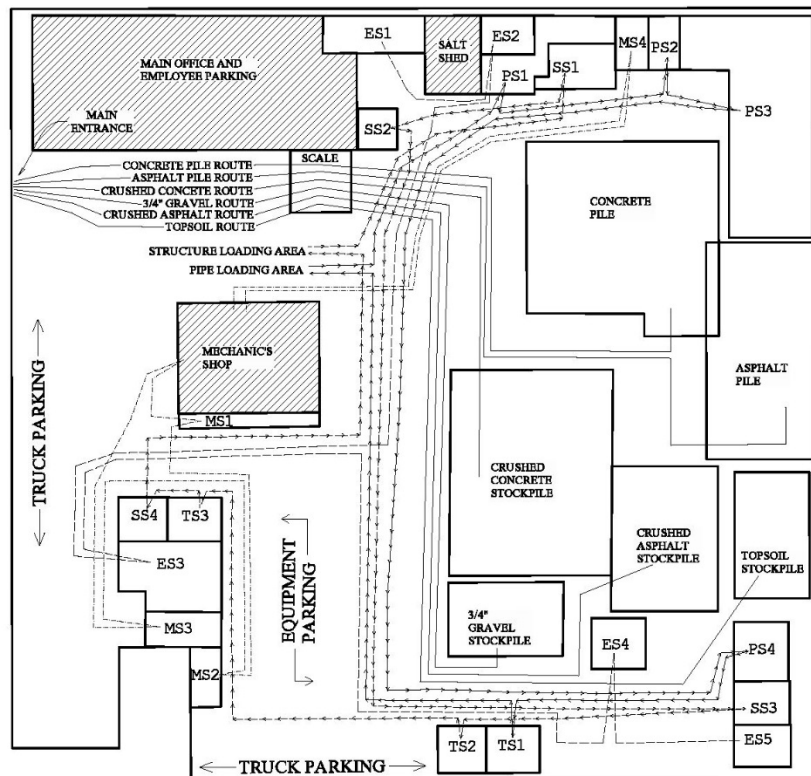


Figure 4. Spaghetti diagram.

The final category studied was non-utility supplies such as geotextile fabric and small construction equipment such as cones, barricades, and road-work-ahead signs. It was found that there were four storage areas for these items located in various locations within the yard and with no clear system for organization. There were no signboards or labeling, and some of the storage areas were located behind others with no clear distinction between stacks of materials. Due to

the lack of organization, an employee would travel a distance of 2,224 feet walking between the locations in search of materials and supplies.

Overall, it was found that there were multiple storage areas for each category of materials, supplies and equipment. Much of these materials and equipment were intermingled with other storage, and there was no clear form of organization to discern between the piles of clutter. There were also storage areas that were located behind other storage areas and thus were not easily visible from the general traffic route. These different locations of storage areas created wasted time spent moving between locations or searching for supplies. Figure 4 shows the spaghetti diagram for the Digger Construction yard and the movements within the yard mapped.

With the storage areas and movements between them mapped, the spaghetti diagram was used to create an improved site plan. The individual storage areas were consolidated where possible and rearranged to have a continuous flow around the yard with reduced distances between locations. The improved site plan is shown in Figure 5.

The improved distances traveled for each aggregate pile were as follows: Crushed Concrete Route from the main entrance to pile, 700 feet to 604 feet; Concrete Pile Route from the main entrance to pile ramp, 827 feet to 704 feet; $\frac{3}{4}$ " Gravel Route from the main entrance to pile, 928 feet to 893 feet; Crushed Asphalt Route from the main entrance to pile, 1,144 feet to 1,094 feet; Topsoil Route from the main entrance to pile; 1,221 feet down to 917 feet. The only route that increased in length was the Asphalt pile route, from the main entrance to pile, 1,013 feet to 1,092 feet.

Mechanic's supply areas were consolidated and relocated next to the maintenance shop. When measuring the distance an employee would walk to visit all locations, this relocation reduced traveling distance from 2,500 feet to 520 feet.

Utility pipe storage was consolidated and relocated to the northeastern portion of the yard. All of the pipe, tools, and fittings are now in one area, and an employee does not have to search various locations throughout the yard to find materials. This improvement reduced the travel distance an employee would travel from 2,738 feet to 565 feet.

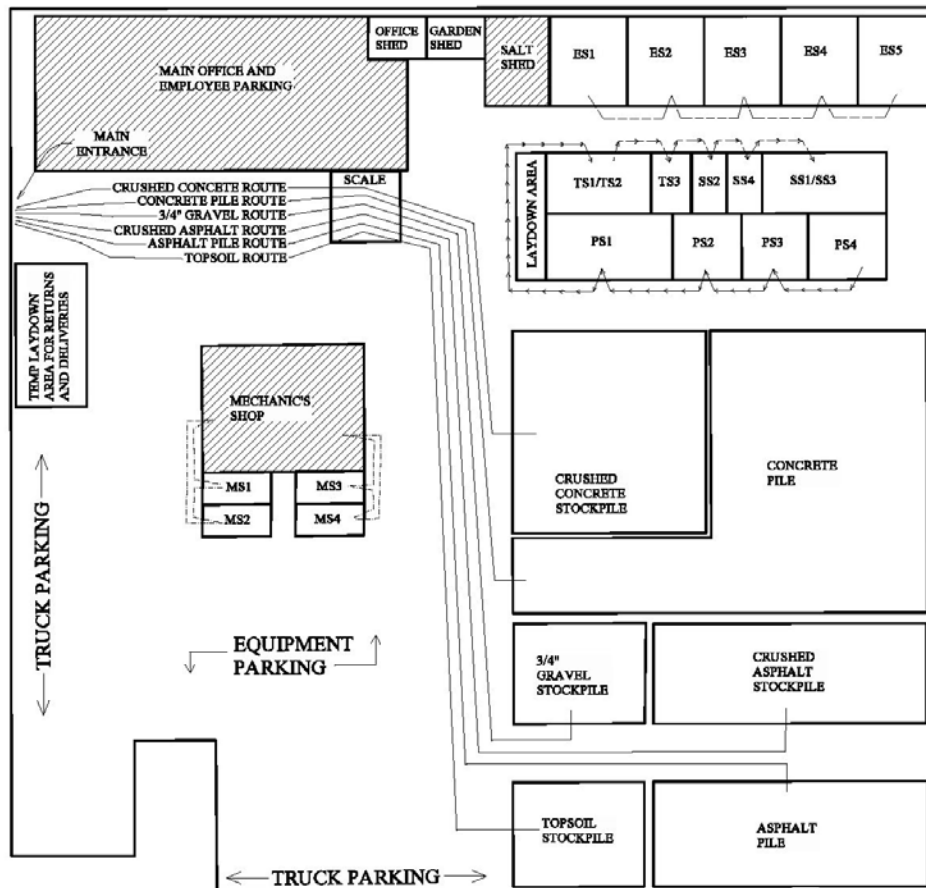


Figure 5. Improved layout.

Utility structures were also consolidated and relocated to the northeastern portion of the yard, adjacent to pipe supplies. All the structures, castings, adjusting rings, brick and block, shoring, and tools were now in one area, and an employee does not have to search various storage locations throughout the yard. This improvement reduced the travel distance from 2,490 feet down to 260 feet.

Non-utility supplies and equipment were consolidated and relocated along the northeastern border of the property. With these materials and equipment relocated and consolidated, an employee would not have to travel to different locations to find supplies. With everything consolidated, the travel distance an employee would travel between storage areas was reduced from 2224 feet down to 300 feet.

An advantage of consolidating and relocating the pipe, structures, and equipment was it allowed room for a road that leads around the materials, so trucks can get in and around them. This greatly reduced the distance traveled from a central loading location to individual storage areas. With this improved layout, trucks can drive right to the supplies and load them directly.

The reduction in travel distances for each category includes a significant reduction in cost from time spent searching for materials as well as accessing materials. For aggregate materials, travel distance represents a dump truck entering the yard, stopping briefly at a drive-on weigh scale, and traveling to the location of material. All dump trucks that enter or leave the yard must drive onto the scale, which weighs the truck to measure how much material is entering or leaving the yard. From the scale, they travel to the pile needed. A dump truck at Digger Construction costs \$100 per hour to operate and will have on average two trips per hour for eight hours in and out of the yard for any given material. A dump truck typically drives through the yard at a speed of five miles per hour.

The distance traveling to the Crushed Concrete Pile was reduced 96 feet. This travel distance can be doubled to 192 feet, since the truck travels the same route when leaving after loading or unloading aggregate materials. 192 feet distance times an average of 16 trips per day equals 3,072 feet. 3,072 feet divided by 5,280 feet per mile equals .58 miles of saved travel distance per day. At a rate of five miles per hour, a truck travels .58 mile in .116 hours. At a rate

of \$100 per hour, that equates to \$11.60 per truck per day saved. With an average of five trucks per day, and utilizing the material 80 days per year, this becomes an annual savings of \$4,640.

The distance traveling to the Concrete Pile was reduced 123 feet, doubled is 246 feet. 246 feet times 16 trips per day equals 3,936 feet. 3,936 feet equals .75 mile of saved travel distance per day. At five miles per hour, a truck travels .75 mile in .15 hours. At \$100 per hour, that equals \$15 per truck per day saved. Five trucks per day operating 80 days per year, gives a savings of \$6,000.

The distance traveling to the ¾" Gravel Pile was reduced 35 feet, doubled is 70 feet. 70 feet times 16 trips per day equals 1,120 feet. 1,120 feet equals .21 miles of saved travel distance per day. At five miles per hour, a truck travels .21 mile in .04 hours. At \$100 per hour, that equals \$4 per truck per day saved. Five trucks per day operating 30 days per year, gives a savings of \$600.

The distance traveling to the Topsoil Pile was reduced 304 feet, doubled is 608 feet. 608 feet times 16 trips per day equals 9,728 feet. 9,728 feet equals 1.84 miles of saved travel distance per day. At five miles per hour, a truck travels 1.84 miles in .37 hours. At \$100 per hour, that equals \$37 per truck per day saved. Five trucks per day operating 20 days per year, gives a savings of \$3,700.

The distance traveling to the Crushed Asphalt pile was reduced 50 feet, doubled is 100 feet. 100 feet times 16 trips per day equals 1,600 feet. 1,600 feet equals .3 mile of saved travel distance per day. At five miles per hour, a truck travels .3 mile in .06 hours. At \$100 per hour, that equals \$6 per truck per day saved. Five trucks per day operating 20 days per year, gives a savings of \$600.

The distance traveling to the Asphalt Pile was the only aggregate pile that increased in distance. The distance increased by 79 feet, doubled was 158 feet. 158 feet times 16 trips per day equals 2,528 feet. 2,528 feet equals .48 miles of extra travel distance per day. At five miles per hour, a truck travels .48 mile in .1 hours. At \$100 per hour, that equals \$10 per truck per day extra. Five trucks per day operating 20 days per year, gives an extra cost of \$1,000. When this extra cost is compared to the savings from the other piles, the dollar value overall is worth the cost.

The distance traveled by the mechanics to visit their storage areas was reduced 1,980 feet. At two trips per day to the storage areas, a mechanic would walk 3,960 feet, or .75 miles. At two miles per hour, a mechanic walks .75 mile in .375 hours. With the mechanic's hourly rate at \$50 per hour, this equals \$18.75 per day that is saved on labor costs traveling around the yard.

The distance traveled to gather and load utility pipe was reduced by 2,173 feet. This reduction was possible by relocating all utility pipe supply areas and tool locations next to each other. Also, by creating an access road around the new utility supply area, trucks could drive right to the storage area instead of going out and picking all the parts with a fork lift and returning to a central location. At one trip per day, a utility crew would walk and drive a forklift .41 extra mile to gather materials with the old site layout. At three miles per hour, the crew would travel .41 miles in .14 hours. With a crew consisting of a foreman at \$73 per hour, and two laborers at \$55 per hour, this crew would save \$25.62 per trip with the new layout. This savings can be multiplied by the average trips per year, which is approximately 50 trips through the yard, which equals a total annual savings in labor costs of \$1,281.

The distance traveled to gather and load utility structures was reduced by 2,230 feet. This was possible by relocating all utility structures and supply areas and tool locations close to

each other and by utilizing the new access road. At one trip per day, a utility crew would walk and drive a forklift .42 extra mile to gather materials with the old site layout. At three miles per hour, the crew would travel .42 miles in .14 hours. With a crew consisting of a foreman at \$73 per hour, and two laborers at \$55 per hour, this crew would save \$25.62 per trip with the new layout. This savings can be multiplied by the average trips per year, which is approximately 20 trips through the yard, which equals a total annual savings in labor costs of \$512.

The distance traveled to gather and load non-utility supplies and equipment was reduced by 1,924 feet. This also was possible by relocating these storage areas and tool locations close to each other and by utilizing the new access road. At one trip per day, a laborer would walk .36 extra miles to gather materials with the old site layout. At two miles per hour, the laborer would travel .36 miles in .18 hours. At \$55 per hour, this laborer would save \$9.90 per trip with the new layout. This savings can be multiplied by the average trips per year, which is approximately 100 trips through the yard, which equals a total annual savings in labor costs of \$990.

It is important to note that these estimated cost savings are based on average use of the yard and typical traveling scenarios. If an employee would stop in the yard for just one item, that employee would not necessarily have to travel to each location if that employee had prior knowledge of where that item was stored. Or, if an employee was searching for a specific item, and happened to find that item right away, that employee would not have to travel to all the other storage locations. So, these cost saving calculations are general averages of typical situations.

ABC Inventory Grouping

Along with spaghetti mapping, this study utilized ABC inventory grouping to give consideration for an item's priority level when working with the improved site plan. Spaghetti diagramming consolidated unnecessary movements between work areas and categories of

inventory, ABC Inventory Grouping helped determine where the consolidated and improved work areas were to be located within the overall site. Table 1 shows the inventory grouping table used to determine ABC ranking.

Table 1

ABC Inventory Grouping Table

Category/Item	Average Unit Price	Number of Annual Sales Transactions	Annual Usage Dollar Value	Percentage of Total Usage	Ranking
Crushed Concrete	\$30	6400	\$192,000	25%	A
Concrete Pile	\$20	6400	\$128,000	17%	A
Utility Structures	\$2,000	60	\$120,000	16%	A
Utility Pipe	\$1,000	110	\$110,000	14%	A
Non-utility supplies	\$500	100	\$50,000	7%	B
¾" Base Course	\$20	2400	\$48,000	6%	B
Topsoil	\$30	1600	\$48,000	6%	B
Crushed Asphalt	\$20	1600	\$32,000	4%	C
Asphalt Pile	\$20	1600	\$32,000	4%	C
Mechanics Supplies	\$50	30	1500	0.2%	C

For Digger Construction, the categories of items identified in the spaghetti diagram were used for ABC analysis along with an estimated average unit price for each category. Next, the number of annual sales transactions was estimated, and the annual usage dollar value and percentage of total usage were calculated. This generated the ranking percentage of the items.

It was found that the highest ranking items were the crushed concrete and concrete pile items as well as the utility pipe, and utility structure items. These A items represent roughly

72% of the total inventory usage. B items included non-utility supplies and equipment, as well as ¾" Base Course and Topsoil. These items represent roughly 19% of the total inventory usage. C items included asphalt and crushed asphalt, as well as mechanics supplies. These were the lowest ranking categories, representing just over 8% of the total inventory usage.

Consideration was given to these ranks when creating the proposed site map. The A items were located closer to the entrance of the yard than B and C items. This made the travel distance shorter for A items and puts them within clear view of the entrance. This makes it easy to find by employees as they enter the yard. Consideration of theft is also important for A items, as they have the most value. With some of the current storage areas hidden behind aggregate piles, the new visible location helps reduce the possibility of someone stealing supplies with no one looking. Further, accessing the supplies requires driving past the main office, which can reduce the potential of theft as office personnel can see vehicles coming and going. B and C items were located further away from the entrance to the yard. These items were not as valuable as they did not account for a large percentage of inventory usage.

The overall layout was limited by certain restraints. This study did not include areas of the yard that were unfeasible to be moved. This included general parking areas for employees as well as truck and large equipment parking areas. Also, there was a shore land zoning setback on the southern half of the yard. This setback limits construction of buildings or structures within its zone. For this reason, management wanted utility and non-utility supplies located in the northeastern portion of the yard. This location is outside the shore land zone and would accommodate future buildings to store the supplies.

During research of the existing yard, a need was identified for storage areas that did not exist within the existing layout. These were a temporary storage area for delivery and returns,

storage for office supplies and gardening and grounds equipment, and a laydown area for temporarily storing supplies such as utility supplies or equipment.

As vehicles enter the yard, the first new storage area was a temporary storage area for deliveries and returns. This area, where delivery drivers drop off and pick up materials that are purchased or are to be returned, was located directly next to the entrance as it was the most accessible location for delivery drivers. This area was to be identified with a large signboard and the storage area itself constructed out of concrete landscaping blocks or concrete barricade walls.

Second, as employees drive straight into the yard, was a temporary laydown area. This area was for temporary storage of materials for specific jobs and was to have changeable signboards to identify each storage bay. The storage area itself consists of multiple bays constructed out of concrete landscaping blocks. The signboards in each bay reference a specific project, identified by the project number and name on the signboard. Each bay would be used for one project, and these storage bays used to centrally locate items for pickup by field staff. When materials cannot be directly delivered to a project site, they can be temporarily stored here until pick up, and project managers can stage materials or equipment here for pick up as well. By having this temporary storage area, in-demand materials can be quickly found and identified.

Ultimately, by understanding the current movements throughout the yard, and by creating a reorganized site plan, wasted time was greatly reduced. In addition, more space was created within the yard, as shown in the proposed site plan as the additional equipment parking area.

Sort

The sorting phase focused on developing tools to sort and sift through the existing area to identify and remove waste. Waste was either broken or damaged items or items that were not used or needed. To identify items as waste, red-tagging of the items was used. Due to the

materials and items in the construction yard being of larger size and exposed to the elements outdoors, pink marking spray paint was recommended to be utilized to red-tag the items. Pink spray paint is kept in inventory at Digger Construction and is readily available. Management staff, field supervisors, and maintenance mechanics were to go through the yard and red-tag items that were broken, unneeded, or generally garbage. Large X's and marks were to be painted on the waste items to identify them. Field staff were to then go through the yard to dispose of the waste items, using hand labor and heavy machinery to sort and dispose of the waste.

Items such as scrap metal were recyclable. These items were to be taken and placed in the company's scrap metal dumpster. Some items such as scrap engines were to be taken into the mechanic's shop to be drained of oil and hazardous materials. The hazardous materials were to then be disposed of per company regulations, and the left-over metal placed in the scrap metal dumpster for recycling. Non-metal waste, consisting of plastic pipe and materials, was to be sorted and piled in an open area of the yard. A hydraulic excavator was to be utilized to smash the large pieces into small chunks and scooped up into a dump truck and disposed at a land fill. Concrete waste items were to be relocated to the company's onsite concrete recycling pile. Wood waste items and other remaining waste items were to be loaded into dump trucks and hauled to a local landfill.

Set-in-Order

The next step was developing a plan to set-in-order. With the new site plan created and the red-tagging event complete, materials were to be relocated and set-in-order at their respective locations, and those locations organized and labeled. This was to ensure items had a specific

location where they belong and that those locations are always used, and nothing else is placed in their location.

To set-in-order the yard, storage areas were to have designated partitions divided different storage locations. This was to be any form of physical barrier to act as fencing to differentiate the areas such as concrete landscaping blocks, concrete road barriers, or scrap railroad ties. Enclosed storage structures were ideal due to the ability to designate a whole structure to a certain category of items. This included semi-trailers and shipping containers, which were secure and heavy-duty, and could be outfitted with storage racks and shelving to store materials.

It was important that the storage areas and materials in those areas were labeled so all employees know their locations and that the same locations are always used. The tool used for labeling these areas was the signboard strategy. Signs and labels were to be created to identify the individual areas, where each area receives its own sign. These signs were to be durable to withstand outdoor placement and large enough to be legible within a vehicle driving through the yard. Every building and storage area within the site was to be specifically labeled, such as the main office and mechanics maintenance shop, and building entrances were to be labeled to differentiate between customer and employee entrances. Other areas were to be labeled based on broad categories and then broken down into specific categories. The degree of labeling was to be determined by experienced staff or management or frequency of use. Highly used items were to be labeled with more detail. Decorative signs were to be utilized for areas that were trafficked by customers, but any sign used by employees, vendors, or delivery drivers was to have a high contrast, such as those that are found in the Manual on Uniform Traffic Control Devices (Federal Highway Administration, 2017). By utilizing this strategy, everyone will know exactly where each item belongs.

Shine

With clutter and waste items removed and remaining items organized in previous steps, the next stage was to develop a system to clean and polish the site to make it shine. The 12-acre parcel owned by Digger Construction consists of a primarily gravel surface with asphalt near the office building for parking and landscaping around the property. These areas were what need to be cleaned and polished along with individual items and individual storage areas.

Cleaning and polishing the site was to consist of using Digger Construction owned machinery and grading equipment to polish the property. First, a grader was to be used to smooth the gravel surface of the yard to remove imperfections and ruts caused from vehicle traffic. Second, fresh gravel was to be placed in wet areas and low spots to help reduce future rutting. Gravel for this purpose was to be 1-1/4-inch crushed concrete, which is kept in inventory at the yard, and is readily accessible.

With this complete, the storage areas themselves shined. Storage containers that were old and damaged but still useful were to be repaired as needed and painted to improve their appearance. Stored vehicles were to be parked parallel to each other and in line with each other, and vehicles, equipment or materials that were muddy or dirty were to be cleaned with a pressure washer. Individual materials, tools, and supplies were to be cleaned as well. Pipe materials that were previously stored directly on the ground were to be pressure washed to remove dirt and restored on pallets or blocks of wood to keep them off the ground. Any material that had labeling on it was to have that labeling refreshed.

Standardize

The next step was to develop standardization policies to keep the system organized, orderly, and clean. This was done by developing example policies and procedures for

standardization. The benefit of standardizing the new inventory system was to ensure all employees (including office staff) knew the system and maintained the system. This study proposed implementing a site tour to train employees on the site, a site etiquette policy, and a new tool inventory management program.

The first process for standardizing is establishing a training program for new and all current employees. This training program consists of a site tour given by a management staff member or field supervisors and includes a tour checklist that is filled out during the tour and kept in the employee's employment file. The importance of the tour was so that all employees are familiar where items were located. This reduced wasted time spend searching for materials or equipment. The purpose of the checklist was to standardize the tour. Everyone received the same tour, so no one could say they weren't shown where an item is.

The tour was to include all buildings, highlighting off-limit areas and company property limits. The tour was also to include locations of all equipment, tools, and materials. The tour is accompanied the tour checklist, which is a document that lists all of the tour locations. When an employee was shown an area, that location was checked off the list of locations.

When a new employee is hired, they are given their New Employee Handbook. Once they have reviewed the contents, they are ready for the tour. This is not a self-guided tour; a management staff member or field supervisor will act as the tour guide. Consistency with every tour given is important to ensure the tour guides show every area.

Every location on the checklist should be located and shown to the employee. The checklist should contain boxes for checking off locations as the tour is conducted, which is filled out by the tour guide. There should be a column on the form to note a reason why a location was not shown in the event the tour is not completed or if equipment is not at the yard. The bottom

of the tour checklist should contain signature lines with dates for both the employee and tour guide to fill out. An example tour checklist is shown in Figure 6.

The form contains instructions on how to conduct the tour, a note that requires the form is signed and turned into the office, and other pertinent information. It is important to include this information so the tour is standardized. With the tour complete and the checklist filled out and signed by both people, the sheet is returned to the office to be kept in the new employee's personnel file. A copy should be given to the employee as well as, if possible, a site map showing the locations for future reference. Extra copies of the site maps should be located in the office and maintenance shop and at specific work areas for future reference. The benefit of the site tour is that all employees are familiar with the yard and the locations of equipment and materials they may need.

Employee Name:	Tour Guide Name:	Date:
Location	Check if shown	Check if not shown and reason
Employee Signature:		Date:
Tour Guide Signature:		Date:
<i>Sign and return to the main office.</i>		

Figure 6. Example tour checklist.

Along with the site tour and tour checklist, a site etiquette policy is established. The site etiquette policy addresses company policies pertaining to organization, cleanup, and maintenance of the yard. The policies will most likely have to be created new, since any existing

policies were ineffective, unknown, or inadequate to keep the site organized and cleaned. The policy should be part of the training program and updated as needed to keep the policies current and pertinent. The policy should address company rules about how to identify items that are waste or garbage, what to do with them, and who to contact with questions. The site etiquette policy should also address frequency of cleaning, how and what to clean, and location of cleaning supplies and equipment. It could also address punishments for violating the policy.

Ultimately, knowledgeable management staff should create the policy. All employees are given two copies, one to keep and one to return signed that it was read and understood. The signed copy is returned to the office and stored in the employee's personnel file. Current employees are given the form in their paystubs to be returned to the office, and all future employees will receive the same forms in their New Employee Handbook. The policy form should also be laminated and posted in various locations throughout the property. This will standardize the policies and standardize awareness of the policies.

To ensure tools and equipment are not removed from their respective locations unnecessarily, a companywide tool issuance program and policy should be created. This will ensure all employees receive a standardized issue of tools and equipment required to do their job. This will also standardize the issuing of tools throughout the company, and will eliminate certain tools from being stolen or not returned to their locations.

The first step for implementing this program is to identify and record what tools are needed for each position within the company. All the different positions within the company should be evaluated and the results should list the position, the tools the company will provide, and tools required the company will not provide.

The second step is to do a companywide inventory of existing tools and equipment. Every piece of equipment and tool should be inventoried to document what items the company currently owns and what employee possesses it. An office manager will meet with each employee, and the employee will bring all company owned items. For the initial inventory, the employee will return those items he or she was in possession of so they can be reissued in the correct quantity.

Employee Name:		Position:		
Item:	Authorized Quantity:	Quantity Received:	Unit Cost:	Date Received:
Employee Signature:			Date:	
Manager Signature:			Date:	

Figure 7. Example standard issue form.

The manager will issue the employee the tools he or she is required and the manager will document the items on the standard issue form. The form has a location for employee name and position, and columns for the issued items, the authorized quantity of items issued, the quantity of items received, the actual dollar amount cost of the item, and the date the inventory form was filled out. The bottom of the form should have signature lines and a line for a date of signature,

as well as signature and date lines for the staff member completing the inventory. The back of the form will list policies that go with the standard issue program.

The column for authorized quantity shows the quantity of that the employee is allowed to have for an item. The quantity received column is to document the actual amount received, if less than the authorized quantity. This would be happen if the company inventory becomes depleted before issuing all items an employee should have. If at a later date the company orders more items, the employee can come in and receive the additional items. If items are added at a later date, the manager and employee should initial and date by the item that was received.

This form should also have listed the cost/price of each item so the employee and company know the value of the items issued and their replacement costs. Policy should be created in conjunction with this stating that if an employee loses or damages the item, the cost is clearly known and the employee is responsible for replacing the item or covering the cost for replacement. This transfers liability to the employee and ensures the employee is responsible for his or her issued items. Items that are broken or damaged through normal wear and tear can be replaced at the company's discretion. The employee should receive a copy of the standard issue inventory form and a master copy of the form kept on file at the office in the employee's personnel file. The form is to stay in the employees personnel file at all times, taken out only to update the inventory. Figure 7 shows an example standard issue form.

By implementing this standard issue program, each employee has his or her own equipment and should never have to waste time looking for tools. The employee can no longer can state he or she was not given tools, as they were issued and documented. This will also reduce theft or inventories mysteriously being depleted through attrition.

Follow-up inventories should be conducted at reoccurring times, typically annually. Every year, the inventory manager meets with employees and has a new inventory form. The full inventory is completed again and any missing items are replaced at the employee's or company's expense. The inventory manager will go through the items the employee has and check to make sure the employee still has the correct quantity and items are in good working order. Care should be taken when performing the inventory so that an employee has all items present and accountable for. If an employee is issued two shovels, but forgets one at home for the inventory, only mark down one shovel. The form can be updated as needed at a different time. Any surplus items are turned in to the company. If an employee is issued one wheelbarrow and shows up for inventory with five, management can investigate why. If every employee is maintaining his or her own items, there should be no shortage or surplus, so any discrepancies in the issued amount should be looked into by management. A surplus for one employee could mean a shortage for another employee, or theft. With the surplus put back into the company inventory, it allows those tools to be given back to an employee who may be missing items.

Other policies pertaining to the tool program could be created to ensure compliance as well and would be determined by management. Again, these policies should be written on the back of the inventory form so the employee can read them. Signing the form acknowledges reading and understanding the policy. Implementing this standard issue program sets a company-wide procedure for managing inventories of tools. It ensures every employee has the tools necessary to do the work as needed, and protects the company from careless damage or theft, as the employee has signed for the items issued. Ultimately, this program will standardize the tool inventory within the company and at the construction yard.

This standard issue program could be utilized elsewhere, such as for company-owned trucks as well. Company owned trucks that are driven by designated drivers could also have a standard issue checklist. Items such as fire extinguishers, first aid kits, spare tires, and other necessary items can be on this list. The list would then be maintained by the vehicle operator and inventoried annually. Other vehicles such as dump trucks which do not have assigned drivers can have an inventory list kept in a glove box of the vehicle and periodically checked by staff.

Sustain

To sustain the new system, this study developed example policies to ensure future compliance. The first policy established is a policy stating the frequency of cleaning and maintenance. Once a year minimum the yard will go through the sorting, set-in-order, and shine phase. Ideally this would be every spring and fall, in conjunction with the start and end of the construction season in Wisconsin. This will utilize multiple office and field staff to go through and organize and clean up the yard.

The second policy is a policy created to reduce waste from entering the yard. If materials are damaged at a different location, they are to be analyzed and discarded if needed, before being brought to the yard. This eliminates most of the waste before it has a chance to pile up and clutter the yard. All materials, good or bad, entering the yard are to be inspected by an office manager or field supervisor.

The next policy covers monitoring and controlling other items entering and leaving the yard such as deliveries or materials that are to be picked up for return to suppliers. This will ensure the cleanliness of the yard is not compromised by delivery drivers not employed by the company as well as ensure theft or improper documentation does not occur. The policy states

that all delivery and return drivers' check into the main office and all delivered items are to be inspected for damage and correct quantities. All return items are to be inspected and counted by the driver as well as an office staff member or field supervisor.

This policy also covers the rules regarding the Temporary Storage Area for Deliveries and Returns location. This area is permanent so delivery drivers who constantly deliver to the property always know where to go, and employees always know where to look for delivered items. The process for returning materials is this: Any material that is in good condition can be brought back to the yard by a field staff member. That employee checks in with the office, and the project manager assigned to the project/materials will review the items. Any supplier-returnable materials are then placed in the Returns area, and the project manager will notify the vender or supplier of the returns for pick up. Any nonreturnable items such as partial rolls of fabric or partial pieces of pipe can be brought to their respectable inventory storage areas, and any remaining damaged items can be thrown away.

These policies include contact information of whom to contact with questions. It also addresses punishments for violating the policy: first offense is a verbal warning, the second offense is a written warning, and the third offense is termination. All employees are given two copies, one to keep and one to return signed that it was read and understood. The signed copy is returned to the office and stored in the employee's personnel file. Current employees are given the policy form in their paystubs to be returned to the office, and all future employees will receive the same forms in their New Employee Handbook. The policy is also to be laminated and posted in various locations throughout the property. This will standardize the policies and standardize awareness of the policies. The policy is also to be given to delivery drivers. This will ensure sustainment of the organization and cleanliness of the construction yard.

Lastly, there is a policy to allow for future kaizen events and brainstorming events for changes and improvements to the system. This consists of a cross-functional team scheduled in one-year intervals to meet and analyze what is working and what needs to be improved. It also allows new ideas to be considered for changes. By using a cross-functional team consisting of field staff, field supervisors, accountants, and office managers, the processes and systems can be analyzed from different perspectives and allow feedback from all areas of the company. This will ensure future improvements and ultimately a sustainable system.

Summary

This study utilized lean and 5S methodologies to develop an improvement plan for the cleanliness and organization of the yard. With the reduction of waste and organization of materials, there is less risk of injury from tripping or injuries from damaged materials, and there is less inventory carrying costs for items that are unneeded or that can be returned. By reorganizing the yard using spaghetti mapping and ABC inventory organization, the yard has a more efficient flow, which reduces wasted time searching for materials and moving between storage areas. This study also used 5S methodology to further organize the yard as a whole and improve workflow, as well as proposed example policies and documents that can be used to standardize and sustain the new layout. The following chapter discusses these results as they apply to Digger Construction.

Chapter V: Discussion

Digger Construction specializes in excavating and earth moving for government and private civil construction projects. Comprised of approximately 60 employees, Digger construction has grading crews, underground utility crews, and project management staff, estimators, and civil engineers. The company headquarters is located on a 12-acre property which houses an office building and a maintenance building and is used for temporary and permanent storage as well as a laydown area for equipment and materials.

Due to years of improper care and control, Digger Construction's headquarters had become an unsafe and disorganized laydown area for construction materials and equipment. The 12-acre construction yard was cluttered with excess materials, waste inventory, and broken-down vehicles and equipment. This disorganization created extra costs from employees trying to navigate areas of the property to locate needed items, as well as unknown inventory carrying costs.

The purpose of this study was to develop a plan to implement lean and 5S methodologies at the Digger Construction headquarters property. This study outlined the steps required to implement and execute a reorganization project and focused on reduced inventory investment, reduction of waste, and the improvement of safety through reduced clutter. This was accomplished using 5S methodology, which eliminates waste, and the lean methodologies of spaghetti mapping and ABC inventory grouping to reorganize the layout of the yard and reduce wasted time spent searching for materials.

This study researched literature pertaining to lean and 5S methodology and outlined some similar research that had been completed on this topic. Lean methodology studied included research in spaghetti diagraming and utilizing ABC inventory principles. The research also

looked at the five pillars of 5S: sorting, setting in order, shining, standardizing, and sustaining. Each pillar contained different tools to assist implementation, such as red-tagging events to sort and reduce waste, signboards to identify and set in order, developing policies pertaining to cleaning and shining the work area, policies to standardize the changes, and policies to sustain the changes.

This study also looked at the methodologies of lean and 5S. By using the research studied, the methodologies were shown as general recommendations and implementation tools. These methodologies included spaghetti diagrams and utilized ABC inventory principles. The methodologies also included the five pillars of 5S– sorting, setting in order, shining, standardizing, and sustaining. Each pillar contained different tools to assist implementation, such as red-tagging events to sort waste, signboards to identify and set in order, developing policies pertaining to cleaning and shining the work area, policies to standardize the changes, and policies to sustain the changes.

Next, these methodologies were applied specifically to Digger Construction, to generate specific results. Spaghetti diagram mapping and ABC inventory principles were used to reorganize the general layout of the yard, and 5S was used to develop specific area improvements. The sorting phase outlined red-tagging by using pink spray paint, an item that is readily available to Digger Construction staff. The set-in-order phase outlined organization of the items that remained after the red-tagging event and labeled them with sign boards, and the shine phase outlined polishing the final product. The standardize and sustain phases developed different policies and procedures that could be implemented to maintain the yard, as well as how to train employees, monitor practices, and allowed provisions for future red-tagging events to occur.

Limitations

This study was conducted to develop a proposal to Digger Construction for reorganizing improvements. These results were limited to the property owned by Digger Construction that is used as a headquarters and storage yard. This was further limited to the exact property referenced in this paper, as it would not apply to other properties owned by Digger Construction due to other properties having different requirements, configurations, and layouts.

For this study, the research project was also limited to being completed within a reasonable timeframe, and the results of the study could have been implemented either concurrently during the research or any time after the research is complete. However, the information was based on the condition of the property when the research was conducted. If implementation of the results was delayed after the research was complete, there was no guarantee the results will be applicable or as effective. If the layout of the yard changed in anyway, it could alter the conclusion of the results.

Costs associated with cleanup were considered short-term implementation costs and were assumed to be offset by long-term cost savings through the benefits of implementing lean and 5S methodologies. Final execution of results and recommendations was decided by Digger Construction management outside the parameters of this project.

Conclusion

This proposal outlined the steps required to implement and execute a reorganization project and focused on the safety of employees, reduced inventory investment, and reduction of waste. This was accomplished using lean and 5S methodology to develop a plan to eliminate waste and reorganize the layout of the yard and to develop policies to sustain the improved system.

Employee safety was the number-one priority for Digger Construction. This study looked at making the property a safer work area for employees who use the site. Through red-tagging in the sort phase, it was proposed that clutter and waste items be eliminated. With the set-in-order phase, remaining clutter was to be reorganized and set in order to reduce safety hazards. The shine phase developed a plan to clean and shine the yard, making it a safer work environment.

The second purpose of this proposal was to reduce the inventory investment contained within the site. This study developed a plan to reduce inventory investment through the sort phase of 5s. The plan called for reducing waste by eliminating garbage items and returning items that had value to vendors. This study also utilized ABC inventory organization methodologies to rank inventory items. Asphalt and crushed asphalt had some of the least value of inventory items, and could be eliminated to make room for more valuable items if needed.

The third purpose of this study was to reduce wasted time spent searching for materials. This study utilized spaghetti diagramming to map the existing site and created a proposed improved site plan. This improved site plan reduced travel distances substantially for the general categories of storage in the yard. Utilizing average usage costs, the annual savings was calculated at over \$17,000 in annual savings from labor costs spent navigating and searching the yard. This was accomplished by consolidating similar inventories, creating better access to the materials, and by utilizing ABC inventory grouping to put high-value items in the best locations.

To further eliminate wasted time, policies were developed to sustain the system and train employees on the use of the yard. These policies included a site tour, which was a guided tour given by management to show employees where items were located in the yard. A site etiquette policy was created to address cleaning protocol and rules for keeping the yard clean. Also, a

companywide tool inventory program was developed to track and manage the company tool inventory. This was to eliminate wasted time spent searching for tools.

Finally the sustain phase developed policies to sustain the yard, including cleaning frequency, reducing waste from entering the yard, controlling what enters and leaves the yard, and a policy to allow for future red-tagging events. All together, these policies and tools were created to reduce time spent searching for items, and ensuring the program remained successful.

Recommendations

This study recommends using the methodologies discussed in these chapters to implement lean and 5S techniques. A proposed site map has been created, and, with implementation, will reduce waste time spent searching for materials, supplies, and equipment. With 5S implemented, there will be a reduction in waste inventory, inventory carrying costs, and a better understanding of the actual inventory kept on hand. This will aid in the cost estimating process, and the cleaner, more organized site will ensure a standardized system that is efficient and easier and safer for employees to use.

It is important that the results of this study be implemented within a reasonable time frame. Changes to the yard could alter the results of this study and make the proposals less effective. Going forward, with the new system in place, it is recommended that regular inventory audits for materials are completed on the site. This should be done to determine what materials are on hand for use in future projects. These materials should be tracked in a spreadsheet and be accessible by job cost estimators and management as well as field staff and foremen. Knowing what is onsite and in inventory will help eliminate repurchasing the same materials for new jobs.

It is also recommended that storage buildings or shelters be constructed over the tools and supplies. The construction of buildings will improve the longevity of the materials by moving them indoors as well as increase security by having materials, supplies, tools, and equipment in buildings that can be locked shut. Also, many of the materials present on the site are Ultra-Violet light sensitive, such as plastic pipe, and, by keeping those items sheltered, the materials will last longer in inventory. Further study will be required for the sizing, design, and costs involved with these buildings and areas, and the same 5S and lean methodology should be applied to the process.

As outlined in the sustain phase, the results of this study should be maintained. This is best done through annual red-tagging events and cross-functional team meetings to discuss what is working and what needs improvement. While the specific results and policies applied only to the storage yard itself, the methodologies and tools provided could be applied universally, such as in other areas of the company, jobsites, or project areas. Implementing these policies and recommendations will create a cleaner, safer, and more organized work space, and ultimately, a more efficient company.

References

- Alarcón, L. (1997). *Lean construction*. Brookfield, VT: A.A. Balkema Publishers.
- Bhasin, S. (2015). *Lean management beyond manufacturing*. Cham, Switzerland: Springer International Publishing.
- Fabrizio, T., & Tapping, D. (2006). *5S for the office: Organizing the workplace to eliminate waste*. New York, NY: Productivity Press.
- Federal Highway Administration. (2017). *Manual on uniform traffic control devices*. Retrieved from <https://mutcd.fhwa.dot.gov/>
- Feld, W. (2001). *Lean manufacturing: Tools, techniques, and how to use them*. Boca Raton, FL: St. Lucie Press; Alexandria, VA: APICS.
- Graves, A. (2012). *5S: Sort, set, shine, standardize, sustain*. Retrieved from <http://www.sixsigmadaily.com/5s-sort-set-shine-standardize-sustain/>
- Hirano, H. (1995). *5 pillars of the visual workplace: The sourcebook for 5S implementation*. Portland, OR: Productivity Press.
- Lewis, J. (2011). Extreme 5S: Workplace organization on steroids. *CabinetMaker FDM*, 25(3), 20. Retrieved from <http://ezproxy.lib.uwstout.edu/login?url=http://search.proquest.com/docview/1324473028?accountid=9255>
- Mezentseva, O. (2013). *Implementation of the 5S Concept in Company XYZ* (Master's thesis). Retrieved from <http://www2.uwstout.edu/content/lib/thesis/2013/2013mezentsevao.pdf>
- Millstein, M. A., Yang, L., & Li, H. (2014). Optimizing ABC inventory grouping decisions. *International Journal of Production Economics*, 148, 71-80.
- Nyaude, A. (2013). *The 5S code for workplace organization: Implementing a sustainable 5S program* (1st ed.). (n.p.): Alaster Nyaude.

- Orr, L., & Orr, D. (2014). *Eliminating waste in business*. Berkeley, CA: Apress.
- Santos, J., Wysk, R. A., & Torres, J. M. (2006). *Improving production with lean thinking*. Retrieved from <https://ebookcentral.proquest.com/lib/uws-ebooks/detail.action?docID=700084#>
- Sarkar, D. (2006). *5S for service organizations and offices: A lean look at improvements*. Milwaukee, WI: ASQ Quality Press.
- Schreibfeder, J. (2005). Ranking your way to effective inventory management. *Construction Distribution*, 8(2), 52-53.
- Standard, C., & Davis, D. (1999). *Running today's factory: A proven strategy for lean manufacturing*. Dearborn, MI: Society of Manufacturing Engineers
- Thomopoulos, N., & SpringerLink. (2015). *Elements of manufacturing, distribution and logistics quantitative methods for planning and control* (1st ed.). Cham, Switzerland: Springer International Publishing.