Lean Manufacturing — A Systematic Approach to Improving Productivity in the Precast Concrete Industry

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This article presents an overview of lean manufacturing, a process by which precast concrete plants can reduce waste and improve their production operations. The authors describe eight types of waste that can be eliminated and identify seven principles that can substantially improve success in the application of lean manufacturing. Many examples from the industry are given to show how waste can be eliminated and plant operations can be improved. Although relatively few PCI member companies are currently using lean manufacturing, those that are applying these techniques are showing that production costs have decreased, rework has been reduced, and production capacity has been enhanced.

The industrial engineering discipline known as lean manufacturing has been applied in manufacturing in the United States and other industrialized countries for more than a decade. At one time, the process was called "Just in Time" manufacturing.

Despite its wide use in other industries, lean manufacturing has only recently been applied to the precast concrete industry. Today, it is estimated that about 5% of PCI Producer members have undertaken a serious initiative in applying lean manufacturing. At this writing, 8 to 10 companies have active lean manufacturing programs out of about 150 PCI Producer member companies in the United States. The initial reports cited in this article and elsewhere suggest that these companies (**Fig. 1, 2**) are attaining a 20% or more improve-

Photo courtesy of Oldcastle Precast, Inc.

Fig. 1. In this plant, hollow-core productivity increased by 18% and wet-cast productivity increased by 48%.

Photo courtesy of Heldenfels Enterprises, Inc.

Fig. 2. Beam production increased by 50% in this plant without new capital spending.

ment in labor productivity per year, up to a 50% increase in production (without major capital spending), and up to a 50% reduction in defects and rework.

Despite these early successes, the companies also report considerable difficulties both in startup (typically after an initial failure) and in sustaining the gains achieved. In actuality, there is both great promise and recurrent problems in applying lean manufacturing principles. This article reviews the application of lean manufacturing to the precast concrete industry and provides producer management with the means to evaluate these methods, proceed logically, and avoid typical pitfalls.

WHAT IS LEAN MANUFACTURING?

Lean manufacturing is a systematic approach to process improvement. The method is based on finding and reducing waste coupled with continuous improvement. It was first developed by Toyota (the Japanese car manufacturer), but has now been applied to many diverse industries and businesses. In particular, tools have been developed that help producers stay focused on finding and reducing waste.

Lean manufacturing methods have been applied across entire firms, including engineering, administration, and project management departments, as well as manufacturing and construction. Lean manufacturing finds waste and reduces costs. Its end purpose is to transform a company into an efficient, smoothly running, competitive, and profitable organization that continues to learn and improve.

Reduction of Waste

Lean manufacturing starts by defining "value added." Value added is defined as any activity that transforms the product toward what the customer wants. Everything else is defined as "waste." Waste is any processing step that consumes resources without adding value. The lean manufacturing discipline has identified eight categories of waste (**Table 1**). Often, businesses have become so accustomed to waste that it is not recognized. Just learning to identify waste is an important part of the lean manufacturing process.

To illustrate this point, an operations manager noted[1] recently that pedometers were placed on plant personnel working on a long-line casting bed. It was revealed that these workers walked as many as 11 miles (18 km) per day. Time studies[2] have shown that precast concrete plant personnel typically are paid one to two hours a day for just walking. Walking is not value added, and does not transform the product toward what the customer wants. Thus, unnecessary walking is waste.

Here is another illustration. An architectural precast concrete plant manager observed six operations personnel in the yard. One was sandblasting a panel while the other five were operating or riding lifts, patching, walking, and waiting. In reality, the customer is only interested in seeing the panel sandblasted, an operation that adds value to the product. The other operations do not add anything to the value of the panels in the yard; the customer is not willing to pay for any of those valueless operations. Therefore, those operations are all defined as waste.

The natural inclination is to focus on the value added operation, such as sandblasting, and look for ways to improve that operation through technology. By looking at the world through eyes trained in lean manufacturing, however, we are suddenly able to see waste that is a good candidate for elimination. This phenomenon has been called "Lean Thinking."[3]

A recent cross-industry study involved 120 companies

Table 1. Eight types of waste* that occur in the precast concrete industry (see continuation of table on the next page).

Waste Type	Description	Typical Examples of Waste	Typical Root Causes
Motion	Any movement of people or machines that is not value added†	• Walking or looking for tools, parts, drawings, people, information • Checking, counting, measuring • Extra product handling or product arrangement	• Poor workplace organization, visual control, and housekeeping • Lost items (searching) • Inadequate training and inconsistent work methods or standards • Misunderstanding • Scheduling changes to correct on-time delivery problems • Poor tool design
Waiting	Idle time created while waiting for items that are not immediately available	Waiting for: • Drawings, information • Approvals • Tools • Quality control inspection • Rework corrections • Materials—concrete, inserts, reinforcement • Concrete cylinder breaks • Crane or equipment availability • Watching a machine run	• Poor layout • Drawings not ready, incomplete • Project management approvals • Upstream quality problems • Poor scheduling or work balance • Poor employee sub-objectives • Waiting on materials, or no materials • Unexpected problems • Large lots • No tools or wrong tools • Unreliable equipment
Defects	Product does not meet customer specifications	• Design errors • Drawing errors • Fabrication errors • Casting defects • Materials defects • Inspection errors • Concrete finishing defects • Repetitive defects	• Not doing it right the first time • Incomplete project specifications • Specification requirements not understood • Customer needs not understood • Inadequate sample approvals • Poor manufacturing methods and standards • Confusion over drawings, parts, materials • Poor training/Don't know • Inattention /Don't care
Transport	Moving work over short or long distances without adding value	• Inefficient material flow within the plant or yard • Repetitive handling of concrete, parts, or product • Transport-related waste in space, people, and tracking systems	• Poor layout between operations • Poor design of process flow • Work in process storage • Temporary storage areas • Disorganized storage areas

*Waste: Any activity that consumes resources but does not add value.

†Value added: Any activity that advances the product toward what the customer is buying; any essential, transforming step.

that tracked their day-to-day activities. The results indicated that, on average, only 5% of activities were value added while the remaining 95% are waste. Today, Toyota and other companies actively participating in lean manufacturing have increased their value-added activities to about 35%.[4]

Plant management is generally doing everything they know how to do to improve efficiency. In this environment, lean manufacturing has been effective because it brings two entirely new dimensions to the aid of plant management. The first is the new definition of waste, which can be used with new ways of looking for waste such as "value stream mapping" (see the following section). The second is specific new tools and methods to reduce waste, also found in the following section.

Value Stream Mapping

The basic, analytical starting point in the lean manufacturing process is to break down the work process into detailed steps. The process steps are then classified as either value added or waste. **Table 2** provides a good example of this

Table 1. Continued from previous page.

Waste Type	Description	Typical Examples of Waste	Typical Root Causes
Overproduction	Making more product earlier or faster than is required by the next process step	• Work in process inventory • Repetitive handling • Inventory space required • Paperwork and communication • Extra product is scrapped	• Poor scheduling • Missed pours, missed schedules • Disruptions caused by rework • Equipment breakdowns • Inspection delays • Need something to do
Inventory	Inventory in excess of the minimum needs of the next transforming step	• Work in process waiting to move to the next step • Finished goods in excess of next erection phase • Raw materials in excess of minimum stocks needed	• Poor scheduling • Rework delays • Unreliable shipments by suppliers • Unreliable production steps in the plant • Misunderstood communications • Acceptance of overproduction • Inventory is comforting • Buffer against downtime
Process	Work processes or materials that add no value to the product from the customer's viewpoint	• Handling parts, products, tools, or paperwork more than once • "Feel good" steel not required by the design • Over-thick welding • Extra rich design or batching chemical usage • Finishing beyond specification • Excessive form oil	• Traditional way it's always done • Aggregate moisture out of control • Lack of process controls • Inattention to process controls • Customer requirements not defined • Product changes without process changes • Lack of process standardization • Missing or improper fixtures, tools, jigs
People	The waste of not using employees' mental, creative, or physical abilities	• Wasteful work practices • Poor safety record, injuries • Busy work that could be eliminated • Waiting to be told what to do • Working without a plan, objectives, standards • Repetitive errors—rework • Lack of engagement, slow to react • Missed pours • Low labor productivity • Overtime as a way of life	• Low expectations • Failing to involve the people who do the work when looking for solutions to problems • Poor hiring practices • Low investment in training • High employee turnover • Poor leadership, micromanagement, reactive management • Organizational layering

process. The key insight to be extracted from the information in Table 2 is this: 90% of the effort that is expended in this "steel shop" example does not add value to the product, at least from the customer's viewpoint.

The reality is that once producers see their manufacturing processes in this manner, they typically find that less than 10% of their work activities are value added. Waste is typically even worse in non-manufacturing processes.

Once the value added and waste process steps are identified, the next step is to combine this value classification with a process chart that shows the material flows and processing steps pictorially. The result is the value stream map that illustrates how value is added to the product. The value stream map identifies waste and redundancies so that lean tools can be applied (**Fig. 3**).

LEAN MANUFACTURING METHODS AND TOOLS

Lean manufacturing provides tools and methods that effectively reduce waste once it is recognized in the workflow. Here is a brief summary of some of the tools that producers have used successfully:

- **Rapid improvement events (also called "Kaizen")** — This tool involves setting up a cross-functional waste reduction team to focus on a specific problem area. The team (6 to 10 people) usually includes staff from management, engineering, and sales, as well as salaried and hourly production staff. The team sets goals and is guided by an experienced team member. The team follows a proven method to find—and then eliminate—

Table 2. Example of value stream classification in the steel shop.

Activity	Value Added*	Time, min	Waste†	Time, min
Unload reinforcing bar from delivery truck			Transport	12
Shake down bar from storage racks			Motion	5
Transport bar to shear			Transport	5
Set stops for cutting bar			Process	1
Cut bar on shear	Value added	3		
Stack bar in piles			Motion	3
Transport to bender			Transport	7
Set stops on bender			Process	1
Bend bar	Value added	3		
Stack bent bar in piles			Motion	7
Wait for crane to be available			Waiting	3
Transport to cage building area			Transport	10
Total of all activities	10%	6	90%	54

*Value added: Any activity that advances the product toward what the customer is buying; any essential, transforming step.

†Waste: Any activity that consumes resources but does not add value.

waste in a certain work area within a given time period (typically five days). The team then creates standard work programs so that the gains can be sustained. Producers typically have one or more Kaizen events per month that focus on different areas of the plant or office.

- **Standardized tasks** — There is usually one way to perform a task most efficiently. The key milestones in a Kaizen event are to find waste, eliminate waste through improved methods, apply the methods to get efficient flow, and then standardize the tasks and methods. The standardized tasks should then be recorded for use in training and for reference **(Fig. 4)**.
- **Balanced flow (sometimes called "Takt time")**—Once standard tasks are established, process cycle time and standard staffing can be developed. Balancing staffing and material flows **(Fig. 5)** to minimize walking, waiting, and repetitive material handling is frequently a source of significant improvement in precast concrete plants. Achieving balanced flow is a fundamental objective.
- **Workplace organization (sometimes called "5-S")** — Many producers are familiar with this workplace organization and housekeeping system and have tried it. Unfortunately, many producers have also found that it is easy to slip back into poor habits. Clutter wastes time and hinders standardization.
- **Visual controls** — This tool can be as simple as painting lines on the floor to guide the placement and flow of materials. Visual controls communicate essential information without words **(Fig. 6)**. They almost seem to make operations and product flow an intuitive process.
- **Plant layout** — Most producers find many opportunities to streamline material flow, minimize crane time, and reduce walking. This tool includes an analysis of flow and how it relates to inventory. The carpenter shop and the steel shop are often a good place to start. A thorough analysis, together with Kaizen events, can help to locate substantial waste opportunities and to correct them **(Fig. 7)**.
- **Mistake proofing** — All processes should be designed so that it is harder to do them wrong than to do them right. For example, it pays to think about the design of cast-ins so they do not look similar and

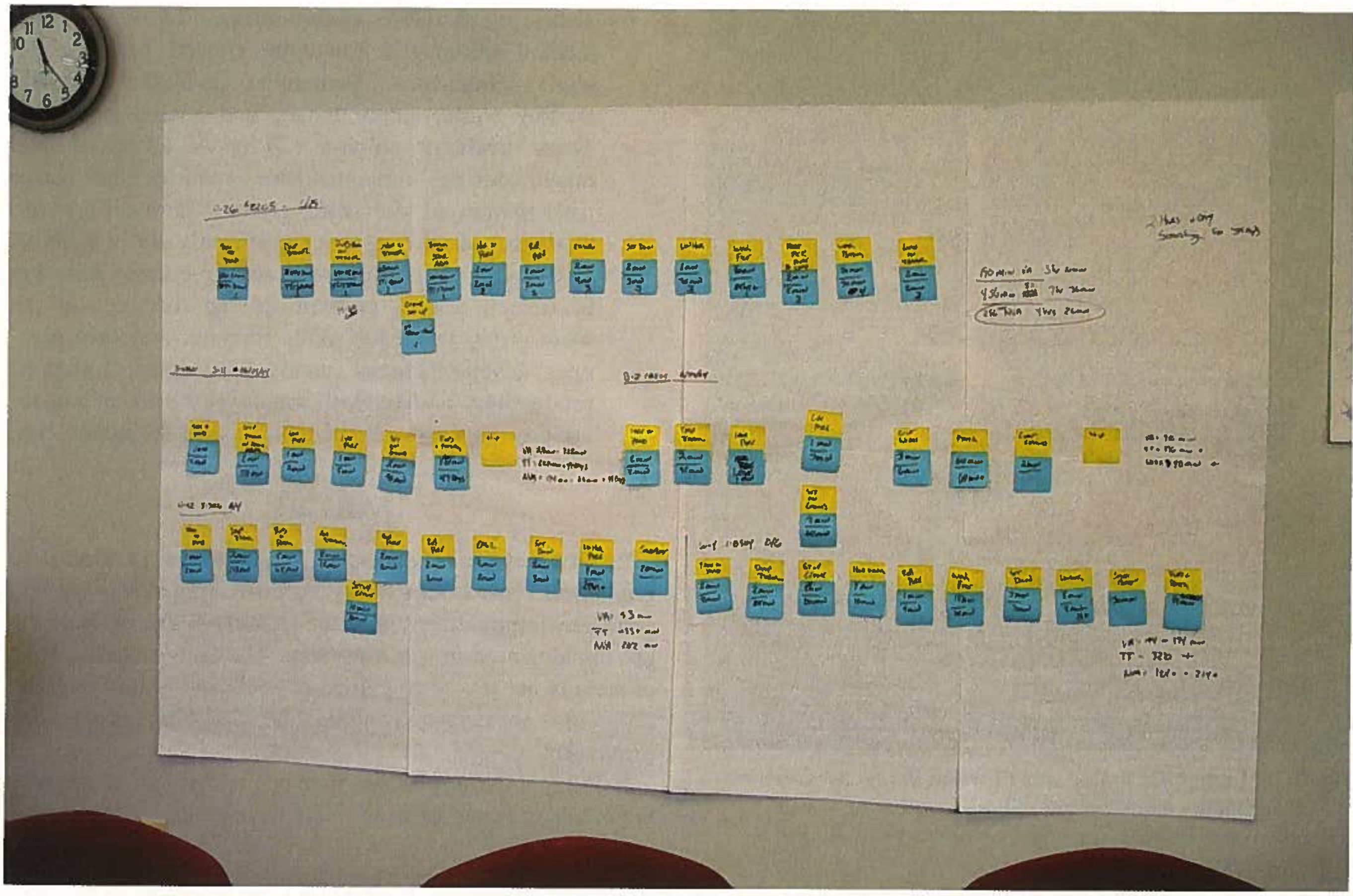

Photo courtesy of Spancrete Industries, Inc.

Fig. 3. Example of value stream mapping.

cannot be put in backward or in the wrong place. As another example, common reference point dimensioning should be standard practice on shop drawings.

- **Lead time reduction** — Producing a work product in batches that are unrelated to immediate need is almost always a wasteful practice. There are several examples that illustrate this point. Vendors deliver their goods in batches that are frequently unrelated to production needs. Shop tickets are chronically late due to batching in the drawing or approval process. Standard precast concrete products, such as manholes, are built to stock rather than built to a customer order. In the end, improved efficiency comes when operations are closely driven by customer demand.
- **Inventory reduction** — Inventory is waste for the following reasons: It has to be handled and stored. It is often subject to damage or obsolescence. Someone must keep track of inventory and find it when needed. It ties up capital that should be earning a return on an investment. To be specific, work-in-process inventory beyond the needs of the immediate casting is waste. There are opportunities to reduce finished-goods inventory and still maintain the accelerated construction schedule the owner demands. For example, during production scheduling, pieces with the same mark number are often batched together. This is a practice that usually results in excessive finished goods inventory.
- **Correction at the source** — Quality cannot be in-

Photo courtesy of Oldcastle Precast, Inc.

Fig. 4. Before spending large sums of money on an automated cutting and bending machine, correct the source of most waste with improved material flow and standardized procedures.

Photo courtesy of Oldcastle Precast, Inc.

Fig. 5. Bed setup is a major area of waste in precast concrete plants and offers many opportunities for reducing waste through more efficient procedures, standardization, and improved material flow.

spected *into* the product; it must be *built* in. Self-check procedures, accountability, and mistake proofing reduce rework by prevention rather than by inspection and correction. Precast is often subject to repetitive errors. Typically, nonconforming pieces are sent to the "hospital" and not repaired by the casting crew. But, has the root cause been addressed? How often are pieces sent to the jobsite knowing that they will require fieldwork? Plant systems that correct nonconformance by prevention are the most efficient, resulting in a huge payoff for most producers. Most producers are familiar with the "rule of 10" because it speaks to the value of prevention rather than correction: It costs 10 times as much to fix it in the yard as it does to do it right the first time, and it costs 10 times as much to fix it on the job as it costs to fix it in the yard.

- **Bed setup reduction** —The schedule for the manufacturing of precast concrete components is typically constrained by bed setup times. Planning, standardization, materials staging, and consciously working to minimize crew movement and walking can reduce bed setup time. Most producers find multiple opportunities to streamline bed setup and reduce the opportunity for error. Streamlined bed setup typically improves flexibility and reduces work in process and finished-goods inventory (Fig. 5). Improved bed setup often is the key to pairing production closely with customer demand. Here is a signal for management: When the setup crew is spread out over the length of the casting bed, an opportunity for waste reduction exists.
- **Total preventative maintenance (TPM)** — This method minimizes downtime created by unscheduled maintenance. Equipment breakdowns create waiting waste, safety issues, and quality problems.
- **Team problem solving (TPS)** — Effective lean manufacturing implementation requires the active participation of the work group. There are proven methods and training that significantly aid in team effectiveness. This step requires structured inclusion in Kaizen events, problem-solving meetings at the work-group level, job skills training, and best practices development of standardized tasks. Increased productivity and reduced employee turnover and retraining expenses are benefits reaped by using TPS.

FAILURE

It is typical for producers to fail in their first attempt to implement lean manufacturing. A few Kaizen events are held and many improvement ideas are generated. The ideas do not get implemented in a lasting way. The lean manufacturing process is not linked to company goals and objectives. The program is not sustained and falls far short of continuous improvement.

Industry experts observe that up to 90% of those who begin a lean manufacturing program quit shortly thereafter.[5] Another 5% to 7% persist in form, but without substance. This means as little as 3% of businesses truly transform the way they are doing business and achieve the continuous improvement that is possible when following lean manufacturing principals.

KEYS TO SUCCESS

Lean manufacturing can truly transform an organization. Indeed, by its very definition, the lean manufacturing process will not be successful unless a company changes the way it does business. What do the experiences of producers tell us about what it takes to succeed?

Management commitment — The lean manufacturing process is implemented at the worker level, but it has to start at, and be clearly supported by, top management. For example, the general manager/chief executive officer should be involved in leading some Kaizen events. An ongoing 20% improvement in productivity does not happen by itself. Management must be involved and personally vested in the results. Top management should expect their personal commitment to exceed one year before the process becomes embedded and self-sustaining.

Learning and change — Lean manufacturing is a learning process resulting in permanent change; Kaizen events typically set the pace. As a rule of thumb, the number of events that should be scheduled yearly is set at plant employment divided by 10. If a plant has 150 employees, experience has shown that 15 Kaizen events per year is a reasonable pace. Learning the "why" of lean manufacturing should be an important part of every Kaizen event. These events truly enlighten and inspire most participants. Pace is important; information should be presented at a rate that does not overwhelm. Similarly, events

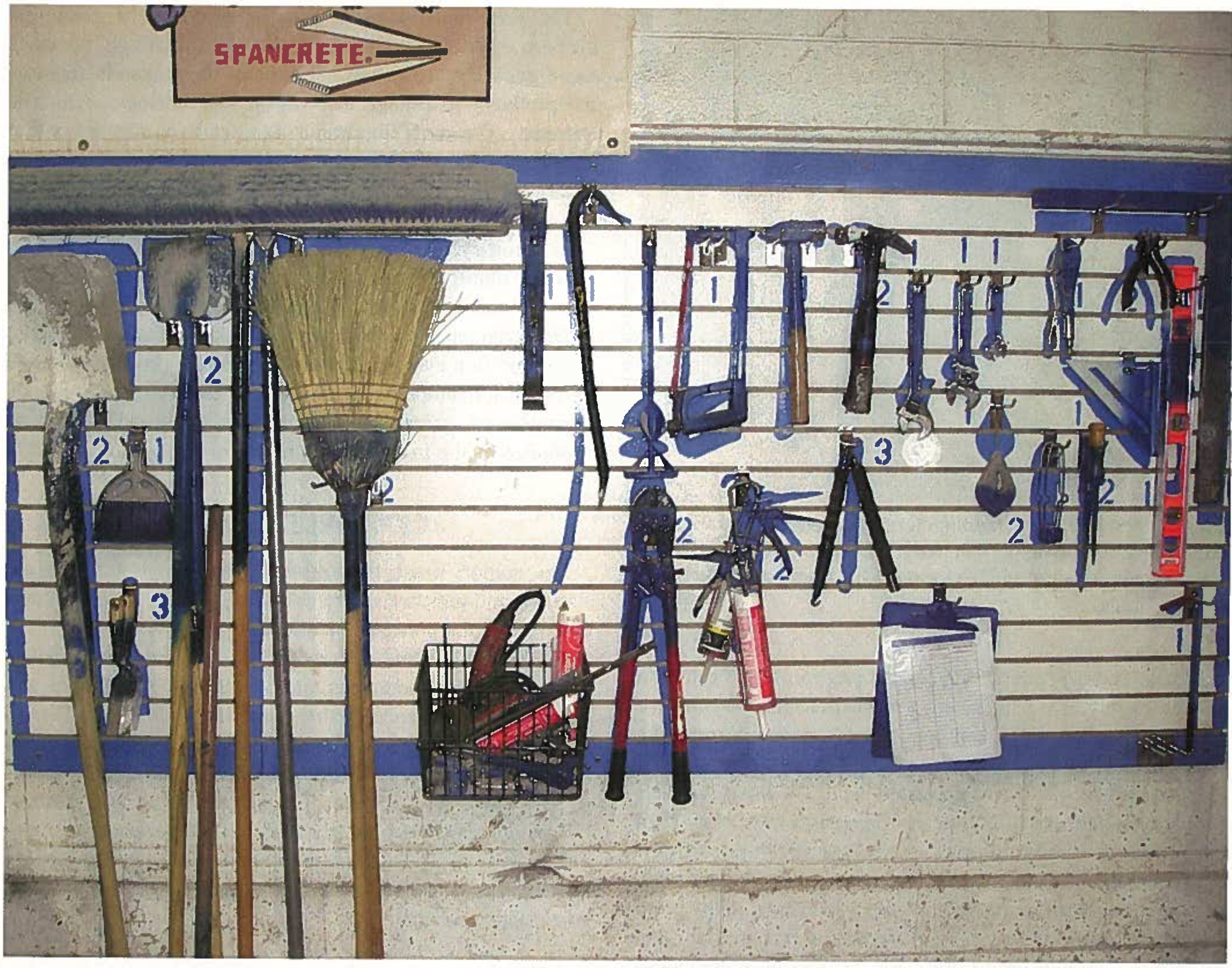

Photo courtesy of Spancrete Industries, Inc.

Fig. 6. Shadow boards and visual aids are valuable means for improving efficiency and safety in plants.

must be frequent enough to maintain interest and excitement. The bottom line is that management must be confident that learning and transformation are taking place.

Dedicated staffing — The most common start-up errors are to assign the lean manufacturing initiative to a manager or supervisor as a part of other duties, to rely excessively on consultants, or both. Lean manufacturing needs a full-time champion to facilitate the process. Dedicated staffing should be equal to about 1% of plant site workers. For a plant with 100 employees, there should be 1 person with no other duties aside from focusing on lean manufacturing. For the smaller plant, the lean manufacturing champion will have nonproduction complementary duties such as quality control, personnel, or process engineering. A lean manufacturing initiative will typically reduce salaried and hourly staffing enough to easily find the appropriate headcount. Hiring should be from within if the right person is available and lean manufacturing training can be provided. Alternatively, about half of producers have hired a person with lean manufacturing experience and then trained them in the precast concrete business.[6] An active and aggressive lean manufacturing champion will more than pay for his or her salary.

Organization structure — Often the lean manufacturing champion reports operationally to the plant manager. There are three important organizational guidelines that should be followed. First, while not disturbing operational reporting, successful producers typically create a steering committee that represents all of the company's key functions, including project management, engineering, and sales. Second, hourly employees at the work-group level must be consciously included. They will provide significant input to the insights in a Kaizen event. Third, the lean manufacturing champion should act only as a facilitator. Production supervision and the work crews must own the process and be accountable for achieving the results.

Management style — The lean manufacturing process requires an involved and participative management style. This is something managers can learn how to do, but it can be a challenge. If this type of management style is a poor fit to the corporate culture, then lean manufacturing may not be effective. It is frequently the case that lean manufacturing is a poor fit to the management style of a certain supervisor. That person will have to be retrained in a new management style or moved to another position where he or she cannot try to defeat the lean program.

No cuts policy — Lean manufacturing should not be per-

Photo courtesy of Oldcastle Precast, Inc.

Fig. 7. Precast concrete manufacture involves considerable handling and moving of both materials and finished products, creating ample opportunities for reducing transport and waiting waste.

ceived as "cold-hearted." Successful programs are built on a no-cuts policy. It is usually not a problem to finesse turnover and work assignments, but job security concerns must be recognized at the beginning.

Consultants — Getting started is not a do-it-yourself project; this course of action has proven to have very high cash costs in failed initiatives, as well as a high rate of failure to achieve the identified productivity goals. A lean manufacturing consultant must be found who can be in the plant frequently until the company champion is fully trained and effective. The consultant does not need to be knowledgeable in precast concrete, although this knowledge does help. When researching a consultant, there are several key items to keep in mind. The consultant should have had experience in the lean manufacturing transformation process as a high-level manager or leader with a proven track record of implementing lean manufacturing tools. As well, that person should have had line managerial experience above the supervisory level. The documented rule of thumb is that the first year's payback will be three times the consulting fee and dedicated staff expenses, and five times those expenses in subsequent years.[5]

Further reading on lean manufacturing can be found in the Suggested Reading section at the end of this article.

CONCLUSION

Producers who have successfully implemented a lean manufacturing program are lowering costs, improving productivity, and improving quality. Ultimately, producers following lean manufacturing principals will grow, inspiring new producers to adopt this discipline; indeed, based on the authors' observations, this is already happening. Precast concrete is a cyclical industry, often with commodity margins. Lean manufacturing can translate into a 20% improvement in productivity and a sharp reduction in rework, which can easily double profits.

The lean manufacturing process provides an economic cushion at the bottom of the cycle and effectively provides more capacity at the top. Achieving these results requires the producer to change the way it does business, which is not easy. The most important ingredient for success is that continuous improvement must become a business mantra, embraced by employees at all levels and supported by the management system.

In summary, lean manufacturing is not a fad, and the precast concrete industry is ripe for the producer who wants to embark on a real transformation. The producer who is willing to find the right person to get them started, make the staffing commitment, question every aspect of their current process, and stay on the lean manufacturing course will experience continuous improvement, grow profitably, and be in a good position to capitalize on the future opportunities in our industry.

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SUGGESTED READING

1. Emiliani, B., Stec, D., Grasso, L., Stodder, D., *Better Thinking, Better Results*, The Center for Lean Business Management, Kensington, CT, 2003.
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2. Galsworth, G. D., *Visual Systems, How to Improve Quality and Productivity Through Non-Verbal Signs, Signals, Controls, and*

Constraints, American Management Association, New York, NY, 1997.
This book is a comprehensive guide to a successful approach that uses visual indicators, signs, and controls to direct and support activities on the shop floor.

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This is the sequel to the author's earlier successful book, *Kaizen*. This book summarizes and extends much of the earlier work with examples and case studies. "Gemba Kaizen" means continuous improvement in the workplace.
4. Kobayashi, I., *20 Keys to Workplace Improvement*, Revised Edition; Productivity Press, New York, NY, 1995.
The author highlights 20 different skills in a broad perspective that can be used to make the lean manufacturing journey possible. It also contains an evaluation system that helps pinpoint facets where improvements are needed.
5. Liker, J. K., *Becoming Lean: Inside Stories of U.S. Manufacturers*, Productivity Press, New York, NY, 1997.
A book written by senior executives who have led and implemented lean manufacturing processes in their careers. Only read this book *after* you have read *Lean Thinking*.
6. Mondon, Y., *Toyota Production Systems,* Third Edition, Springer, 1998.
Since the first edition (1983), this book systematically describes the changes that have occurred to the most efficient production system in use today. It is written for both practitioners and academics, providing a balanced and broad approach to the Japanese production system.
7. Rother, M., Shook, J., Womack, J., Jones, D., *Learning to See*, Spiral Edition, Lean Enterprise Institute, Brookline, MA, 2003.
This is the starter book for value stream mapping. Techniques are outlined and clearly illustrated. The text is easy to read without a lot of academic jargon. The seven guidelines found in Section III are particularly helpful.
8. Suzaki, K., *The New Manufacturing Challenge, Techniques for Continuous Improvement*, Free Press, New York, NY, 1987.
This introductory text describes factory operations practicing lean production, but not how to convert a traditional plant. There is a 3.5-hour complementary video available from the Society of Manufacturing Engineers.
9. Womack, J. P., Jones, D. T., and Roos, D., *The Machine That Changed the World: The Story of Lean Production,* Harper Perennial, New York, NY, 1991.
This is the seminal book on lean manufacturing. This study of the world automotive industry by a group of MIT academics reached the radical conclusion that the Mercedes craftsman techniques were a throwback to the pre-industrial age, while Toyota was far ahead in both cost and quality. This book is a very useful and informative account of what this important production development and technique exactly is.
10. Womack, J. P. and Jones, D. T., *Lean Thinking: Banish Waste and Create Wealth in Your Corporation* (Revised and Updated), Free Press, New York, NY, 2003.
All serious lean manufacturing organizations have this book as required reading for all key managers, supervisors, and staff members. Many companies have gone so far as to provide copies of this book to all employees in their organization.

ON THE WEB

The PCI Process Improvement Committee publishes an e-newsletter devoted to process improvement in member facilities. Process improvement articles typically focus on productivity improvements achieved by working smarter.