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THINKING LEAN– TOOLS FOR DECREASING COSTS AND INCREASING PROFITS

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THINKING LEAN– TOOLS FOR DECREASING COSTS AND INCREASING PROFITS

2008

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CONTENTS

1 EXECUTIVE SUMMARY

This project updates research that was conducted in 2005. It examines the lessons learned in other industries (non-construction) in applying the concepts of Lean thinking and how those concepts are being applied in construction. The need for the update is driven by the increasing complexity of the construction industry. Increasing technology, financial pressure, and customers seeking greater involvement and value from their projects are the main contributors to this complexity. The objective of the research was to identify the Lean principles and techniques used successfully in other industries, which could be and were most easily implemented in construction. To accomplish this, the project concentrated on:

- Identifying the Lean principles used successfully in manufacturing and service industries;
- Defining how "Lean" applies in the heating, ventilation, and air conditioning (HVAC) and sheet metal construction industry;
- Determining which Lean techniques were most applicable and useful in the construction industry; and
- Identifying how HVAC and sheet metal construction companies were already successfully applying these Lean principles.

Since Lean thinking is relatively new to the HVAC and sheet metal industry, this research also reviewed basic Lean principles as developed to lay the foundation for applying the Lean tools and techniques.

What does Lean look like?

- Fast, uninterrupted flow of construction;
- Elimination of waste in the shop, yard, and construction sites;
- Flexible planning process effectively responding to changes;
- Design process supporting the "pull" of construction. Pull refers to a construction technique where work is not performed until needed;
- Low inventories and no stashes of materials on site;
- Frequent replenishment of materials;
- Safe work environments;
- Empowered and engaged workers;
- Organized yards, shops, and offices; and
- Rapid response to problems.

Key findings of the research are:

1. Lean works in manufacturing. There are numerous examples of how Lean has been and is successfully applied in various types of manufacturing companies and industries.
2. Lean works in construction, both in field installation and in shop fabrication. It has also proven useful in the office and other support functions and in service work. While Lean is relatively new to the construction industry, there are enough successful applications to demonstrate its value.
3. Customers will demand Lean of contractors. Large customers are

increasingly aware of the value of using Lean in construction and are beginning to demand Lean applications of their contractors.

This research concludes that the Lean principles that have led other industries to higher profitability and lower costs are easily applicable to the HVAC and sheet metal industry. Some HVAC and sheet metal contractors have already successfully applied Lean, and most contractors are interested in learning about Lean. Those contractors that learn how to use Lean effectively will have a definite competitive advantage in their productivity and in meeting customer needs and expectations.

2 INTRODUCTION

A recent study compared manufacturing to construction in terms of productive and non-productive time. Figure 1 shows that the productive time or value-added work time for manufacturing is six times that of construction.[1] The gap has not always been this wide, but it has been growing as manufacturing has focused on reducing waste, while the construction percentages have remained relatively constant.

Productivity in manufacturing has made significant gains in the past 10 years. While many factors have contributed to this productivity improvement, Lean

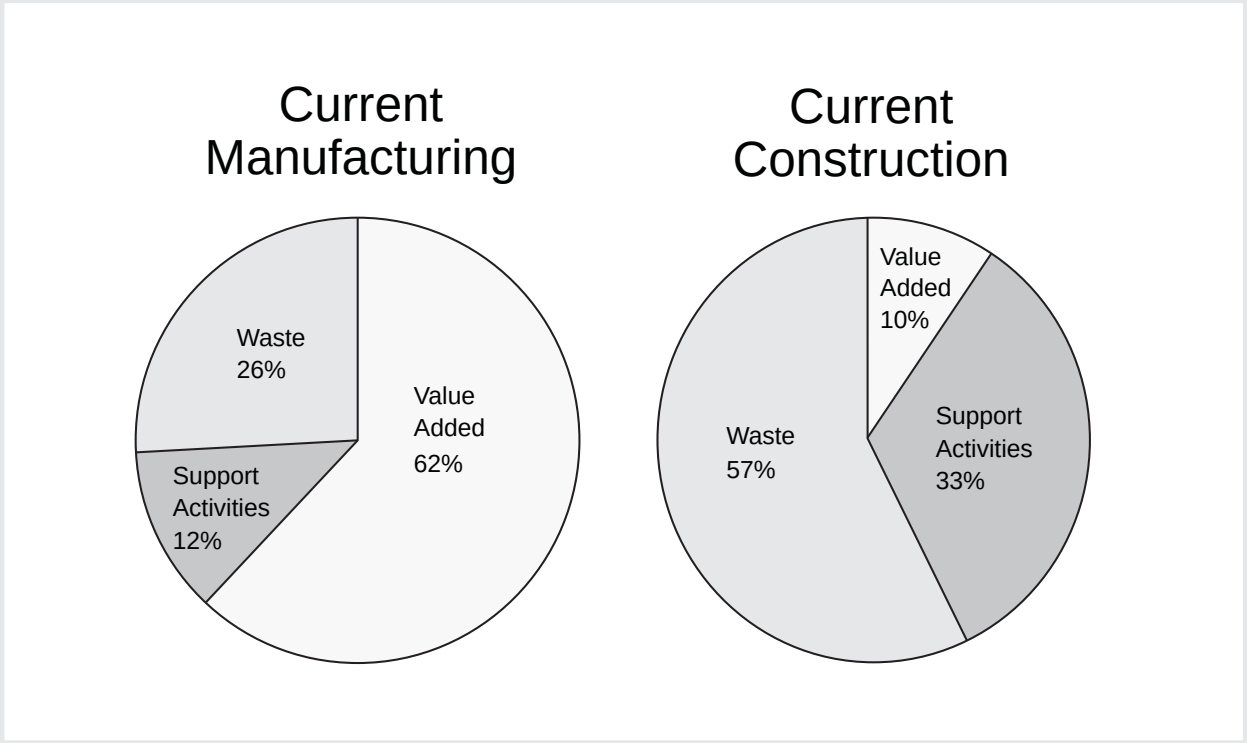

Figure 1: Waste Comparison for Manufacturing and Construction

manufacturing has played a significant role in these gains. The Lean principles were mostly developed and refined by Toyota and are sometimes called Kaizen or the Toyota Production System. Most leaders give Toyota's Taiichi Ohno credit for developing the Lean approach though he never called it "Lean." The term "Lean" was first used by James Womack and Daniel Jones to describe Toyota's methods.[2] Ohno claims to have based much of his initial effort on the works and ideas of Henry Ford, making the ideas as much American as Japanese.[3] The Lean approach grew out of many years of trial and testing to continuously improve methods and results. These ideas and techniques are still being refined and advanced.

Regardless of its origin, American and international manufacturers have embraced Lean and achieved remarkable results. Companies have seen improvements in the following areas:

- Manufacturing lead time has decreased to less than 1 day;
- Delivered quality has reached 3 parts per million (PPM) (3 PPM means three defective parts in a million parts);
- Delivery performance has risen to 99+%;
- Inventory turns have realized an unthinkable rate of more than 50 turns per year;
- Product conversion costs (the cost of production starting with the materials and all work to finished goods) are 25 to 40% less than for non-Lean mass producers;
- Manufacturing space has been reduced 35 to 50% relative to non-Lean mass producers; and
- New product development time has been reduced to less than 6 months.[4]

Appendix A provides examples of manufacturing companies that have been recognized for successfully implementing Lean.

Peter Drucker, the father of modern-day management thinking, said this about Lean:

> "What has changed manufacturing, and sharply pushed up productivity, are new concepts. Information and automation are less important than new theories of manufacturing, which are an advance comparable to the arrival of mass production 80 years ago. Indeed, some of these theories, such as Toyota's "Lean Manufacturing," do away with robots, computers, and automation."[5]

The manufacturing industry has realized great benefits from Lean. While the HVAC and sheet metal industry has some manufacturing components, construction is not like manufacturing in mass producing products. Can the same Lean techniques work in a construction environment? The answer is yes! While Lean thinking is still relatively in its infancy with regards to its application to construction, there are sufficient examples of contractors who have successfully applied Lean concepts and techniques to validate Lean's applicability to the HVAC and sheet metal industry. Examples will be shared throughout this report.

3 WHAT IS LEAN?

Toyota's long-term goal is to "*Give customers what they want, deliver it instantly, with no waste.*" The essence of Lean is covered in Toyota's

goal. Lean is first about giving the customer value and always working to add value. Lean is building only what the customer needs and delivering the product or service (almost) instantly. Finally, Lean is about eliminating waste. In fact, "waste" is defined as the opposite of value, as anything that does not add value to the customer.

Value is what the customer actually wants to purchase. The economist defines value as the ratio of usefulness (to the customer) over cost. Value includes the product's functions and features and relates to the whole product or service. Cost includes the price paid and the cost of time and hassle in obtaining and using the product or service. In today's fast-paced world, customers often place greater value on experiencing less hassle and faster schedules than on price.

A Lean company views its processes from the customer's perspective and is dedicated to reducing or eliminating the waste and non-value-added activities. The seven basic types of waste, in no particular order or priority, are as follows:

1. Waste of DEFECTS – product that does not function as designed or intended, thus is defective. This waste includes rework of any type, wrong installation, defects in welds, punch lists, and change orders caused by incorrect design or installation. Misunderstanding the customer's requirements or expectations can cause waste. This waste also includes code-compliance issues. Defective waste often stems from not having and using standard processes.

2. Waste of TRANSPORTATION OF GOODS – inefficient movement of materials or goods. Though necessary, any movement of a product does not usually add value. Unless one fabricates while transporting the product, nothing is changed that adds value. Sometimes, during transportation, damage causes more waste. For construction, this waste occurs by moving material around the shop (by hand or on carts), loading it on the truck or trailer, hauling it to the work site, unloading the material from the truck, or moving the material around the job site from the staging area to the point of installation. This waste happens in the office and in other support functions as material requisitions, timesheets, and invoices are moved from desk to desk. This waste is caused by poor site, yard, shop, or office layout; by the lack of an organized system for materials placement or staging; by poor logistics planning; or by receiving material too early to use or install.

3. Waste of OVERPRODUCTION OF GOODS – fabrication or ordering more product than is needed at that time. Examples include fabricating material ahead of schedule to keep the shop busy and stockpiling material either in a warehouse or at the job site. It can include printing more blueprints or financial reports than needed. Estimating jobs that are not won is also an example of waste of overproduction.

4. Waste of employees or equipment WAITING on processes or other equipment to finish work or for an upstream activity to be completed (Figures 2 and 3). Examples are when crews are waiting for inspections, field instructions, or material; when a worker is waiting for the coil line to fabricate material; or

when payroll is waiting for late timesheets. Waiting in the field can occur due to incomplete material deliveries, unanswered requests for information (RFIs), or a failure of another trade to be reliable in fulfilling a commitment. This waiting is often caused by poor communication between the field and support functions or suppliers, when people are unsure of what is required, or because of poor coordination between trades.

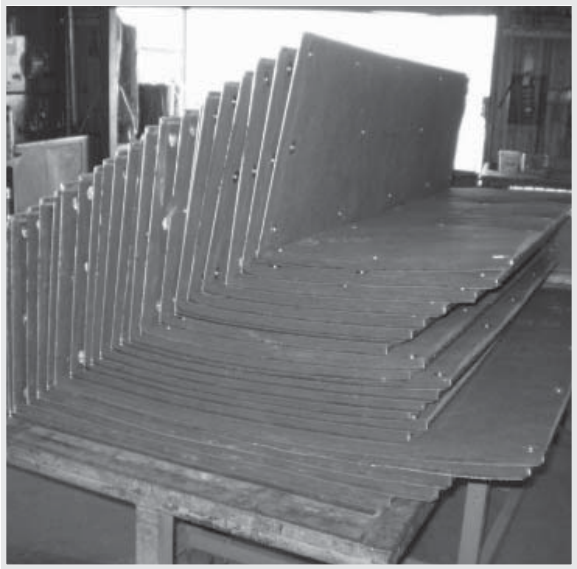

Figure 2: Sheet Metal Waiting to Be Processed

Figure 3: Finished Duct Waiting to Be Shipped

5. Waste in OVERPROCESSING – unnecessary or extra steps in a process or steps that do not create value from the customer's viewpoint. Overprocessing includes writing too many material requests for the same job, overengineering, purchase orders requiring several signatures, duplicate entries on forms or in data entry fields, inspections, getting double and triple estimates from suppliers, and providing more polish or "a professional look" than is needed. Overprocessing is caused by a lack of standard methods, poor communication, or poor planning. This waste often occurs when a process changes slowly over time and no regular examination is conducted to assess whether the process meets current requirements.

6. Waste of MOTION – people moving their hands, feet, or body without adding value to the product or service. Examples

include workers in the shop looking for tools, material, or information or reaching for tools away from the worktable; or office workers searching for contracts, files, or vendor catalogs. Waste of motion is caused by poor planning and organization or by a lack of standardized methods.

7. Waste of INVENTORY – materials or parts not being used by the customer. This includes raw material, work in process, and final fabrications. Regardless of whether the material is called "inventory" or is job costed, if the material is not yet installed, it is in reality inventory, and thus is waste. This type of waste includes parts; excess space; and unused tools, copies, and reports. Stashes and personal stockpiles are also waste. While inventory may be needed to ensure that the work is performed in a timely manner, Lean organizations consider any type of inventory to be waste. Inventory is an especially costly and usually overlooked waste because inventory seems to be useful. After all, it is good product! However, inventory ties up working capital and space, requires controls to ensure security, must be continually monitored, and leads to additional handling.

   Companies have traditionally accumulated inventory because of unreliable support from the shop, suppliers, or delivery function or because of efforts to save money through bulk buying. Usually the money saved in bulk buys is wasted away by the hidden, but real, costs of holding inventory. Inventory sometimes results from free shop time used to fabricate ahead of schedule or as a just-in-case contingency. Inventory can be a particularly serious waste because it may produce, or hide, other wastes.

Two other types of waste have been identified beyond the seven basic types, including

1. The waste of NOT BEING USED OR NOT MEETING THE CUSTOMER'S NEEDS. This includes designs, installations, and reports that may be perfectly sound and functioning but do not meet the need defined by the customer. For example, a system that does not provide a facility with the proper heating or cooling is waste.

2. Waste of NOT USING TALENT AND KNOWLEDGE OF HUMAN RESOURCES. Not asking for, involving, following up, or implementing the ideas and suggestions of employees is waste. The front-line workers are closest to the action and see more problems than management may ever identify. Waste results when workers' ideas are ignored. Waste happens when field or shop supervision is not involved in reviewing design drawings for constructability. Waste also occurs when lessons learned and best practices are not shared or replicated from one project or work team to another or across the company.

The biggest opportunities for reducing waste typically are found in labor, material and equipment, and tools – areas in which Lean concentrates on improving. Lean or Lean thinking focuses on delivering value (as seen by the customer) and eliminating waste. Lean is not Total Quality Management (TQM) but is one approach to continuous improvement, which is an element of TQM. Lean is not *Six Sigma*. (Six Sigma is a statistical term meaning 3.4 defects per million opportunities. It is a system of applying defined problem-solving techniques to improve performance. The

method includes measuring performance before and after the problem-solving analysis.) Lean focuses on reducing or eliminating waste in the process, while Six Sigma focuses on measurable problem solving and reducing variability of performance. Some companies are now practicing what is called Lean – Six Sigma. In this approach, Six Sigma methods are used to solve problems that surfaced in Lean activities. Lean construction is the term used to reference the application of Lean thinking to construction.

4 THE LEAN APPROACH

James Womack defines the approach to Lean thinking as:

- Understanding Value vs. Waste,
- Value Stream Mapping (VSM) (sometimes referred to as Value Stream Analysis),
- Making the Process Flow,
- Pull, and
- Continuous Improvement toward Perfection.[2]

4.1 Understanding Value vs. Waste

To fully understand Lean requires an understanding of value and waste as defined previously. Value is what the customer sees as worth or useful to him. Value-added steps or activities are those that create the value the customer wants. One way to judge if a step adds value is to ask, "If it were not done, would it affect the product or service as used by the customer?" If leaving that step out would cause the customer to see less value in the product or service, then the step is value-added. All non-value-added steps or activities are waste. These steps may be necessary, given the current way the work is done, but being necessary to complete a process does not make the step value-added. Rework is necessary to get a system functioning, but it is not value-added.

Value can go beyond the basic steps in the current processes. Womack describes how a homebuilder in Texas (Doyle Wilson) redefined his business based on learning more about how the customer sees value. Doyle had been building homes successfully since the mid 1970s. In the early 1990s, Doyle started a TQM initiative that allowed him to increase customer satisfaction and sales. He did this in a flat market by outperforming his competition. He even won the National Housing Quality Award in 1995. But in looking at his customers and markets, Doyle realized that new-home building was only 22% of the total home-buying market. Even if he were to capture all the new-home market, he was still not touching the used-home-buying market, which was 78%! Doyle listened to what the home-buyers of older homes thought was value. They bought used homes because they wanted a no-hassle factor in negotiating a contract, a short lead time to get into the house, and did not want the inevitable punch list after moving in. Doyle decided to create a hassle-free home-buying experience to draw these home-buyers into the new-home market. This led him to make major changes in his processes and operations. He had to shrink the industry average time to build a house from 6 months to 30 days.[2] Focusing on value as seen by the customer can change how services are delivered in any industry.

A better understanding of the concept of value requires an understanding of the nature of quality. In its most simple definition, quality is meeting the customer's needs. These needs must be valid, and valid is verified by the customer's willingness to pay for the product or service. Customers' needs include expected but unstated needs such as the product working as designed as well as working per the specifications. Value comes by giving the customer the right amount of what he needs, when he needs it, and where he needs it.

4.2 Value Stream Mapping (VSM)

The value stream includes all the processes and activities used to design, produce, and deliver the product or service to the customer.[2] A process is a series of operations or steps that creates a deliverable. All work is a process. In analyzing the value stream shown in Figure 4, all steps fit into one of three possible categories, including those that:

1. Add value,
2. Do not add value but are necessary, or
3. Do not add value and are not necessary.

Typically, about 3% of process steps add value; the rest fall into the two non-value-added categories.

Many productivity improvement efforts focus on improving the value-added operations or on all the steps to try to improve efficiency. Problems or ambiguities that occur in the handoffs between operations within a process are common causes of increased waste and costs. Figure 5 shows how Lean looks at the non-value-added operations and at the handoffs (space) between the steps.

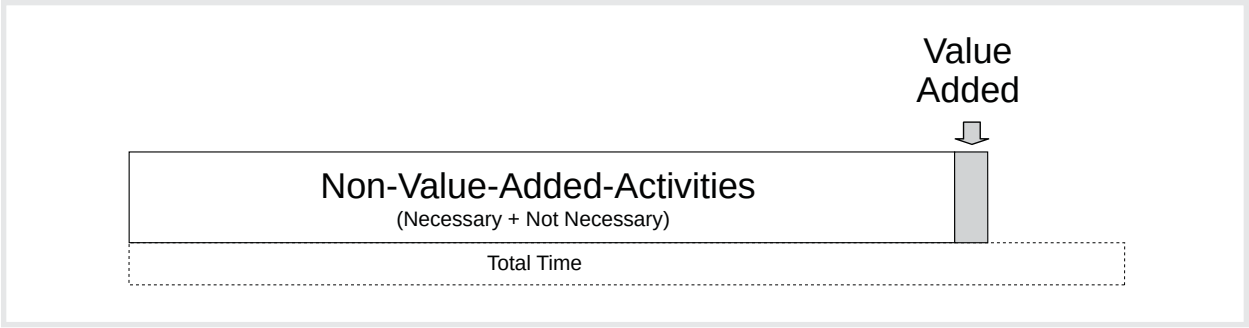

Figure 4: Value Stream Mapping

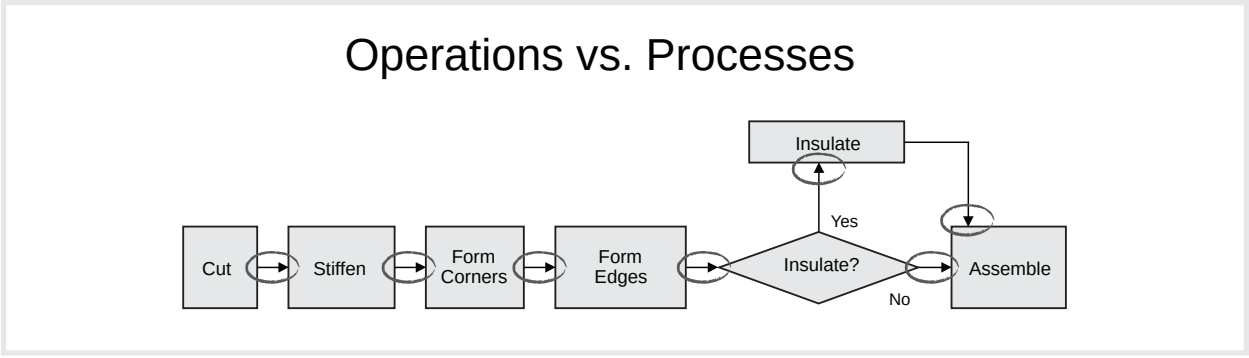

Figure 5: Lean Focuses on the Handoffs

To be Lean, a company optimizes the entire work system. Suboptimization leads to waste. VSM looks at the whole system to avoid suboptimization. An example of suboptimization in construction is where a shop fabricates duct in advance to level its workload and not to meet the time requirements of the field. The fabricated duct may then be delivered to the field early, requiring the field workers to stop installation to unload, store, and control. Alternatively, the duct is stored in trailers or in a warehouse until needed. While the shop optimizes its workload, the net results to the company can be increased cost, reduced cash flow, and the risk of rework due to damage or field changes. VSM begins with mapping the workflow from start to finish.

4.3 Making the Process Flow

When a piece of metal flows through the typical fabrication, the piece starts, stops, waits, and starts again as it moves through the process. The same can be said for a materials request for a purchase order or for a check request. Most of the work we do and experience is accomplished in a batch and queue (wait and go) method. Waste occurs when work is done in a batch mode, as there is much lost time when material is waiting. In Lean, the objective is to make value flow. The ideal batch size is one piece.

While it seems efficient to do all parts or pieces at the same operation and then move the batch to the next operation, Lean has shown that single-piece flow is more efficient. A simple exercise demonstrating the problems of a batch approach can be demonstrated in asking several people to date and sign the same document. If it takes each person 30 seconds to locate the signature line and then sign and date the document, it would take 5 minutes per person to do a batch of 10 documents. Five people would take 25 minutes before the batch is processed through all required signatures, assuming no wait time between each person. If each person signed the document then immediately passed it on to the next person to sign, it would take 7 minutes to process all 10 documents in a single batch flow process.[6] The other 18 minutes is the wasted time the various documents are waiting to be signed at the various workstations. Similar delays and waits happen at every step in sheet metal fabrication and construction when accomplished in a batch mode.

Similar to snow skiing, where weight is placed in a position that at first feels opposite of how we balance ourselves, flow is counterintuitive. A good indication of the lack of flow is wherever the product or inventory is piled up between operations or at sites. Working to improve flow led Toyota to develop the just-in-time (JIT) approach employed by many progressive manufacturers today. JIT is also employed by some contractors in delivering material to the job site.

4.4 Pull

In Lean, a product is not worked on until it is pulled from the previous step upstream in the process. This is the opposite of a "push" approach where each operation upstream makes the product based on a schedule and pushes it on to the next step regardless if it is ready to accept the product. Lean companies do not want to make anything until it is needed, and then they make it very quickly. A "pull" system in construction is where the

product is not fabricated until it is ordered from the field. Material is not delivered from a supplier until it is needed.

Why pull? The concept of pull gives the company the ability to respond almost instantly to customer orders and frees up cash by reducing in-process and finished-goods inventory. By not fabricating until the product is needed, the waste of overproduction is avoided, and the risk is reduced of making something that is later changed. In many fast-moving design/build projects involving many trades, there is a high risk when something is fabricated too early. Changes happen in construction and, regardless of who caused the changes, waste is created. If another trade beats the contractor to the intended route or the customer made a design change, waste still occurs when the product is fabricated too soon. Even when the contractor is paid for the change, the fact remains that there is a wasted product.

To pull, the process must first flow; batches must be small; and quality needs to be high. Pull requires accurate and ongoing communication between those ordering the product (field) and those in fabrication.

Pull is easier to understand in a shop environment because it is similar to manufacturing. But pull also applies to the field. Waste occurs when a rental crane is on site days before it is needed or when an air balance technician is called in before duct installation is finished. In some ways, pull seems to be common sense, but is not always a common practice in construction.

4.5 Continuous Improvement toward Perfection

The goal of Lean is perfection and the total elimination of every kind of waste. The paradox is that perfection can never be achieved but must be pursued nevertheless. Lean offers another way to work toward perfection. An example occurs in the way most contractors bid work. Typically, contractors bid work based on estimates of direct costs. Cost takeoffs are developed from the plans and by the particulars of the job. This becomes the bid's base cost. The profit margin is added, resulting in the bid price.

Lean contractors start with the targeted market price needed to get the job. From that market price, the profit margin is subtracted, resulting in the targeted direct job (base) cost. The targeted job base cost is lower, even much lower, than the bid's base cost. While it may be nearly impossible to really know the market price needed to win the job, most experienced estimators know the ballpark price for the job. If one does not get the job, the whole process of bidding is wasted effort! The quest for perfection becomes more than just talk when contractors use the targeted base cost to drive down the cost of operation. Most contractors would be thrilled to get a 10 to 15% reduction in their direct cost of operation. Using Lean, manufacturing companies have experienced cost reductions in the 30 to 40% range, suggesting that construction can also achieve significant reductions. This translates into greater profit. The drive to perfection is to keep reducing the waste in the value stream.

5 LEAN CONCEPTS – THE CONTEXT

All organizations, including contractors, consist of the "3P's" – *People* who work on *Processes* to achieve the organization's *Purpose* – as shown in Figure 6.

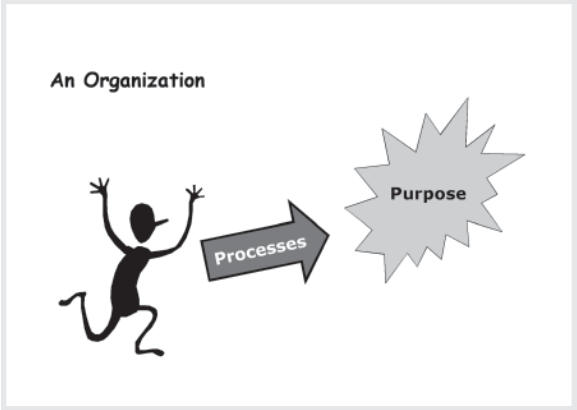

Figure 6: The "3P's" – People, Processes, and Purpose

Lean concepts that form the context or fiber of all improvement efforts are tied to these 3P's. These include having engaged employees, standard processes, and leadership by top management.

5.1 Engaged Employees

People make work (and profits) happen. No Lean effort has been successful over the long term without the support of the company's front-line employees. Engaged employees support Lean because Lean operates at the front lines of the workplace, not in the executive offices.

To develop engaged employees requires involvement plus communication. Employees see more problems and experience more workplace barriers than management.

Companies involve employees by asking for their ideas and suggestions for improvement. In traditional American companies, the number of suggestions per employee per year averages 1:5 – one idea for every five employees. Lean companies in Japan and in the United States (US) average more than 15 suggestions per employee per year. The difference in Lean applications and the traditional suggestion box system is that, in Lean companies, the supervisors work with the employees to share and implement their ideas. Traditional suggestion systems often bypass front-line supervision and go to some designated suggestion coordinator. This bypass approach reinforces distrust and fear, encourages bureaucracy, and slows the implementation process. Lean techniques do not require PhDs, complex information technology systems, or sophisticated mathematical models. However, Lean's success depends on people being involved in continuous improvement. Lean failures have happened when management tried to do Lean **to** employees rather than **with** them.

Lean companies recognize the key role workers play and spend time communicating more with the workforce than may be customary in other organizations. What is communicated? Employees need to understand the why and how of Lean applications; where the company stands on safety, productivity, absenteeism, and performance; and the company's vision and priorities. Failure to communicate results in mistakes, misunderstandings, and a workforce that does not feel valued or trusted.

One of the hallmark characteristics of Toyota is that the employees are constantly encouraged and recognized by supervisors to identify new ways of getting work

accomplished. Every suggestion is viewed as an experiment, a test. Tests sometimes fail, and making mistakes is acceptable and valued as part of efforts to improve processes. However, employees are expected to avoid making the same mistake twice. Lean companies do not punish employees for making mistakes but use errors as learning opportunities. *If the student has not learned, the teacher has not taught.*

The role of Lean in safety is critical. While Lean techniques can be applied to safety processes just like any other process, Lean does not focus specifically on safety. Lean processes incorporate safety. Companies with safety as a value will find that Lean is in harmony with and supports good safety practices. Waste is a violation of sound safety requirements. Material cannot flow when work is shut down to deal with an accident. Lean encourages employees to find new and improved ways to be safe as well as productive. Lean has also proven to be very useful for improving safety. A study in Denmark found that the safety incident metric on construction sites using Lean was 68% lower than those not using Lean. The safety incident rate was measured by the number of accidents per 200,000 man-hours worked.[7]

5.2 Standard Processes and Operations

To continuously improve, each process or operation must first be defined. To have consistency in any process, there first must be a standard way of performing each step. The standard way should be the best method known. Good management and Lean require that processes be standardized first and then improved. Managers and supervisors should always ask these key questions:

- Have we defined the process?
- Is it standardized?
- Do we follow the standard?
- How can we improve the process?[8]

5.3 Top Management Leadership

Nearly every new initiative ever started in any company required top management support to get underway and then to maintain the gains. Lean also requires top management leadership. Management needs to set the vision for Lean implementation. Employees at all levels want to know where the company is going and why. Creating the vision is not sufficient; management must communicate the vision with passion to every member of the workforce and instill enthusiasm for achieving the vision. One contractor created a stump speech discussing the company's vision and why the organization had to become Lean. This compelling story drove the change actions throughout the company.

If leaders aren't interested in being Lean, the workforce will soon recognize that commitment is lacking. A shop superintendent was dragging his feet in implementing Lean, but his manager kept encouraging him. She let him know by word and action that they were going to implement the 5S's (Section 6.1). After a few months of seeing how Lean improved the operations, the shop superintendent saw the light and has now become one of the real champions for Lean in the company.

In any company, the pathway to success includes a focus on the right priorities for how work is accomplished. The role of leadership includes setting the right

priorities for operations. The priorities for manufacturing are making product as ordered, reducing inventory, and reducing costs.[9] Many companies get these priorities backwards and are always downsizing or cutting costs at the expense of keeping product flowing out the door. Construction contractors do not make money until the product is installed. In manufacturing, the most expensive equipment is usually what everyone tries to keep operating. In construction, the most expensive "equipment" is the field crew, and efforts are focused on keeping the crew productively installing. Thus, the logistical priorities for success and profitability in construction are:

1. Keep the crews busy installing product,
2. Reduce inventory, and
3. Reduce costs.

These priorities form the basis for tradeoffs in Lean applications. For example, inventory is waste and to be eliminated as much as possible, but it is better to keep some inventory on hand if that ensures that the crews keep installing. The trick is to know how much to keep and no more.

5.4 Continuous Learning

One other principle woven into the context of Lean is that of being a learning organization. The old saying that those "who can't learn from the past are doomed to repeat it" is very true for construction and for companies trying to be Lean.

Dr. W. Edwards Deming, recognized quality improvement expert, taught the *Plan, Do, Check, Act* (PDCA) cycle of continuous improvement: *Plan* the improvement. Test or *Do* it. *Check* to see if the plan was followed and if it worked as an improvement. Then *Act* to make the new method the standard way to do that work if it proved to be a better way.[10] Measures are used as a tool to determine whether improvement occurred. Wherever improvement is made, the Lean organization communicates the better methods to all areas of the company.

5.5 The Toyota Way

Toyota developed a business philosophy to guide its way of doing business. This is called the Toyota Way, and Jeffery Liker, who has studied Toyota extensively, summarizes these principles:

1. Base your management on a long-term philosophy, even at the expense of short-term financial goals.
2. Create continuous process flow to bring problems to the surface.
3. Use "pull" systems to avoid overproduction.
4. Level out the workload (work like the tortoise, not the hare).
5. Build a culture of stopping to fix problems, to get quality right the first time.
6. Standardized tasks are the foundation for continuous improvement and employee empowerment.
7. Use visual control, so no problems are hidden.
8. Use only reliable, thoroughly tested technology that serves your people and process.

9. Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.

10. Develop exceptional people and teams who follow your company's philosophy.

11. Respect your extended network of partners and suppliers by challenging them and helping them improve.

12. Go see for yourself to thoroughly understand the situation.

13. Make decisions slowly by consensus, thoroughly considering all options; implement rapidly.

14. Become a learning organization through relentless reflection and continuous improvement.[11]

6 LEAN TOOLS AND TECHNIQUES

6.1 5S's

The 5S's are fundamental to reducing waste in every shop, field, and office operation and to help improve productivity and actively engage employees in continuous improvement. The 5S's came from Toyota and are actually "S" words in Japanese. When these words were brought to America, they were given English terms. While the words are at times translated slightly differently, the meanings remain the same. Union craftsmen find the Lean technique of 5S's especially appealing because it reflects their pride of workmanship. The 5S's with the Japanese word given in parentheses are discussed below.

1. *Sorting (Seiri)* – To go through a designated work area and to sort out the necessary from the unnecessary, as shown in Figure 7. Necessary is defined by frequency of use. For example, if an item is not used at

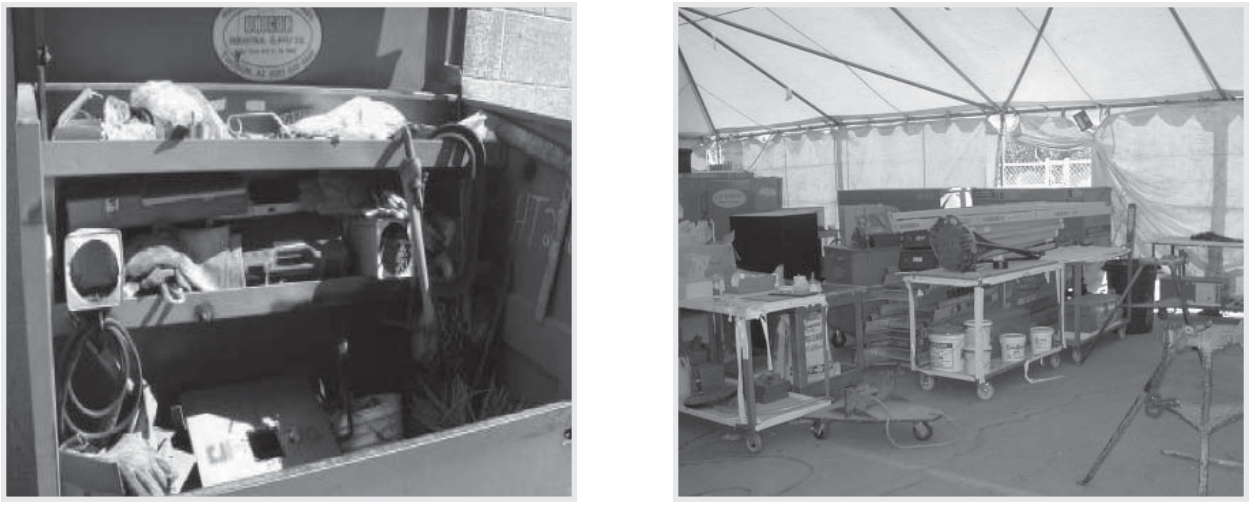

Figure 7: Areas Ripe for Sorting the Necessary from the Unnecessary

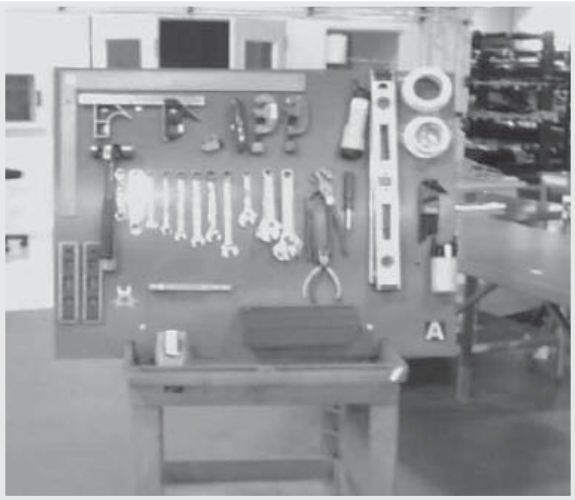

Figure 8: Examples of Simplifying

least annually, it is probably not necessary to the work. An item not used at least monthly probably does not need to be kept near the work operations. Items that are necessary are kept and all others are disposed, recycled, or returned.

2. *Simplifying (Seiton)* – To put everything (that we determined necessary in Sorting) in a designated place (as shown in Figure 8 above) and to mark items visually. Not only is a place established for every necessary item, but also the actual location is based on how often it is used. The items used most often are located closest to the person doing the work.

3. *Sweeping (Seiso)* – To physically clean the work area and to deliberately pick up all parts and materials that are out of place and return each to its assigned place as defined in Simplifying.

4. *Standardizing (Seiketsu)* – To create standard ways to keep the work areas organized, clean, and orderly and to document agreements made during the 5S's process. Employees must understand the value of using and maintaining standard methods if this S is to be successful. Furthermore, the first three S's must be repeated frequently to achieve continuous improvement.

5. *Self-Discipline (Shitsuke)* – To follow through with the 5S's agreements. Changes made using the 5S's must be maintained to reap full value.

Because the 5S's came out of a manufacturing shop environment, the practices are a natural fit for fabrication shops. One sheet metal shop was able to return over $5,000 in material that was no longer needed. A shop's management thought more space was needed to expand; instead, after implementing the 5S's, additional space was gained and costly expansion avoided. Shops have found that performing the 5S's led them to rearrange their shop material flow and move equipment closer together, reducing transportation waste. Tools have been color coded and assigned to pieces of equipment. Work areas are cleaner

and inventory is better organized. One shop rearranged its deliveries from a supplier so that all three semi-trucks did not arrive the first thing each Monday morning, relieving workers of a major unloading effort at the shop's busiest startup time. Employees no longer had to find a place to put the newly received inventory until it could be moved in with the current inventory. The three trucks represented a weeks' worth of work. Now, the company keeps smaller inventory (two days' worth) and has the supplier deliver more often in smaller lots, saving space and time. Other successful ideas that companies have implemented include:

- Consolidating tooling into one location. In the past, tools were located somewhat randomly around the shop;
- Sorting excess fittings by specification and placing spare valves into one segregated area;
- Sorting the bucket of hangers into the various sizes to avoid having to look through one bucket to get the correct size;
- Striping the walkways and labeling and color coding tools and parts;
- Devising standardized tool kits for each workstation.[12]

A duct fabrication foreman for Miller Bonded, Inc., a mechanical contractor, says the biggest value he has seen from the 5S's is organizing shop tools so employees do not waste time looking for them: "We pay our employees to be productive; the 5S's is an investment to help them do that."

Grunau Company, another mechanical contractor, used the 5S's on its main yard. The yard, like those of most construction companies, was littered with stacks of material returned from jobs and saved for "just-in-case" situations. The yard also was crowded with equipment and material being made ready to go out to the job. After applying the 5S's, a manager reports, "It was like night and day to see the difference."

The 5S's also work well in organizing offices. One mechanical contractor's purchasing department had problems finding partially issued purchase orders when a buyer was out for the day. They applied the 5S's and redesigned the buyers' work area so that each buyer had a designated tray for all unprocessed orders and another for those partially filled. This seems small, but time was saved for other buyers and for accounts payable staff when looking through stacks of orders.

Another office color coded reference binders using one-inch colored dots placed on the binder's backs. The dots were marked "1 of 5", "2 of 5", etc., enabling anyone passing by the shelf to see whether binders were missing or out of order.

In another HVAC contractor's office, the accounting department kept duplicate copies of all shop invoices. Over the past two years, about 18,000 invoices had accumulated. When the group decided this was no longer necessary, discarding the duplicates freed up file space and administrative time.

Because of the changing nature of field construction, applying the 5S's presents unique challenges – and unique solutions. One site set up a rack and put names on it for the air balance crews to hang their harnesses. Less time was spent untangling and resizing the harnesses each morning. With 22 employees

working the air balancing, this approach saved about 15 to 20 minutes each morning for each employee on a three-week job. Organized gang boxes with the 5S's saved the crew's time looking for tools.

Yard lay-down areas are ripe for the 5S's. If the site has been around for any length of time, stashes of material are everywhere. One sustaining work site's crew found the same excess material stored in several different trailers, in boxes, behind the trailers, and on top of shelves. Each foreman had his own stash. Foremen had come and gone, yet piles remained. The team consolidated the material and reduced much of what was being stored. There was much excess material to return or junk. Some very expensive parts were unusable because they had sat out on a pallet for several years.

The 5S's apply to service processes as well. In addition to the parts storage area and office, the 5S's can be easily applied to vans or trucks used by service technicians. Even when the fleet consists of different types of vehicles, having a common area designated and clearly marked for various parts makes it easier for technicians to find what they need. This is even more critical when the technician has to use a different vehicle. When Miller Bonded, Inc., started the 5S's in service, they found that sorting through the vehicles resulted in getting rid of much material that was either used or not needed, a step the technicians welcomed.

A key point to remember about the 5S's is that this tool is not about just being organized and neat. The 5S's are applied to allow the work to flow better and faster. A neat shop would have all tools put away, out of sight. This would not necessarily make the shop's work flow better and could actually increase waste by requiring the shop workers to move more often and further to obtain needed tools. Another example of just being neat and logical would be to arrange consumable items in bins by their size or part number. The 5S's would arrange the parts by frequency of use. The 5S's are about everything having a place and being in its place when not in use; and that place is determined by how frequently the item is used and how it is used.

In 1999, the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) published *Sheet Metal Made Lean and Clean*. This guide serves as a good reference for contractors wanting to implement the 5S's.[13]

6.2 Last Planner System®

The Last Planner System® (LPS) is a Lean tool developed by the Lean Construction Institute and is a unique Lean application for project management. The Last Planner is the field supervisor who assigns work to the crews. The basic elements of the LPS are a pull-phased schedule developed collaboratively; a make-ready look-ahead plan; weekly work plans; and a method for measuring, recording, and improving planning reliability.

The LPS approach routinely gets better results than traditional project management – 30% better as a median.[14] LPS does this by

- Reducing variability so the work flows from the completion of one task to another;
- Doing ongoing planning that moves to increasing levels of detail. The Last Planner (supervisor/foreman) makes a weekly work plan and evaluates progress made the previous week;

- Making work ready so when the crews start a task, they can finish it without interruption, rework, or remobilization. A look-ahead plan is updated weekly to ensure the work is ready to be performed;
- Creating a stable platform for coordination where people make commitments to each other in support of the schedule. In the weekly coordinating meeting, a review is made of each foreman's weekly work and look-ahead plans. They also review the constraints that keep the work from being performance as planned. These may include manpower, coordination with other trades, weather, missing information, etc. Finally, they review the percent of planned work that was completed (PPC) in the past week. The Last Planner makes the commitment on the work that is planned for the week ahead based on what is actually ready to be completed;
- Controlling the project through monitoring the plan's completion rate (measured by PPC) rather than the progress compared to schedule (effort). Learning occurs by investigating plan failures;
- Analyzing the PPC rate and the constraints that keep work from being performed as planned, leading to problem analysis and preventive actions.

Many contractors are using the LPS to improve performance. An article in the *Silicon Valley/San Jose Business Journal* reads, "Sutter Health tells its builders: Make it Lean. Hospital giant taking the lead in dictating new construction approach for its $6 billion project."[15]

While learning how to implement the LPS is not complicated, explaining it is beyond the scope of this research. However, the following case studies demonstrate the value of LPS.

The Boldt Company is a construction services company that completes $500 to $600 million in projects annually. Boldt has been developing and implementing Lean project delivery principles and has used the LPS successfully on over 200 projects. Boldt has found that applying Lean principles and processes to the development, design, and construction of facilities contributes to:

- Shorter schedules, up to a 20% reduction on some projects that fully committed to the process;
- New benchmarks in lower project cost;
- Higher levels of quality and less rework;
- Higher levels of customer satisfaction and received value; and
- Improved profitability due to shortened schedules (reduced general conditions) and improved productivity. (Much of Boldt's work is negotiated guaranteed maximum price (GMP) so the savings go back to the customer in the form of growing contingencies.)

In 2001, the Lean Construction Institute published its research that found, on projects where PPC was greater than 50%, companies averaged a productivity factor of 85% (meaning the projects averaged 15% under budget). Jobs with PPC less than 50% averaged a 1.15 productivity factor (15% over budget). While the statistics did not explain why the cutoff was at 50%, the data

support the logic that, if more of the work is completed as planned, the crews will be more productive.

A large mechanical contractor worked with a large computer chip manufacturer to do a pilot study for tool install using the LPS system. Two tools were installed from November 1999 to March 2000. The customer found that durations were reduced on major tool installs by 29% with an even greater potential. This was of great interest to the customer!

The LPS is also being used in other parts of the world with success. A project in Peru was contracted to develop, design, finance, build, sell, and deliver 420 low-cost apartments. Rafael Simpson, in a presentation to the Lean Construction Institute, said

> "At first we thought the constraint would be market demand. But the demand was huge, shifting the constraint to production. We needed to produce four complete housing units per day to keep demand satisfied and not lose clients because we could not deliver quickly. The LPS allowed us to deliver them as fast as was required. We not only reduced by more than half the time to make the profit (increasing the system throughput), but also increased the expected profit itself by 61% because of good work structuring, productivity, and other factors. Not only is there an increase in the absolute value of profit, but also in how fast it is produced. Therefore, we are making more profit per year, a greater present value or increased rate of return. Finally, there is also an opportunity because having the cash earlier makes it possible to make other investments with more returns."[16]

The numbers for this project are:

	Original Business Plan	**Actual to Date (95% complete)**
Income	US $9.75M	US $10.4M
Costs	US $7.70M	US $7.1M
Profit	**US $2.05M**	**US $3.3M**
Time to complete	2 years	10 months

A $60M upgrade to a functioning facility at the SSM Cardinal Glennon Children's Medical Center is using the LPS. While the project is not completed at the writing of this research, they report the following successes to date:

- Designs are 100% signed off by the users of the documents. They attribute this to making and keeping commitments;
- After 24 months of working, only 63 RFIs. At the usual administrative costs of $600 per RFI, they are incurring far lower costs. For a usual project of this type, they would expect about 1,000 RFIs;
- The project's PPC is running at 74%;
- Safety – only three incidents in 152,000 hours, less than half of the industry average;
- They are on a schedule to finish the project 3 months early;
- At 50% complete, over 94% of the construction contingency is intact and rising, perhaps to over 100%; and
- This is a preferred job site: morale is high; quality is high; no facility interruptions; subs are making fair profits; and they're having fun![17]

6.3 Stopping the Production Line

In manufacturing, Lean companies design into the process the ability for front-line workers to stop the production line when problems are observed with product quality or the process's operation. This approach is based on the principle that it is always less expensive to catch quality problems as early in the process as possible. Pull requires quality production. When the line is stopped, the line foreman works with the worker to identify and resolve the problem. The supervisor may involve other resources to develop a preventive cure for the problem. Line stoppages are not feared in a Lean operation but are seen as opportunities to improve the process and prevent quality problems downstream.

In construction fieldwork, the concept can be applied through the Last Planner System®. The "Last Planner," who is the foreman, sets the weekly work plan and has the right to stop the line by not committing to do a task if the work is not ready to be completed. This is different from the usual way that job-site tasks are assigned or pushed on to the foreman without an actual commitment by the foreman.

6.4 Kaizen Event (Kaizen Blitz)

The Kaizen Event is a quick-hit method for Lean process improvement. An event consists of several days of intense training combined with immediate application of the concepts just taught to identify and eliminate waste in a specific process. Manufacturing has been using Kaizen Events since the early 1990s. Dana Corporation reports that using a Kaizen Blitz improved productivity by more than 400% in one plant alone. At its Whitman plant, the company achieved the following results:

- A 97% reduction in parts traveled,
- A 94% reduction in floor space needed,
- A 75% reduction in work-in-process inventory,
- An 85% reduction in cycle time, and
- An 83% reduction in setup time.[18]

The Grunau Company conducted a Kaizen Event applying the 5S's in its tool room. The company took a week to train and test the Lean concepts, resulting in a 50% reduction in the number of steps for scheduling tools.[19]

Veridian Homes, with headquarters in Madison, WI, uses what the company calls *Kaizen redline* events to review all its home model plans. This is done to develop plans that are more constructible. Veridian has 50 different plans, and, by involving the people who design and build these models, the company has made major improvements. It uses opportunity for improvement (OFI) teams to resolve issues surfaced through the plan reviews and by defect analysis. Veridian's quality improvement efforts have accomplished the following:

- Model homes sold cycle time reduced from 32 to 15 days;
- Drafting time per model reduced by more than 1 hour;
- Estimating time per home reduced by 32%;
- Material variance (difference between ordered and used, possibly due to damage on site) down by 20% for lumber, 24% for siding, and 30% for trim;
- Paperwork processing reduced by 208 hours per year;

- Person hours down by 200 per year through escrow and warranty process improvements; and
- Inspections (and their costs) reduced by 50% while at the same time defects by over 50%.[20]

6.5 Kanban

Kanban is a communication tool or signal used in JIT production systems. The signal is used to tell workers to pull parts or refill material to a certain quantity used in production. One example is a two-bin system of consumable parts. When the first bin's materials are completely used, the bin is moved to a designated spot to signal the need to order more. Meanwhile, the operation continues production by drawing from the second bin. Instead of two bins, the signal may be a card on the side or inside a box of parts or materials. When consumption reaches the card or when the box with the card is depleted, the card goes to a person who replaces the material. The card shows the item to be ordered, the quantity, part number, and supplier. Another technique is painting a line on the side of a large bin. When the level in the bin reaches the line, an order is placed for a refill. Manufacturing has used Kanban-type signals to keep inventory at a minimum and still keep production going. Some construction companies are beginning to apply this simple technique in their shops. Kanban can also be used for consumables carried in service trucks and used in field installations.

6.6 Poka-Yoke

Poka-Yoke is a mistake-proofing method or device used to prevent an error or defect from happening or being passed on to the next operation. A most common application is an electronic form that when not filled out correctly will immediately signal an error. A vacuum cleaner manufacturer used the Poka-Yoke concept as a final check for defects. The company weighed completed packaged boxes before shipping; an incorrect weight indicated something was left out or too much had been added. That detection method worked well, except the customers complained that the operating instructions were often missing. The first solution considered was to buy a more accurate scale. Instead, a Poka-Yoke approach was used to alter the way the instructions were packaged in the box. Instead of drawing from a large stack of instructions, the packaging worker was trained to put one copy of the instructions on the floor of the assembly area each time he started to pack a box. If, at the end of packing, the instructions were still on the floor, it was not in the box! This simple signal solved the problem and avoided spending $50,000 for a new scale.

As another example, some contractors kit materials with ducting so that the proper gaskets and parts are available when doing the installation.

6.7 Process Mapping/Analysis

A process map is a flow chart identifying all the activities, operations, steps, and work times for a process. The process is mapped and then analyzed to identify waste. Each step is categorized into value-added, non-value-added but necessary, or non-value-added and not necessary. Also, the maximum and minimum times to perform each operation are noted, along with the distance traveled from operation to operation. Wait and delay steps are recorded. Improvements come by reducing the travel time or distance and by reducing or

combining steps of operations. Any non-value-added and not necessary steps should be stopped immediately. Process mapping is used in Kaizen Events and with process improvement teams. One of the core benefits of doing process mapping is to get everyone to agree on what the process is and is not.

Most manufacturers report major reductions in cycle time, steps performed, and space used when doing process mapping. An air strut assembly plant made major improvements using process mapping. For the dirt shield part alone, they reduced:

- The distance a dirt shield traveled from 4,300 to 75 feet;
- Dirt shield lead-time from 18 days to 39 seconds;
- Work-in-process from 9,078 dirt shields to 10;
- Steps in the process from 42 to 14; and
- Inventory space required from 288 square feet to zero – no inventory.[21]

One mechanical contractor mapped its tool repair process and was able to save 8 to 9 hours per week of the repair technician's time by rearranging where parts and tools were kept and setting the priority for repairing tools. Several steps were eliminated as not needed and non-value-added.

VSM is a variation of process mapping but uses pictures and arrows to diagram the work flow. In VSM, the process analyzed includes all the steps currently completed to bring the product from raw material to fabricated product. Other process analysis tools may focus on any process and may be limited in scope as defined by that process. VSM analysis looks at the big picture of workflow to improve the whole process, not just parts. Usually mapping the whole process from mining metal to final end user involves too many diverse organizations, so most VSM is limited to the door-to-door process within a company. The Boldt Company used VSM to reduce accounts payable from 87 days to 67 days. It has targeted a future state level of 11 days and is still working to reach it. Tracer Industries Canada, Ltd., specializes in providing turnkey management systems for industrial and commercial projects. They applied VSM to their engineering design time and decreased the total time from 20 days to 1.2 days. Direct labor cost per drawing has decreased and is generating a $1.3M increase in earnings before interest and taxes (EBIT) annually.[22]

6.8 Rules of Release

Lean concentrates on the handoffs between operations. Rules of release are established to ensure that handoffs are done right the first time. These rules list the information and product quality required by the receiving side to be able to do the next operation correctly.

Figure 9 is an example of the rules of release for operations in a shop fabrication process. Defining these rules and then living by them help ensure the work is done correctly.

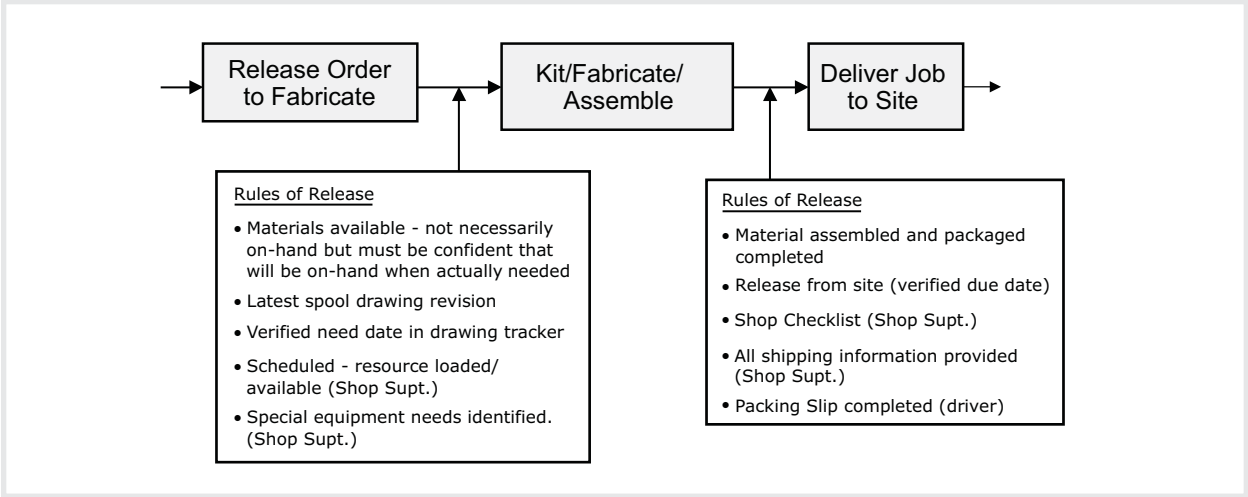

Figure 9: Sample Rules of Release for Shop Fabrication

6.9 Reduced Setup Time

Setup time is wasted time that Lean companies work to reduce. While the ideal setup time is zero, many manufacturing companies have reduced their machine setup time by factors of 10 by applying Lean techniques. This is because much of the time in construction is nonproductive time. Preparation and cleanup times consume a major portion of the day. Contractors have done very little to systematically reduce setup time in the shop, service, or field. The example given above, in which the 5S's were applied to an air balance job to reduce the time searching for harnesses, shows how setup time can be reduced in the field.

Mapping the steps can be helpful for attacking and reducing setup time. A useful approach often is to separate the steps into two groups: those that can be done while the equipment (or crew) is still running and those that must be done while the equipment (or crew) is stopped. The 5S's, base plates, markings for adjustments, and standard parts can help. In most cases, once employees are involved and trained, they can identify many opportunities to reduce setup time.

6.10 "Spaghetti" Chart

A useful and simple tool to see how a product flows or work is performed is the "spaghetti" chart. A physical map of the work area is drawn that shows the path taken by a specific product or a person who is being observed. A line is drawn from start to end indicating the path moved by the product or person. A completed chart resembles a plate of spaghetti because the product or person typically moves all over the area being studied. In one sheet metal shop, the spaghetti chart helped raise questions about how the various machines were located in relation to each other. This led

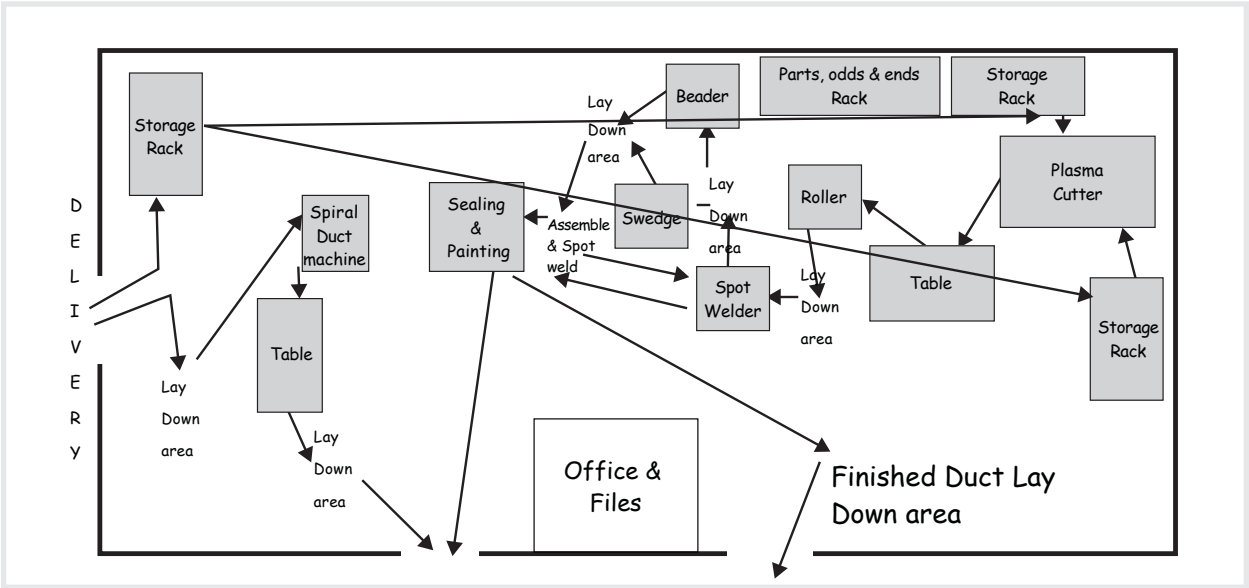

Figure 10: Spaghetti Chart for Spiral Duct Shop

to a closer and more logical relocation of several machines and substantially reduced the distance fittings traveled through the shop. Figure 10 shows an example of a spaghetti chart.

6.11 Takt Time

The key to continuous flow in manufacturing is Takt time, named by German manufacturers who used the rate of customer demand to set the pace of production. Takt time is the available production time (less breaks and lunch) divided by customer demand. For example, if the shop operates 480 minutes per day and the field orders 75 pieces of duct, the Takt time is 6.4 minutes.

While Takt time can be calculated for any process, it is used in Lean operations to set the pace of the main production process. By setting and working to achieve a constant pace, the product flows more evenly through the process. Applying this idea to the shop example above, with 6.4 minutes Takt time, pieces of duct would need to move from one station to the next every 6.4 minutes. When an operation takes more than 6.4 minutes, the team would work to split it into smaller components to balance the flow. When a process is started with a set Takt time, roadblocks to continuous flow will become very evident. This method obviously works best in a plant with long production runs of the same product; however, job shops are also learning to apply Takt time.

6.12 Total Preventive Maintenance

Total preventive maintenance (TPM) is a set of methods used to ensure that production equipment is always working properly and does not stop production.[23] Many manufacturing companies have applied TPM with great success, but the research found few contractors that have applied it. Only two contractors in the Lean survey conducted for this research reported having tried TPM.

6.13 Visual Control

Sometimes called transparency, the visual control Lean technique displays tools, schedules, and performance reports in full view of front-line workers so everyone can see the status of work and their unit's performance. Visual control also includes marking the locations of equipment, tools, inventory parts, disposal cans, cabinets, etc., so that everyone knows where everything belongs. Visual control examples include using colored hard hats to identify specific trades or new employees to the work site, posting the weekly work schedule showing progress as the week progresses, having a flow chart showing how to run the weekly payroll, using color-coded labels on fabricated duct, marking duct so the installers know which ends go together, and using a flashing red light to tell supervision when there is a problem in the installation area of the facility. Using visual control helps eliminate waste, is a valuable part of any 5S's effort, and is also used to identify problems. The more the workflow is visible, the easier it is to see where bottlenecks exist.

6.14 Summary of Lean Tools

Table 1 summarizes the Lean tools and provides additional information useful when considering possible applications. These are simply guidelines and should not limit one's decision to try the tools in different functions or situations. The exact time needed for training and implementation will vary by company and scope of application. The numbers are most useful to give relative magnitudes and not absolute facts.

	Applicable To:						
Lean Tool	**Field**	**Shop**	**Office**	**Service**	**Time to Implement**	**Training Time**	**Type of Tool ***
5S's	Med	High	High	High	2-3 weeks	2-3 hours	Action
Last Planner System	High	Low	Low	Med	2-3 months	4-8 hours	Action
Kaizen Events	High	High	High	High	1-3 days	1-3 days	Action
Kanban	High	High	High	High	Minimal	Minimal	Action
Poka-Yoke	High	High	High	High	Varies	Minimal	Action
Process Mapping/ Analysis	High	High	High	High	2-4 weeks	2-3 hours	Analysis
Rules of Release	High	High	High	High	1-2 hours	Minimal	Action
Reduced Setup Time	High	High	Med	High	1-3 days	2-3 hours	Action
Spaghetti Chart	High	High	High	High	1-2 hours	Minimal	Analysis
Takt Time	?	High	Med	?	2-3 weeks	2-3 hours	Action
Total Preventive Maintenance	Low	High	Low	Low	2-3 months	4-8 hours	Action
Visual Control	High	High	High	High	2-3 weeks	2-3 hours	Action

* 'Analysis' means the tools provided information for taking improvement actions.

'Action' means the tools identified specific actions to take.

Table 1: Lean Tools Summary

7 HOW TO BECOME LEAN

Lean is not one technique, nor is there an exact recipe of steps to follow to become Lean. There are techniques that work in most companies and some that fit one firm or operation better than others. Norman Bodek, who is considered the grandfather of the Lean movement outside of Japan, once said,

> "Ohno and Shingo both loved to say simply "do it!" and then leave you the challenge to figure it out for yourself. They rarely ever had a cookbook approach for you. In fact, Ohno would never let anything be written down on how to do Lean. He wanted it to be a system that allowed for constant change."[24]

Such an approach actually works well for contractors who are accustomed to trying whatever it takes to get the job done rather than using detailed research on the theory of construction. "Just try it" can be one tactic for getting started on improving a process. On the other hand, Lean is not a one-time test because Lean uses the *Plan*, *Do*, *Check*, *Act* (PDCA) approach with continuous efforts to improve. Contractors will realize the success of Lean construction only when they stay the course and keep working on adapting the Lean techniques to their operations. The following are ways to implement Lean – use as best fits each company's unique situation.

7.1 Define Value

Lean is all about value as defined from the customer's point if view. Redefining or validating the value a customer is looking for in a project sounds a little academic. After all, "we" already know what they need! Redefining value takes some discipline, but the effort of redefining Lean can also lead to new understandings on what is value to the customer and give those who make the investment in this examination a sizable competitive advantage.

Value to the customer is not always as contractors see it. Value is the usefulness of the product or service compared to the cost to obtain it. The end-user customer is looking for a comfortable room or a high-purity air quality operation at a reasonable cost. Value may be a shorter duration to get a plant operating but only if the other parts of the project can take advantage of a shorter startup. To install the ducting ahead of schedule may not be useful if the air-handling unit cannot be expedited.

How do you proceed in asking the customer to define value? Start by identifying the customer: Is the customer the mechanical contractor, the general contractor, or the owner/operator? (The customer can be all three, and maybe a few more!) Two approaches can be used once the customer is identified. Start at the micro level and work with the next-in-line customer to obtain his or her view of value, or start with the end user and work backwards through the system.

Womack suggests that addressing the Lean Enterprise is the next frontier for manufacturers that have mastered many of the basic Lean techniques. By "Lean Enterprise," Womack is referring to the entire value stream from raw material to the final customer such as the homeowner, building tenant, or manufacturing worker. He suggests that, as the entire value stream is viewed without regard to company boundaries and self-imposed walls, there will be many opportunities to streamline subprocesses and eliminate duplicate efforts. This undertaking is beyond the scope of this

report; however, the Lean Enterprise concept offers rich possibilities.

A more usable and practical approach is to try the Customer – Output – Process – Input – Supplier (COPIS) method.[25] The flow of this approach is shown in Figure 11. Using COPIS begins with identifying the customer requirements. There are multiple ways to reach out to customers to obtain their ideas on their current and future requirements. Customer surveys, focus groups, and corrective action systems, along with bid specifications, all provide listening posts. Once the requirements are identified, the outputs that are needed to meet the requirements are identified. Look also for the hassle-free requirements of the customer. Is there a match in outputs to needs? Are priorities aligned? What is missing? What outputs fail to meet the requirements?

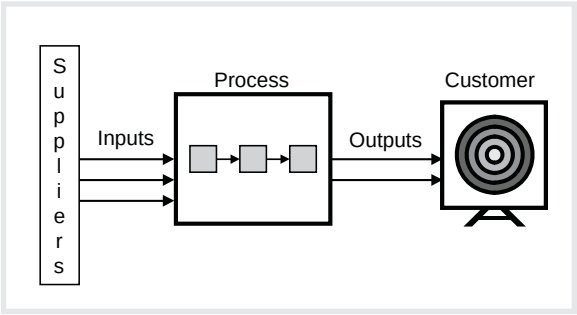

Figure 11: COPIS Flow

Moving next to the process, examine all steps that produce the key outputs. Fully review those processes that fail to meet requirements. Where in the process flow does the failure start?

After examining the processes, examine the inputs. "Garbage in, garbage out" is the rule. Failure may be due to bad inputs. Almost in sequence with examining the inputs is a review of the suppliers. The root cause of a failure to meet requirements may be a failure in the supplier's processes.

COPIS works backwards. The process starts with what the customer requires to avoid conducting an entire analysis based on misinterpretations of what is most important to the customer. Through this analysis, barriers and problems are uncovered, root causes discovered, and preventive or corrective actions taken.

7.2 Organize the Workplace

Many manufacturing companies have found that doing the 5S's is a good place to start implementing Lean. The 5S's are quite acceptable to front-line workers because they organize the workplace. The 5S's help eliminate many of the treasure hunts that take the workers' time away from doing value-added work. Start with sorting, then simplifying; then set up the sweeping methods; move to standardizing; and incorporate self-discipline. The training required to do the 5S's is not significant; a two-hour session is usually sufficient to start. It is much like learning to ride a bicycle, just start trying.

One problem some contractors have incurred in implementing the 5S's is doing only the first S. Many areas are ripe for sorting. Workers feel a sense of accomplishment when sorting through a yard, office, shop, or even a service truck to get rid of excess materials and clutter. However, applying the other four S's is necessary to reap the full benefits. Another problem people have in implementing the 5S's is thinking they are responsible for making the workplace neat and organized. As previously mentioned, the 5S's are applied to eliminate waste and allow the work to flow in a safe

work environment. Being neat or speeding up the work without safe practices is not Lean thinking.

7.3 Go to Gemba and Watch

One of the ways Toyota teaches managers and internal Lean consultants to implement Lean is to go to where the work is completed and value is added ("Gemba" in Japanese) and watch.[7] Toyota managers are expected to go to the operations area and observe the work for an hour per day every day. By watching the work for more than a few minutes, they can see the waste. When managers initially observe, they are surprised at some of the wastes. Everyone knows that front-line workers see more problems than executive management, yet few managers take the time to observe at the construction site. When at Gemba, managers should answer the following questions:

- Does the work flow or is it constantly stopping and waiting?
- What treasure hunts are happening?
- What waste is occurring? Look for all seven basic types of waste.
- What equipment is missing or is in poor working order?
- Are there work standards, and are they being used?

Managers should follow up on these questions with more questions of why or why not? Ask why five times to get to the root cause of the problem, and then implement countermeasures.

7.4 Establish Standard Procedures and Processes

Many contractors disdain standard procedures and processes, believing the only path to effectively establishing standard operating procedures requires tedious writing and the creation of cumbersome documents. Once documented, many companies file the standard descriptions away and neglect what they see as the arduous task of continually updating the work standards. Lean companies do not have time for wasted efforts but do need standard procedures and processes to be most effective.

Lean contractors will review the main systems for creating work and identify the key processes. They review and document only the key processes and supporting procedures that provide value to the customer. While documenting the process for distributing the mail at the office may meet ISO 9001 standards, this task has little value for getting product installed. During the initial evaluation, managers should focus on the consistency and correctness of their processes and procedures. They may need to write or rewrite the procedures. In a Lean organization, every person performing the same procedure such as writing a purchase order will need to adhere to the same procedure. There can be no improvement if there is no standard way to accomplish each task.

Drafting processes and procedures need not be tedious. They don't have to look like legal documents! Processes and procedures drawn similar to flow charts or with pictures are easy to create and use. Like any Lean approach, the descriptions need to provide value to the user, especially if that user is new or not experienced in doing the task. The documents

or drawings should be located wherever they will be best used, such as displayed on a wall or on a laminated sheet hanging near or on the machines to be used in the step.

7.5 Improve Management of Projects

Contractors who are committed to improving project management should seriously consider the Last Planner Sysytem®. Research proves the benefits LPS brings to the field. Project management is the key area of work that makes or breaks most contractors. Reviewing the constraints identified through research, as shown in Figure 12, finds that almost all the constraints are eliminated with coordination and planning. LPS is very effective in helping field supervision do a better job of integrated and coordinated planning and of committing resources to work assignments ready to be completed. Variance in the work can be reduced and plan reliability increased.

If a new estimating system were introduced into the industry that was proven to outperform the current systems, most contractors are likely to invest time and money in training their people on the new system. LPS has proven to outperform other project management methods and demands serious consideration. To implement the LPS does not require any investment in new software applications or information technology equipment. Implementation does require:

- An investment in training project managers (PMs), superintendents, and foremen on how to do the look-ahead and weekly plans, in making and keeping commitments, and in understanding and

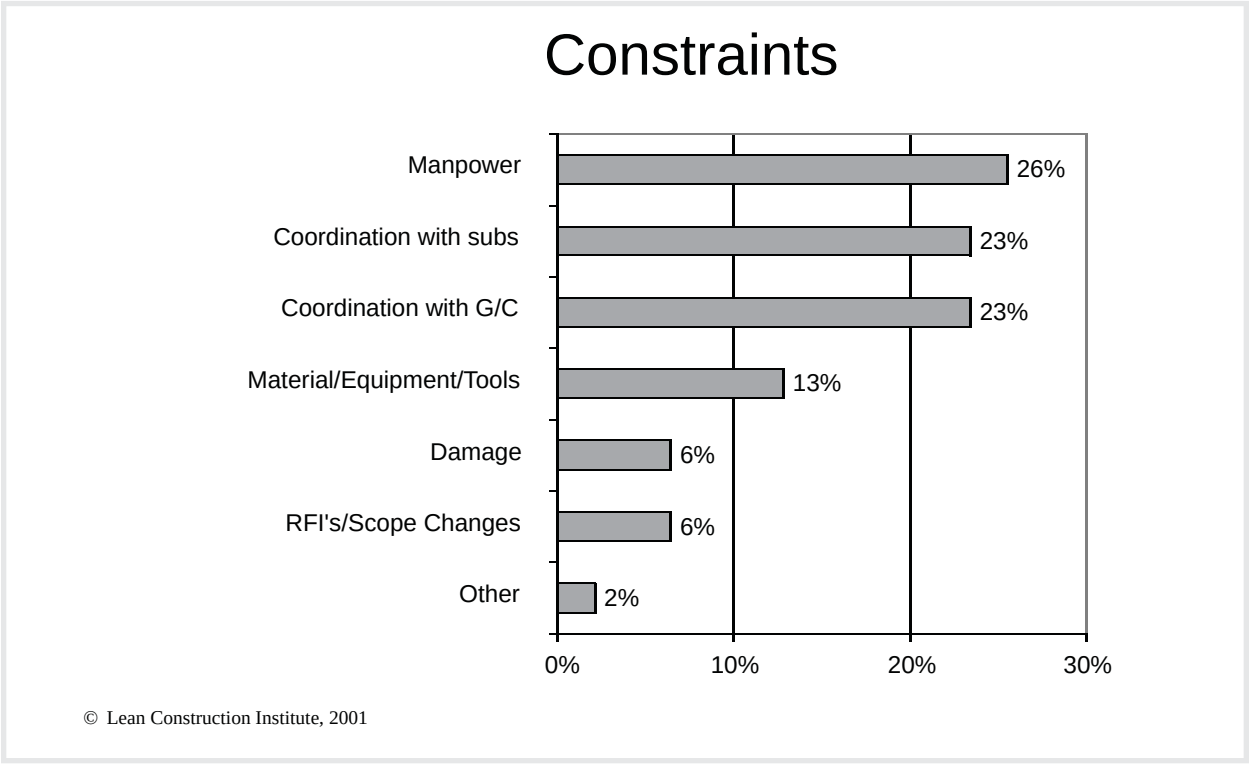

Figure 12: Constraints to Completing Work Assignments

using PPC and constraints analysis to improve the system. Four to 8 hours of training are needed for field supervision;

- An investment in developing an individual or team in the company to champion and coach others on the LPS and to maintain the momentum; and
- Management leadership to maintain a focus on implementation and to encourage continued LPS use by supervisors.

The details for implementing the LPS are beyond this report but can be gained through working with the Lean Construction Institute or its representatives or by serious study of the many papers published about Lean and learning from the companies that have implemented LPS.

7.6 Reduce Batch Size and Make the Product Flow

To improve flow, all workers must pass on only quality products and accept only correct work from the previous operation. The Japanese say, "*Don't get it, don't make it, don't send it*," regarding poor quality work. To produce only quality work, everyone in the process must know what quality is so they can be sure they are receiving, producing, and handing off only quality work to the next operation. To ensure that the handoffs between operations are completed correctly the first time, rules of release are defined from the view of the next-in-line customer. These rules define what makes the handed-off product or information correct.

Product flow improves when all work is performed on a first-in, first-out (FIFO) basis. In a batch mode, it is often necessary to stop work in the shop to rush a job through the process. In one-piece flow, a rush order can be inserted and fabricated in minimum time. In the transition to single-piece flow, situations where FIFO is not working must be identified and backlogs, barriers, or stoppages eliminated. Because there are many barriers and flow blockages in batch systems, a process usually cannot go from batch processing to single-piece flow at once without a disruption in the production rhythm. An initial step can be to reduce the batch size by moving smaller quantities of completed work to the next station and doing so more often. Workflow diagrams (process maps) can help identify improvement opportunities. Root-cause analysis is needed to permanently eliminate problems or barriers to flow.

What happens when detailing sends a batch of drawings to the shop must be considered. Often the drawings represent several weeks of installation but are all marked with the same need date. According to most shop superintendents, these typically arrive late in the week with the required date early the following week. A wild flurry of activities occurs, as well as overtime to meet the need date. Even if all product is delivered on that required date, it will not likely be installed that fast and then must be stored on site. There are many wastes involved in this approach. If detailing-issued drawings in smaller batches are sufficient to match the shop's capacity and the field's actual installation need dates, work would flow more smoothly and waste could be reduced. Look for other batch operations in construction by considering the following:

- Designs passed on to detailing,
- Detailed drawings passed on to the shop,

- Fittings fabricated in groups and put on carts,
- Fittings delivered to the field,
- Material requests sent to a buyer,
- Change orders given to the general contractor at the end of the job, and
- Packing slips for several weeks of deliveries given to accounting.

Reducing the batch size in any of these areas should be a goal.

Another way to improve flow is to move sequential activities adjacent to each other and physically as close as possible to reduce transportation waste and improve communication. This may require ignoring traditional functional boundaries. The best distance between operations is the shortest possible distance. While ample open space seems desirable, Lean seeks to keep the distance to the least possible that is still safe and functional.

Improving the workflow does not happen at once, and the manager must keep removing barriers as they become visible.

7.7 Remove Constraints in Product or Information Flow

Keeping the operations crews installing steadily is the first priority. Lack of material is a major cause of crew work stoppages. To improve material flow, a Value Stream Analysis must be conducted of the material-handling delivery system from estimating takeoffs to material being returned from the site or scrapped. The process must be mapped and the steps reviewed for value-added or non-value-added work. The barriers or constraints that keep the material from getting to the right site at the right time in the right quantity and with the right specifications must be identified.

One contractor performed this analysis, and one of several improvements paid off quickly. The team found that having the foreman review in detail the takeoffs made by estimating at the time of a turnover meeting would be beneficial. The foreman would look at the work from a constructability standpoint and compare the plan to the material takeoff list. The foremen did not want to take the time upfront to do this level of review, but after the first test job identified more than $8,000 in savings in material, this step became standard practice. The group then defined several levels of turnover meetings and rules of release for each stage.

Another contractor solved the industry-wide problem of foremen filling out a material request by hand and not being clear on what is ordered. Foremen often use their own terms for parts and buyers can make a mistake by assuming they know exactly which part is being requested. If they don't know, or are unsure, about which is the "right" part, they have to call the foreman to verify the correct item. All this is wasted time. This contractor developed a spreadsheet with all the parts listed for that job. The parts listed were the correct specifications for that job. Foremen were able to fax in the sheet with the correct parts marked by the quantity listed. The fax was much clearer to read. Later, the process was further improved by enabling the foremen to email the material request, saving more work.

Process mapping and examining the value stream can identify many opportunities to improve the information and the material flow.

7.8 Implement Pull

A pull delivery system can be applied in material handling on the job site. The material delivery department should not deliver the material until it is about to be needed, possibly one day in advance. The shop should not fabricate material more than a few days in advance of when the field actually needs it. Purchasing should resist placing orders and requiring the material to be delivered well in advance of the need dates. Detailers should not release drawings until the work is ordered by the field. This may sound easy, but in construction everyone wants to have confidence that the material is ready for the crew to install, so every step in the current game is to stockpile and "push" material to the next function. Pushing (delivering) duct too early to the field generates waste, as the crews must stop to unload and store it. Materials purchased on a special bulk buy and delivered all at once causes warehousing and inventory expenses. Implementing a pull system requires a reliable system of delivery and honest need dates. For many contractors this will require cultural and process changes.

7.9 Implement Lean in Service

While Toyota has focused its Lean solutions efforts primarily in manufacturing and engineering, other organizations are looking for application in the consumer world. Most HVAC and sheet metal contractors have not seen the applicability of Lean in service as much as in field and shop operations. (Lean's applicability to service operations was rated the lowest of possible areas to apply Lean in the web-based survey conducted in this research. See Appendix C for full survey results.) In 2005, Womack and Jones introduced the idea of Lean solutions to consumers' problems. New ways are being developed to reduce the frustration and disappointment experienced by people trying to get their car repaired or obtaining health care service as well as those looking to get technical help through service phone lines for equipment problems. In the book *Lean Solutions*, Womack shares innovative answers companies have used to increase value and reduce waste for the consumer.[26] The Lean solutions look at consumer complaints or calls as opportunities to solve a problem and to define value as seen by the consumer. The key principles are:

- Solve my problem completely,
- Don't waste my time – don't assume my time is free!
- Provide exactly ***what*** I want,
- Provide value ***when*** I want it,
- Provide value exactly ***where*** I want it, and
- Reduce the number of problems I need to solve.

Womack recommends looking at the entire value stream (process) that produces the service to the consumer and applying these rules:

1. Create a knowledge dialogue with the customer up front to gain greater understanding of the problem so the technician can be better prepared to solve the problem the first time, in minimum time, and with the right resources. Learn to ask the right questions and create a knowledge base.
2. Pre-diagnose the problem by taking extra time to learn exactly what tools, parts,

skills, knowledge, and time are likely to be needed to fix the problem.

3. Level demand wherever possible to allow more reliable promises of meeting the customer's time requirements.

4. Save the time of your employees who serve the customer by making the internal service functions efficient and effective.

The researcher is aware of one test application of this approach applied to HVAC service work, and it is still in the early stages of implementation. Some of the ideas learned while applying this approach are as follows:

- Contractors use a dispatcher to receive calls from customers. The level of technical knowledge varies greatly with dispatchers, but, in most cases, the dispatcher is not knowledgeable enough to ask all the questions a technician would ask to discover the customer's problem. It is often strangers serving strangers. Improvements can come as one increases the detail of the information gathered from the customer in the initial service request call. Creating incentives for customers, especially commercial and industrial customers, to provide advanced and detailed information about their equipment and history of failures can also improve how HVAC service contractors add value.

- Mapping the value stream and validating times for the various activities can help identify pockets of waste, including where the customer's time is wasted because we assume it is free. The pilot project found that as much as 50% of the customer's time is non-value-added.

- The database used by most contractors does not allow for more detailed gathering of information about the customer's problem or for good historical analysis of similar problems with that customer or others. Better information and analysis of that information can lead to the right (skills) technician showing up on the job with the right material and tools to solve the problem right the first time.

- The hours a service department is actually open and the rates charged for after-hours and weekend work does influence the workload peaks and valleys. Contractors should rethink their methods of service in light of what is value to the customer. By leveling the workload, a contractor can become more reliable in keeping the promised appointment time. Many service departments have tried to answer the appointment time challenge by telling the customer the technician will show up in the morning or afternoon. Consumers want more specific appointment times and reliable technicians.

- Contractors can help the service technicians by analyzing the nature of the service work and the reasons the technician leaves the facility to obtain tools or equipment or calls for someone to bring material/tools to him. Stocking the service trucks/vans with the right tools and parts and implementing a system to keep them stocked, but not overstocked, can pay dividends. The tools and parts should be organized within the trucks in a consistent way based on the frequency of use, using 5S's and Kanban Lean tools.

- Toyota uses a "water spider" person to run parts to the assembly line. This person in a lower skilled position delivering needed parts and tools JIT allows higher skilled workers to focus on their tasks. Some contractors use a parts runner or an outside supplier to assist technicians, and this may be a value-adding solution.
- Measure customer fulfillment by the percent of work done right the first time (no callbacks) times the percent of jobs delivered on time as promised to the customer.

8 WHO IS DOING LEAN?

A web-based survey of Lean awareness and application was conducted using larger HVAC and sheet metal contractors. In total, 1,073 contractors were surveyed through their email address (see Appendix C for full survey results). The survey of Lean principles practiced in the HVAC and sheet metal industry found that

- 58% of the contractors in the survey are aware of Lean;
- 48% of those familiar with Lean have implemented it in some way;
- The Lean tools most often used by the survey respondents are:
  - LPS,
  - 5S's,
  - JIT, and
  - Process Analysis;
- There is significant interest in learning more about Lean – 78% said they wanted to learn more about it;
- While the larger (in average number of employees) the contractors, the higher probability they know about Lean, the same linear relationship does not hold true for those who have implemented Lean. Only 28% of contractors in the 100 to 299 average employee size have implemented Lean compared to 56% for companies in the 1 to 99 range and 77% for those in the 300 or more range; and
- 46% of the survey respondents who do residential work are familiar with Lean compared to an average of 59% of the respondents doing all other categories of work (commercial, government, industrial, and schools). All categories show about the same percent having implemented Lean and also their interest in learning more about Lean.

Research has found that general contractors, piping and plumbing, and electrical contractors are also implementing Lean. Recent surveys in the United Kingdom, the Netherlands, and German construction industries also found the same overall results – that Lean is still very new to the construction industry and there is broad and growing interest.[27]

There have been some false starts in companies implementing Lean. Some contractors have thought that doing Lean is an easy fix and have not given adequate attention, resulting in failed Lean efforts. Contractors are learning, as have manufacturing organizations, that successful implementation of Lean

practices requires the commitment of senior leaders; discipline to continue moving forward with the new procedures; and a management style that invites workforce participation.

In many industries, the large leading companies who have mastered Lean have begun to require Lean practices of their suppliers. If construction follows a pattern similar to manufacturing regarding Lean, in a few years the contractors who master Lean thinking will outperform their competition to the degree that they will capture their markets and be the low-cost and high-quality (value) providers. These Lean contractors will also start introducing Lean to their subcontractors. Shea Homes has been teaching its key subcontractors the basics of Lean and Six Sigma for several years with great success.

Lean efforts between the owner, general contractors, and subcontractors as well as the design and engineering communities are starting to be tested. As mentioned earlier, Sutter Health, a not-for-profit health care and hospital system, has started an initiative called the Lean Project Delivery System. It began with Sutter Health committing to provide greater value to their customers. In analyzing how to achieve greater value, they realized that the current way of delivering projects is broken. They committed to implement Lean practices in their health care services and construction. Their approach in construction is called the "Five Big Ideas" which are:

1. Collaborate, really collaborate, throughout design, planning, and execution;
2. Increase relatedness among all project participants;
3. Projects are networks of commitments;
4. Optimize the project, not the pieces; and
5. Tightly couple action with learning.

To turn these ideas into working reality they created the Integrated Agreement.[28] This is a relational contract signed by the owner, general contractor, and architect. It defines how they will act and relate to each other and other subcontractors throughout the project. In working with all their construction vendors, they established these expectations:

- Learn the skills needed for Lean project delivery (LPS),
- Develop an internal implementation strategy (with measurement of progress),
- Demonstrate a commitment to continuous improvement, and
- Exhibit a willingness to share the learning in our project community.

They have formed the Northern California Lean Coordinators group to help accomplish this. They meet monthly and share best practices and experiences in implementing Lean. Through this meeting, in which Sutter Health fully participates, they hold each other accountable for implementing the Lean Project Delivery System.

General Motors (GM), under the leadership of Jack Hallman, Director of the Manufacturing Construction Management Group for the Worldwide Facilities Group, Capital Projects for GM, did a test project using some Lean tools and three-dimensional design. They worked closely with Dee Cramer, Inc., a sheet metal contractor. GM is challenging the

industry to develop, embrace, and implement Lean principles. From this pilot program, GM has developed the following customer expectations:

- Expect construction firms to be proactive in applying Lean concepts;
- Expect support organizations to lead "best of the best" concept identification and application to Lean construction;
- Expect a common approach to maximize owner benefits;
- Expect near-term results from bid through implementation at the site;
- Contractors who master Lean gain competitive advantages:
  - How they do business, and
  - Lower structural costs;
- Owners benefit as well:
  - Lower cost,
  - Higher quality,
  - Faster schedules, and
  - Improved safety on projects.[1]

GM's pilot project was so successful that all construction conducted by GM in North America is using the same approach. Jack Hallman reports that he is working with the Construction Users Roundtable (CURT) to further define and promote Lean practices in construction. CURT's membership includes most of the major companies in the US. As they support and/or require Lean applications on their construction projects, subcontractors will be pulled into the Lean approach.

9 BARRIERS TO IMPLEMENTING LEAN

Change is never easy in a company or industry with longstanding traditions. While Lean has proven successful in many industries, and to some extent in the construction industry, there is and will continue to be resistance. Three essential ingredients are required for lasting change. First, the leaders must see the *need* to change. Next, leaders must develop a *vision* of what the company is striving to become. Finally, a *plan* or roadmap must be developed and shared with all stakeholders. The plan needs to outline how the company will achieve its vision.

Womack has said that health care and construction are highly complex industries and present great challenges to implementing Lean. This is because these industries consist of many crafts and have "secret processes" that the workforce believes are best methods for accomplishing work in a hectic environment. Both workers and managers believe that every job (or, in the case of health care, every patient) is unique and different and cannot be standardized. Indeed, in construction each job is unique, yet the various processes of construction are repeated over and over and, therefore, can be made Lean.

Lean has proven its value in manufacturing and service. Lean is also being successfully implemented in leading health care organizations. The construction functions of purchasing, material management, payroll, billing and collections, and fabrication are very similar to manufacturing. Consequently, these areas are those where many construction companies have first tried to implement Lean. The greatest challenge lies in the field and in project management. Can the Lean world of

order, planning, and organization fit into the construction environment of changing plans, firefighting, and contention? The problem and answer are not really in the nature of construction work but in how workers and, more so, how managers think about their work in order to cope with rapid change.

Lean applications in construction, including in the field, will not be sustained until the PMs and field supervisors believe that their job is not firefighting but defining and improving processes that deliver value to the customer. These masters of work-arounds are being challenged to create consistency. Some people stay in the construction industry because they love the challenge of a hectic, contentious, deadline-driven, and fire-filled atmosphere. How will they become comfortable in a Lean environment of a more reliable and orderly work system? When construction experiences – as has manufacturing – reduce stress and have a more disciplined work environment under Lean, will workers and managers easily make the transition? It is always easier to apply techniques than to change behaviors. The role of leadership becomes twofold: champion the implementation of Lean techniques and help managers and the workforce adapt personally to a new style of working that focuses on planning, prevention, and consistency.

Through research of many successful and failed change initiatives, John Kotter has identified eight reasons why change fails in organizations.[29] Contractor leaders and executives need to understand these potential causes of failure and design their Lean transformation to avoid them. The eight reasons are

1. ***Not creating a sense of urgency*** – Leaders need to communicate the urgent need for becoming Lean to all employees. Over time, the construction industry has come to expect waste as inherent in its operations. The need to change must be clear.

2. ***No leadership coalition*** – While one very passionate leader can do wonders, most successful change efforts require the involvement and commitment of a team. Not all leaders have the title of manager, but in any company there needs to be a critical mass supporting Lean. The 20–60–20 rule fits when making changes in contracting companies. Typically, when a change is announced, 20% of the workforce is behind the change almost immediately. About 60% is usually in a wait-and-see mode, wanting to know whether management is serious about this or if the change is the flavor of the month. Another 20% is against it from the start. Leaders typically spend most of their energy trying to win over the 20% that is against change. Research suggests that this 20% will probably never really buy into the change. It is much more effective to focus on convincing the neutral 60%. Once they are on board, there is a critical mass of 80% ready to move forward. Womack goes so far as to say the sooner you "free up the future" of the negative 20%, the better it is for the company and those individuals.[2]

3. ***Not creating a vision*** – Where there is no vision, the people fail. Leaders need to know where Lean can take them, and they need to share that vision throughout the company.

4. ***Under-communicating*** – Research shows that managers under-communicate the vision, the sense of urgency, and the passion for changing by a factor of 10.

Contractors are among the weakest in communicating with their workforces. Frequent and focused communications are needed.

5. ***Not removing obstacles to the vision*** – Two of the most common obstacles to implementing improvements are time and budget. "We must keep cutting, we don't have time to stop and sharpen the saw," is paraphrased every day in construction. Top management can remove these barriers by making Lean implementation a priority and providing the time and budget.

6. ***Not creating short-term wins and celebrating*** – Continuous improvement is a journey that does not occur quickly. However, making note of and celebrating the wins along the way adds to momentum. Managers will do well to celebrate the small and big wins to demonstrate to employees their commitment to change.

7. ***Declaring victory too early*** – Lean evolved at Toyota over 60 years of trials and improvement efforts. The traditional construction culture has been around even longer. There will be no quick, easy victory, and leaders must stay the course.

8. ***Not anchoring changes*** – To make the changes acceptable, they must align with existing company polices and core values. Companies should avoid rewarding PMs who are not team players even if they do make money on a specific project. Allowing some workers to violate safety rules and expecting the rest to obey or putting processes in place and allowing workers to deviate will not yield a Lean culture. How the organization promotes, recognizes, and rewards employees must complement and reinforce the Lean transformation. Leadership's role is to define, coach, and ensure that the right behaviors are taking place to achieve the best results. Having a contract that supports Lean behaviors is also important. The integrated agreement developed by Sutter Health is a great step in the right direction. Going to Gemba (see page 29) often will help.

In summary, the key to successfully implementing Lean in construction companies lies with leadership that is committed to transforming the company into a Lean machine. Much like getting an individual into physical shape, fad diets and sporadic exercise will not sustain the desired results. Management must lead and remain focused to achieve success.

10 FUTURE POSSIBILITIES

Lean is still very young in its application to construction and especially to the HVAC and sheet metal industry. However, industry leaders are thinking beyond the immediate tools and techniques to what is next for Lean and the following should be explored.

10.1 Lean Enterprise

As previously mentioned, a Lean Enterprise looks at the whole process from raw material to the end product. For the HVAC and sheet metal industry, this span would be from metal ore to a room or facility with proper heating and cooling or a facility with architectural sheet metal adding value. Possibilities for eliminating waste are even greater when

the whole process is considered. Studying construction processes from the vantage point of Lean Enterprise has the potential to yield vast advances because so many trades are involved.

10.2 Submittal Day

One challenge faced by most contractors is delays in receiving approval for submittals. Lean would define most of the time and steps in the submittal review process as waste. Submittals total review time includes the time the submittals travel and wait for someone to review the documents. This is waste. Additionally, Lean could improve the impact of decisions made by one discipline on the others involved in projects. Implementing Lean offers opportunities for reducing submittal cycles and adding value to the customer. An alternative suggested by the Lean Construction Institute is to hold a submittal day. This event would bring all the engineering disciplines together with the general contractor, architect, and facility owner to develop the detailed design and specifications. Ways to implement submittal day should be explored.

10.3 Target Costing

Target costing has been used by the Japanese to reduce the overall cost of a product over its entire life cycle. For construction, the target cost is the maximum amount of operating cost that can be incurred on a project and still earn the required profit margin. Targeted costs are developed by subtracting the profit margin from the market price. This is backward from the way contractors develop a bid price starting with an estimated cost takeoff and adding the profit margin. Boldt and Sutter Health have started exploring target costing. More research in this area may help contractors understand how to drive the life-cycle cost down while adding or at least maintaining value to the owners. As the availability for skilled labor decreases as forecast for the next 10 years, Lean techniques and target costing can allow contractors to complete their work with fewer resources.

10.4 Training within Industry

Training within Industry (TWI) is a training program that gives supervisors key skills to become effective supervisors and to help them rapidly and consistently train their workers. TWI was developed during World War II to train replacements of an industrial workforce that was fighting a war. TWI is recognized as part of what helped the US win that war. During the prosperity of post-war America, the TWI program was dropped and became a faded memory. TWI was introduced in Japan during post-war rebuilding. The basic framework of TWI exists in Toyota and many other companies to this day. It is seen as a foundation to Toyota's success in continuous improvement, and more importantly, in its ability to sustain those improvements. Companies are starting to explore how TWI fits within their Lean initiative to develop the key people and supervisory skills. More research needs to be conducted to see how TWI can help train contractors in Lean techniques and in having and using standard procedures.

10.5 Zone Material Deliveries

One method that can pay good dividends is to eliminate the site yard for material deliveries. One study showed that delivering to zones closer to the actual installation areas reduces

much material-handling travel (waste) between the yard and work area. That study showed a 2 to 4% reduction in the crew's time spent carrying material. With margins so tight in today's market, gaining additional crew installation time can add to profits. More research needs to be conducted on how to determine and arrange for JIT zone deliveries.

11 CONCLUSION

Lean principles and tools are transferable and applicable to the HVAC and sheet metal industry. Most of the principles are simple and can be learned without years of training, much like riding a bicycle. However, it will take time for Lean to be an industry-wide practice because it represents change and requires focused and consistent effort to learn. No one learned to ride a bicycle without some bruises and falls. As more of the larger and progressive contractors embrace Lean principles, adaptation will gain greater speed. Even more critical to the speed at which Lean is adapted in the industry is the level of acceptance of Lean by general contractors and customers. When the customer speaks, contractors listen! However, customers would prefer that contractors take the initiative to bring Lean solutions to them. Contractors can gain a great advantage by leading the way in implementing Lean.

The overall goal of Lean is to improve profitability through better management of the company's resources by adding value and eliminating waste. Waste was once thought of as just rework and scrap. Lean brings a much broader definition of waste and expanded opportunities for reducing or eliminating the many forms of waste in the HVAC and sheet metal industry. Table 2 compares Lean to traditional project management and reveals the differences.

Traditional Project Management	Lean
Perform work-arounds as needed	Perform job as defined with clear understanding of value
Add people to meet due dates when the job falls behind	Keep a constant workforce productive
Add equipment to rush to get the job done	Tools and equipment are sufficient and balanced in their use
Work longer hours when project falls behind	Project is not rushed and less overtime is needed
Every PM and field superintendent learns but does not share. Similar mistakes continue to occur	Organized lessons learned process
Constant firefighting	A rhythm to the flow
Accept waste as part of construction	Continuous efforts to reduce and eliminate waste

Table 2: Comparison of Lean Principles to Traditional Project Management

Although the construction industry continues to lag behind other industries in productivity and in implementing Lean practices, the solutions are readily available. By using and properly applying the principles of Lean that have proven effective in other industries, the HVAC and sheet metal contractor can significantly improve both productivity and profitability. The research survey found that most contractors are interested in learning more about Lean. With both the need for and interest in Lean, the stage is set for major advancements in the industry.

12 GLOSSARY OF TERMS

5S's—Sorting, Simplifying, Sweeping, Standardizing, and Self-Discipline. The 5S's came from Toyota and are used to organize and visually control the workplace to eliminate waste.

COPIS—Customer – Output – Process – Input – Supplier. A method for working backwards through the process to identify and validate requirements and possible errors.

JIT—Just in Time. A system for producing or delivering the right amount of parts or product at the time it is needed.

Kaizen—The Japanese word for continuous improvement. Kaizen has come to mean the philosophy of continuous improvement.

Kaizen Event—A quick-hit method for Lean process improvement, typically consisting of several days of intense training combined with immediate application of the concepts just taught to identify and eliminate waste. It takes place at the production work location.

Kanban—Japanese term meaning "a signboard." A communication tool used in JIT production systems. The signal tells workers to pull parts or refill material to a certain quantity used in production.

Lean Thinking—Focusing on delivering value (as seen by the customer) and eliminating waste.

PDCA—Plan – Do – Check – Act. The cycle introduced by Dr. W. E. Deming, recognized quality improvement expert, as a method of continuous improvement.

Plus/Delta—A discussion completed at the end of a meeting, project, or event used to evaluate the session or activity. Two questions are asked and discussed: What worked? What could we do differently/better?

PPM—Parts per Million. Used to measure the number of defects per million parts produced.

PPC—Percent of Planned Completed. The percent of planned work assignments (tasks) made at the beginning of the week that the crew completed by the end of the week. Partial completions do not count as completed. PPC is a key learning tool for PMs to help remove constraints that hinder completions.

Process Mapping—A flow chart identifying all the activities, operations, steps, and work times for a process.

Poka-Yoke—A mistake-proofing method or device developed by Japanese industrial engineer Shigeo Shingo that is used to prevent an error or defect from happening or being passed on to the next operation.

Quality—Conformance to the customer's requirements.

Root-Cause Analysis—A systematic method of analyzing possible causes to determine the root cause of a problem.

Spaghetti Chart—A physical map of the work area that shows the path taken by the specific product or a person being observed. A line is drawn from start to end to indicate the path moved by the product or person.

Standard—The set, defined way to do a job. As used in this context, it is assumed to be the best way to do the job or task.

Six Sigma—Technically, a statistical term meaning 3.4 defects per million opportunities. The term has come to mean a system of applying defined problem-solving techniques to improve performance. The method includes measuring performance before and after the problem-solving analysis. A Six-Sigma initiative includes systematic training to sustain the effort.

Takt Time—The time required to produce a piece of product ordered by the customer that is calculated by dividing the total production time by the number of units ordered. Takt is the German word for musical meter, and the Takt time is the drumbeat of production.

TPM—Total Preventive Maintenance. A set of methods used to ensure that production equipment is always working properly and does not stop production.

TQM—Total Quality Management. Organizing and operating all functions based on quality management principles and concepts to meet and/or exceed customers' needs and expectations. TQM is not quality control or quality assurance; it is much broader in scope. TQM has more to do with the quality of management than the management of quality. These quality management principles include:

- Having a shared vision;
- Focusing on the customer's needs;
- Maintaining the standard of zero defects;
- Using prevention, not inspection, to work to zero defects;
- Respecting people and involving them in the efforts to improve;
- Continuous improvement of all processes and systems;
- Managing by facts;
- Constantly learning how to improve; and
- Managing for results by managing the process.

TQM is best seen and evaluated using the Malcolm Baldrige National Quality Award criteria.

Value Stream—Includes all the processes and activities used to design, produce, and deliver the product or service to the customer.

Waste—The opposite of value. The seven basic types of waste include defects, waiting, transportation of goods, motion, inventory, overproduction, and unnecessary process steps.

13 END NOTES AND REFERENCES

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3. While Fredrick Taylor is credited with the principles of Scientific Management, Taiichi Ohno gives Henry Ford credit for the initial idea of Lean. Ford did not want to be associated with Taylor's works, and their ideas are very different. Taylor taught that there is one right way to do each job – e.g., shovel dirt – and that the worker should do it that way and nothing else. The worker was not to think or try new ways. Ford would determine the right place to put the dirt first. Ford and subsequently Ohno encouraged workers to be involved in finding efficiencies. See Chapter 12 of Reference 11 below.

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5. Drucker, Peter, "The Economist," p. 12, November 3, 2001.

6. To determine the amount of time it takes 5 people to process 10 cards in a single-batch method (signing and dating each one at a time then passing it to the next person), consider this: The first person takes 0.5 minute to sign and date a card and pass on to the next person. This cycle is repeated 10 times by that person (10 cards times 0.5 minute/card = 5 minutes). This assumes the time to pass the card is included in the 30 seconds. (Elapsed time is 5 minutes when the first person is finished.) The second person must wait 0.5 minute to receive the first completed card; it then takes him 5 minutes to process all 10 cards, one at a time. (Elapsed time is 5.5 minutes when the second person is finished.) The third person must wait a minute to receive the first completed card; it then takes him 5 minutes to process all 10 cards one at a time. (Elapsed time is 6 minutes when the third person is finished.) The fourth person must wait 1.5 minutes to receive the first completed card; it then takes him 5 minutes to process all 10 cards one at a time. (Elapsed time is 6.5 minutes when the fourth person is finished.) The 5th person must wait 2 minutes to receive the first completed card; it then takes him 5 minutes to process all 10 cards one at a time. (Total elapsed time is 7 minutes when the last person is finished.)

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14 APPENDIX A – EXAMPLES OF LEAN COMPANIES

The following are examples of Lean companies and their achievements. All are recipients of the Shingo Prize for Excellence in Manufacturing. This award is named for Japanese industrial engineer Shigeo Shingo who distinguished himself as one of the world's leading experts in improving manufacturing processes. Dr. Shingo has been described as an "engineering genius" who helped create and wrote about many aspects of the revolutionary manufacturing practices that comprise the renowned Toyota Production System.

Maytag's Jackson Dishwashing Products, Jackson, TN, is the exclusive manufacturer of dishwashers for the Maytag Corporation. Some of their recent achievements are as follows:

- Reduced OSHA recordable injury rate by 64%,
- Improved attendance by 16% to 99.1%,
- Improved employee turnover by 50%,
- Transformed very flexible single assembly line with capability to produce "any model/any day" into eight single-piece flow assembly cells with capability to produce "any model/any hour,"
- Improved labor hours to produce a unit by 29%,
- Increased manufacturing floor space approximately 32%,
- In 2003 alone, conducted over 2,000 Kaizen Events and performed 53 Six Sigma projects to help generate several million dollars in cost reductions,
- Machine uptime consistently over 99%,
- Reduced scrap and rework costs by 64%,
- Improved first pass yield by 84% to 99.15%,
- 2002 *Industry Week* – Best Plant finalist, and
- 2003 Shingo Award finalist.

The **ArvinMeritor Gladstone** facility, located in Columbus, IN, was constructed in 1955 to produce light vehicle mufflers for the Ford Motor Company. Some of their recent achievements are as follows:

Quality

- Decreased customer PPMs by 72% (since 2000),
- Decreased supplier PPMs by 99% (since 2000),
- Reduced scrap by 43% (since 2000), and
- Decreased cost of non-quality by 54% (since 2000).

Productivity

- Increased finished goods inventory turns by 30% (since 2000),
- Averaged 36 total inventory turns,
- On-time delivery average is 99.99% (since 1999),
- 100% of all work units have adopted cellular manufacturing,

- Reduced inventory by 73% (since 1993), and
- Increased sales per employee by 12% (since 1999).

Employee Involvement

- 40 hours of annual training per employee (since 1997),
- Average of 21 Kaizen ideas submitted annually per employee (since 1997),
- Average annual savings per employee is $4,285, $204 per Kaizen idea (since 1997),
- Idea implementation rate is 95%,
- Safety incidents declined 86% (since 1999),
- Incident rate dropped 48% (since 2002), and
- Lost-time rate dropped 60% (since 2002).

Plant Recognition

- Ford Q1,
- Ford Full-Service Supplier Award,
- Four-time recipient of the State of Indiana Quality Improvement Award,
- State of Indiana Governor's Award for Excellence in Recycling,
- Indiana Department of Environmental Management 100% Club Award,
- Recipient of 11 ArvinMeritor corporate awards, and
- 2002 Shingo Prize finalist.

Raytheon Missile Systems is the world leader in missile technology and production. The 10,000 employee Tucson, AZ, site works to satisfy the numerous missile mission requirements of the US military.

Delivery

- On-time delivery metric improved by over 38% since implementing Lean.

Quality

- Over 91% success rate on complex program flight tests, and
- First pass yield rates on highly technical products approaching 95%.

Customer Satisfaction

- Recent customer surveys indicate that customers would recommend Raytheon again.

Cost

- Waste reduction efforts have contributed to significant program cost reductions.
- Improvement projects focusing on waste elimination have saved over $223M over the past 3 years,
- Inventory turns have improved by 29%.
- Cost reductions in other non-manufacturing areas (facilities, information technology, etc.) have been created by implementing Lean.

Environment

The employee work environment as well as the natural environment has been significantly improved as a result of the company's focus on people and process:

- Safer workplace: 1.2 injuries per 100 employees per year as following implementation of a culture of safety, 5S's, and ergonomic workstations;
- Reduced hazardous waste byproducts; and in 2003 recycled over 7,000 tons of solid waste; and
- Significantly reduced, from 1997 to 2002, volatile organic compounds emissions.

Affordable Interior Systems (AIS) Hudson, MA, facility, encompasses 2 factories. AIS produces high-quality, top-of-the-line systems furniture. AIS's 175 employees have driven these achievements:

- Productivity gains of up to 88%;
- 100% participation at AIS University where employees learn about Lean methodology and continuous improvement as a way of life;
- Average lead time of 8 days, a 33% reduction in 2 years;
- Shipping 100% on-time for the past two years with a 97.9% completeness rate;
- 76% reduction in panel Work in Progress (WIP);
- 62% reduction in PPM defects and 54% reduction in scrap over last 3 years;
- More than 40,000 square feet of storage space converted to production at two facilities;
- Setup reductions of more than 50% in several cells; and
- Rapid response and delivery to Pentagon for 2,500 workstations to accommodate displaced workers after 9/11 attack.

Source*: www.Shingoprize.org*

15 APPENDIX B – WHERE TO GET HELP

The 5S's

- ***Sheet Metal Made Lean and Clean***, by David Skinner, SMACNA Publication, December 1999.
- ***5 Pillars of the Visual Workplace*** by Hiroyuki Hirano, Productivity, Inc., Portland, OR,

  (1-800-394-6868) www.productivityinc.com.
- "**A Place for Everything and Everything in Its Place**," by Katie Rotella, PM Magazine, February 2003, p. 48.
- "**5S's that would make any CEO Happy**," by Dennis Sowards, Contractor Magazine, May 2004.
- To order the "**The 5S's at Boeing**" videotape, contact Dan Kays at Boeing at (206) 662-0853 or go to

  www.Boe ingimages.com.

Lean Concepts

- ***Lean Thinking*** by James P. Womack and Daniel T. Jones, Simon & Schuster, New York, NY, 1996.
- ***Lean Transformation*** by Bruce A. Henderson and Jorge L. Larco, The Oaklea Press, Richmond, VA, 1999, email: OakleaPres@AOL.com.

- "**The New Manufacturing Challenge**," by Kiyoshi Suzaki, The Free Press, New York, 1987.
- ***Lean Solutions: How Companies and Customers can Create Value and Wealth Together***, by James P. Womack and Daniel T. Jones, Free Press, Simon and Schuster, 2005.
- ***The Toyota Way***, by Jeffrey K. Liker, McGraw-Hill, New York, NY, 2004.

Web Sites

- Lean Construction: www.leanconstruction.com
- Lean Thinking: www.lean.org
- *Learning about Lean*: www.joeelylean.blogspot.com
- Lean Ideas on the Web: www.productivityinc.com

16 APPENDIX C – LEAN SURVEY

A web-based survey was conducted using SMACNA top contractors by size. The survey population was 1,079 contractors, all having email addresses. There were 88 responses yielding a response rate of 8.2%. A summary of the survey responses is shown below.

Are you familiar with Lean as in Lean Thinking and the Toyota Production System?

58% Said Yes 42% Said No

What/who was your source for learning about Lean?

33% through SMACNA offered workshops and material

29% from books and industry magazines

8% through the Lean Construction Institute

8% from other associations including Construction Users Roundtable (CURT) and Mechanical Contractors Association of America (MCAA)

8% from consultants

5% from other companies, contractors, or peers

4% from customers

Note that the total is greater than 100% because some cited more than one source.

Have you implemented Lean in your company? (Answered only by those who were familiar with Lean.)

48% Said Yes 52% Said No

Which Lean tools were implemented?

77% JIT

53% Last Planner System

53% Process Analysis

47% 5S's

41% Value Stream Mapping

35% Root-Cause Analysis

29% Reduce Setup Time

18% Kanban

18% Kaizen Event

12% Visual Controls

12% Plus/Delta

12% Total Preventive Maintenance

6% Spaghetti Chart

6% Rules of Release

0% Takt Time

0% Poka-Yoke

0% PDCA

On a scale of 1 to 5, rate the value you feel Lean has to offer your company in the following areas, where 1 means no or very little value and 5 means very high value:

AREA	AVERAGE RATING
Shop Operations	4.47
Field Installation	3.74
Office	3.65
Support Functions	3.56
Service	3.17

On a scale of 1 to 5, rate the value you feel Lean has to offer general contractors, where 1 means no or very little value and 5 means very high value:

General Contractors 4.09

On a scale of 1 to 5, rate the value you feel Lean has to offer your subcontractors, where 1 means no or very little value and 5 means very high value.

Subcontractors 3.94

What are the top most useful Lean tools for your company and why?

1. Last Planner System
2. JIT
3. 5S's
4. Value Stream Mapping

Would you like to learn more of how Lean can help your company?

78% Said Yes 22% said No

Demographics of Survey Respondents:

Size by Average Number of Employees

41% were in the 1 to 99 employees range

38% were in the 100 to 299 employees range

21% were in the 300 or more employees range

Type of Worked Performed

92% New construction

78% Retrofit

70% HVAC service

34% Other: Including specialty fabrication, air balance, and general contracting

Customer Type Served

94% Commercial

83% Industrial

32% Residential

64% Government

66% Schools

Key Contractor Responses by Size

By # of Employees	1 to 99	100 to 299	300 or more	Combined
Familiar with Lean - Lean Thinking and the Toyota Production System	46%	56%	88%	58%
Have implemented Lean in Your Company	50%	28%	69%	48%
Would like to learn more of how Lean can help your company?	83%	77%	60%	78%

Customer Type	Commercial	Industrial	Residential	Government	Schools
Familiar with Lean - Lean Thinking and the Toyota Production System	58%	60%	46%	61%	57%
Have implemented Lean in Your Company	51%	44%	42%	46%	50%
Would like to learn more of how Lean can help your company?	78%	82%	81%	70%	75%

17 ABOUT THE AUTHOR

Dennis Sowards has more than 10 years of experience in mechanical contracting and over 30 years in helping companies improve the quality of how they manage. He was formerly with Kinetics Systems, where he was the manager of continuous improvement and communications. Dennis is a member of the *Lean Construction Institute* and the *American Society for Quality*.

Dennis has also completed the *Measuring Customer Loyalty* research project for the New Horizons Foundation. Dennis holds a BSE and an MBA from Arizona State University. You can reach him at (480) 835-1185 and through www.YourQSS.com.