

# Pilot Study: Applying Lean to Factory Home Building

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US Department of Housing and Urban Development  
Office of Policy Development and Research

# **Pilot Study: Applying Lean Principles to Factory Home Building**

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# 1

## EXECUTIVE SUMMARY

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Lean production is an approach to manufacturing originally developed by Toyota that strives to eliminate all kinds of waste (time, money, materials, etc.) while creating a culture within the plant of continuous improvement. Lean processes have long been used in other industries, notably automotive, to improve quality while reducing the overall cost of production; however, they are relatively new to the factory built housing industry.

Nine manufactured and modular home production plants were trained and coached in the implementation of lean production methods to their manufacturing facilities. Representatives from each plant attended a week-long training workshop on lean production conducted by the Manufactured Housing Research Alliance (MHRA). Following the workshop, researchers from MHRA helped plant employees analyze their production process using a lean production tool known as *value stream mapping*. Value stream mapping helped the plants identify waste and target specific portions of the production process for intensive improvement activities known as rapid process improvement (RPI) events, conducted with MHRA support.

Results from the RPI events indicate that lean production techniques can provide striking efficiency, quality and other improvements for housing plants. Specific plant production departments experienced productivity improvements ranging from 10% to over 100%. Examples of quality improvements included one plant where defects in the finished drywall process were reduced by 85%. Taken as a whole, the lean production activities have boosted worker morale and improved communication between management and workers.

Each plant conducted at least three major RPI events over the course of eight months. At the conclusion of the project, representatives from the nine plants reconvened to share experiences in an industry-wide symposium.

# 2

## PROGRAM DESIGN

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### 2.1 OBJECTIVES

The objective of this research was to develop and implement lean production techniques for factory built housing and demonstrate their value to both the HUD-code and modular segments of the industry. Guided by the principles of lean production, researchers in partnership with nine housing plants explored how the manufacturing process can be reinvented to dramatically improve quality, safety, productivity, and design flexibility.

The ultimate goals of lean production are to 1) increase design and production flexibility, expanding the range and type of building solutions offered by modular and HUD-code home producers while increasing production efficiency, 2) produce and install homes with zero defects, and 3) eliminate waste in all forms, including production time, excess materials, and excess labor utilization.

### 2.2 BACKGROUND

The construction techniques utilized today in the HUD-code and modular housing industry have changed very little in the past 50 years and differ little from those employed in traditional site built housing. The facilities have gotten bigger to accommodate the larger homes the industry builds today, and materials and methods of manufacture have evolved incrementally, but little has changed in the production processes, management of these processes, materials storage and transport methods or the actual materials used in the construction of the homes. Lean techniques have helped to dramatically improve production efficiencies in other industrial sectors (notably automotive manufacture); however examples of the application of these techniques to factory homebuilding are only beginning to emerge through this and other recent efforts. This research will help to develop these techniques and demonstrate their value to the HUD-code and modular housing industry.

Lean production is an approach to improving manufacturing efficiency. The goal of lean production is to satisfy the customer by delivering the highest quality at the lowest cost in the shortest time, using less of everything. This is accomplished by continuously eliminating waste in all forms: defects, overproduction, transportation, waiting, inventory, motion and processing. Originating with the Toyota Production System, lean production is the result of decades of development by automobile manufacturers, who have reduced average labor hours per vehicle by more than half with one-third the defects. Other industries have followed the automobile industry's lead, achieving similar results. Early studies have suggested similar opportunities for housing manufacturers<sup>1</sup>.

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<sup>1</sup> Mullens, M. and M. Kelley. "Lean Homebuilding Using Modular Technology." *Housing and Society*, 31.1 (2004) 41-54. and Mullens, M. "Production flow and shop floor control: Structuring the modular factory for custom homebuilding." *Proceedings of the NSF Housing Research Agenda Workshop*, Feb. 12-14, 2004, Orlando, FL. Vol. 2.

Lean production methods focus on the value stream. A value stream is a process in which value, as defined by the end customer, is continually added to a product or service. Lean philosophy is applied to two types of value streams: product flow and production flow. Product flow is the design flow from concept to launch of a new product. Production flow is the flow of the product from raw materials to the customer. Lean philosophy encourages the mapping of the material and information flow within these two value streams to identify the value added and non-value added steps or processes. After identifying the non-value added steps in a value stream, considered waste in the parlance of lean production, management can then focus efforts to eliminate that waste and improve safety, quality, and productivity while reducing cost.

Lean philosophy is a culture that becomes ingrained in the workforce of a company. It focuses on processes. It is not merely a management technique based solely on results. The guiding principles of lean production are:

- Elimination of waste in all forms
- Continuous, customer driven workflow
- Continuous improvement
- Employee empowerment

Lean methods are applicable to manufacturing and service industries. For manufacturers, lean methods are applicable to production operations and office functions.

Typical benefits of converting from traditional mass production (sometimes termed “batch and queue”) to fully lean production can be dramatic and have been documented in a variety of industries.

Characteristics of a lean operation include:

- An orderly, clean work place
- Utilization of standardized “best practice” methods
- Plant layout designed to facilitate continuous product flow
- Just-in-time processing driven by customer demand or “pull”
- Single piece or small batch continuous workflow
- Quick changeovers of machines
- Minimal inventories
- Short order-to-ship cycles times
- Total quality control
- Defect prevention built into processes
- Rigorous application of preventative maintenance
- Team-based continuous improvement
- Partnership-oriented relations with suppliers and distributors

The project is the second phase of a research program aimed at developing lean production techniques for home building factories. Phase 1 took a high-level look at production performance, using an industry-wide survey to establish current industry baseline performance levels. Baseline performance can be used to measure the benefits of applying lean production strategies and to set

performance benchmarks for home manufacturers. The research team also performed a case study in partnership with Capsys Corporation, a steel frame modular home manufacturer located in Brooklyn, NY. This study explored the issues identified during the benchmarking study in context, while improving Capsys's production performance. This was accomplished by analyzing production processes, identifying inefficiencies, suggesting lean production improvements, and developing specific recommendations along with an implementation plan. The results of Phase 1 were documented in *Getting Lean: Assessing the Benefits of Lean Production in Factory Built Housing*.<sup>2</sup>

## 2.3 STRATEGY

In Phase 2, researchers applied the lessons learned from the benchmarking survey and the pilot application of lean production techniques in a single plant to nine additional plants. By working with a larger group of plants, researchers gained a broader understanding of the range of improvement opportunities for lean production techniques. Experiences gained by working with the nine plants can more easily be generalized to the industry at large.

In Phase 2 each plant utilized a lean tool known as value stream mapping<sup>3</sup> to identify manufacturing steps that are likely to hold great strategic opportunity in improving overall factory performance. Special consideration was given to areas known for poor quality, low productivity, capacity bottlenecks, and constraints to customization. These areas were then targeted for focused improvement activities known as Rapid Process Improvement (RPI) events.

Gaining the commitment to and ownership of the lean production process by the manufacturers' management teams and labor force is critical to any lean implementation effort. This was recognized as an essential step in the process and was accomplished by requiring that participating companies invest time and resources in the project and assign one or more senior staff members as the lean "advocate" for the plant. The lean advocates were central members of the project team and ultimately are responsible for transferring the knowledge gained through the project to the plant and to the company as a whole.

While the work conducted in Phase 2 is being reported and documented in this report, the emphasis in this effort was to transform the way homes are manufactured, reducing housing costs and improving quality. As such, the focus was on implementing changes to the production process, developing a system to institutionalize these changes within plants, and spreading the knowledge to other companies.

## 2.4 RESEARCH PLAN

The effort was conducted over an approximately 12-month period. The project plan included five steps as described below.

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<sup>2</sup> US Department of Housing and Urban Development, 2005, *Getting Lean: Assessing the Benefits of Lean Production in Factory Built Housing*, prepared by Manufactured Housing Research Alliance, New York, NY.

<sup>3</sup> A value stream is the sequence of actions (both value-added and non-value added) required to bring a product from raw materials into the arms of the customer.

### 2.4.1 Plant selection

In selecting plants to participate, researchers considered a mix of characteristics that impact production efficiency and suggested a variety of approaches for applying lean thinking. The plants selected were different in several important respects, including the following:

- Current performance as measured during Phase 1 benchmarking (efficient and inefficient operations)
- Home price point (low-, medium-, and high-priced homes)
- Product mix (e.g., single- and multi-section, HUD-code and modular)
- Geographic location to capture market and design variations
- Company size (based on total production capacity)

Criteria were developed for selecting plants on a competitive basis. Each plant was required to cover part of the costs of the research and make a significant in-kind contribution. Participating plants were selected based on their willingness to make the following investments:

1. Upper management commitment to lean production methods
2. Willingness to assign a staff person as the plant’s lean advocate to assist in carrying out project tasks
3. Willingness to provide the resources (people, time, materials, etc.) to carry out the tasks required in the project description, including:
  - Participating in a one-week training program
  - Constructing current and future state value stream maps
  - Conducting and documenting rapid process improvement events
4. Participating in a debriefing meeting at the conclusion of the work

Table 1 lists the nine plants and select characteristics at the time of plant selection based on Phase 1 benchmarking study data.

**Table 1 The nine plants with selected characteristics**

<b>Plant and location</b>	<b>Building type</b>	<b>Home type(s)</b>	<b>Avg. sales per floor</b> Low (<20k) Med.( 20-25k) High (25k+)	<b>Plant size</b>	<b>Homes highly customized (%)</b>	<b>Co. size (No. of plants)</b>
1. <b>Cavalier Homes</b> Addison, AL	HUD-code	Multi-section, one story	Low	Medium	<1%	6
2. <b>Chelsea Modular Homes</b> Marlboro, NY	Modular	Multi-section, 50% multi-story	High	Small	100%	1
3. <b>Clayton Homes</b> Andersonville, TN	HUD-code	Single- and multi-section, one story	Low	Large	0%	36

<b>Plant and location</b>	<b>Building type</b>	<b>Home type(s)</b>	<b>Avg. sales per floor</b> Low (<20k) Med.( 20-25k) High (25k+)	<b>Plant size</b>	<b>Homes highly customized (%)</b>	<b>Co. size (No. of plants)</b>
4. <b>Four Seasons Housing, Inc.</b> Middlebury, IN	Mostly HUD-code	Multi-section, one story	Low	Large	15%	1
5. <b>Hi-Tech Housing, Inc.</b> Bristol, IN	HUD-code and modular	Multi-section, one and two story	High	Medium	30%	1
6. <b>Palm Harbor Homes</b> Albemarle, NC	Modular and HUD-code	Single- and multi-section, mostly one story	High	Medium	15%	16
7. <b>Palm Harbor Homes</b> Plant City, FL	Modular and HUD-code	Multi-section, one story	High	Medium	65%	16
8. <b>R-Anell Housing</b> Denver, NC	Modular	Multi-section, mostly two story	High	Medium	50%	2
9. <b>Southern Energy Homes</b> Addison, AL	HUD-code	Single- and multi-section, one story	Medium	Small	0%	6

#### 2.4.2 Selection and training of lean advocates

Each plant identified one or more key staff members as their lean advocate(s). The lean advocates had several responsibilities, including:

- Participate in a one-week training session
- Serve as liaison with the research team
- Create current and future state value stream maps for their plant and document other key measures of performance
- Together with the project team identify areas of operations for potential improvements
- Coordinate the participation of associates within the plant

The lean advocates were brought together at a central location for one week of intensive training covering the concepts and techniques of lean production, including value stream mapping, observation analysis, cycle time analysis, visual control, takt time, product flow, and pull (kanban systems). The training was lead by the MHRA team.

#### 2.4.3 Data collection and analysis

Following the training program, each of the lean advocates collected information about their plant's production process. Information collected and developed to describe operations varied by plant but generally included the following:

- Plant-wide metrics (cycle and lead time, labor requirements, inventory levels, space requirements, quality metrics)

- For selected areas, detailed process flow data (labor and material utilization, replenishment time, plant floor plans, product variation, storage requirements, and changeover times)
- A high-level current state value stream map of plant operations

The value stream map is a core lean tool; value stream mapping is a pencil and paper technique that graphically depicts the flow of materials and information as value is added in the production process. Most importantly, it helps identify opportunities for improvements and operations that consume resources without adding value. Value stream maps can be created at a number of levels: detailed production processes, door-to-door within a plant (the focus of Phase 2), multiple facilities within an organization (the “enterprise level”), and across organizations to suppliers and customers.

This information was reported back to researchers for discussion. Opportunities for improvement via the application of lean techniques were identified and prioritized and a future state value stream map was developed for the plant. A future state value stream map uses the same graphic language as the current state map but depicts the anticipated production flow after selected improvement activities have been conducted.

#### **2.4.4 Rapid Process Improvement events**

The detailed analysis of plant operations, particularly the value stream mapping, suggested opportunities for applying lean techniques. Plans were developed for carrying out rapid process improvement events that would move the production process in each plant closer to that depicted in the future state value stream map.

RPI events are intensive workshops conducted over the course of a few days to a few weeks focused on developing and implementing solutions to previously identified problems and/or opportunities. Participants generally include a cross section of employees representing a wide range of points-of-view and experience.

The goals of an RPI event can include the following: increase productivity, reduce or eliminate waste, standardize building processes, reduce delays, eliminate bottlenecks and unnecessary material handling, raise skill levels, reduce inventories, address defects and problems, and optimize space usage.

The RPI events in each plant were initially facilitated by one of the MHRA team members; later this responsibility was assumed by plant staff, often the lean advocate. The goal was to transfer the capability to conduct RPI events to plant staff and vest the responsibility for leading future RPIs with the lean advocate. The results of each RPI event was evaluated by researchers and discussed with the lean advocate. (The Appendices contain descriptions of selected RPI events and value stream maps and other activities conducted at five plants.)

#### **2.4.5 Dissemination of results**

Program activities and results were disseminated to industry through articles in trade publications, the MHRA website ([www.mhrahome.org](http://www.mhrahome.org)), briefings at industry meetings attended by manufacturers, and most significantly at an industry-wide symposium held in January 2007. The symposium was attended by approximately 100 people mainly representing home manufacturing companies.

# 3

## RESEARCH RESULTS: IMPLEMENTATION LESSONS

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The creativity and perseverance of the nine housing manufacturers in adopting and applying lean principles was truly impressive. Various organizational structures and implementation strategies were developed to provide an environment for promoting lean transformation. A mix of lean principles was applied to reduce waste over a broad range of factory activities. This phase of the lean production program was a rich learning experience, providing a broad view of what can be gained by investing in lean practices.

The most encouraging result is that, after nearly one full year, all nine plants are aggressively moving forward with their lean initiatives, using their own in-house lean advocates. The industry's challenge will be to maintain the momentum of the lean pioneers, while growing the base of companies involved with lean production.

Based on the early experience of these nine pioneering plants, some specific lessons were learned. These lessons relate to three key areas that were the focus of the MHRA lean effort: the value and role of value stream mapping, methods for conducting RPI events, and the importance of management support and lean advocates.

### 3.1 VALUE STREAM MAPPING

Finding a meaningful way to map the value stream in a home building plant is a challenge. Many diverse activities are required to produce a home. Many of these activities occur simultaneously in the same workstation on the same module. Some of these activities require several progressive workstations to complete. Other activities require multiple parallel workstations. Wide fluctuations in product size, complexity, features, etc., result in widely varying process times and activities that 'float' on the line.

On the surface, factory home builders operate according to basic lean principles. The main production line flows continuously; there is no inventory between workstations, and there is little or no finished goods inventory since homes are built to order.

Consequently, value stream mapping proved most useful for three purposes:

- **Training.** Plant level value stream maps enabled production workers and mid-level production managers to visualize the production line as a flow system with interdependencies. Value stream mapping exercises demonstrated how actions at one workstation can affect neighboring workstations. This understanding had the greatest impact if the workers took the lead in creating the value stream maps.
- **Targeting 'problem' departments.** After reflecting on the many activities across the whole plant and collecting some limited information about the waste in each, the lean team can identify departments with high levels of waste or the potential to bottleneck overall production flow. These departments will become the target of rapid process improvement events.



- **Developing a thorough understanding of departmental operations and issues.** Identifying production tasks, estimating their cycle times/inventory/other waste, and summarizing this information in a detailed department map is the starting point of successful lean improvement. This level of analysis is particularly enlightening for off-line production departments (e.g., wall build, dormer build) that can have *disconnected* workstations separated by inventory.

Data collection for value stream maps and for RPIs was a challenge. Wide variation in product cycle times (caused by variations in product design) coupled with long cycle times made it difficult to collect representative data. Further complicating data collection was the fact that work was done by a team of workers that often ‘float’ over multiple workstations. Simply measuring accurate cycle times is a challenge because the product does not necessarily move when an operation is completed nor is it necessarily complete when it moves.

Some plants had difficulty seeing the value of gathering data relative to other priorities and therefore did not provide resources for data collection. Nevertheless, most plants made some attempt to collect production data for their value stream maps and for comparing baseline operations against future improvements. The data most often collected involved the physical configuration of the work area (e.g., floor space, travel distances), work in process (WIP) levels for off-line stations, and labor levels. Reliable data on characterizing productivity was rare. While some estimates of defects and rework were made, these were mostly based on anecdotal evidence and judgment, not hard data.

### **3.2 RAPID PROCESS IMPROVEMENT (RPI) EVENTS**

Traditionally, RPI events bring together a small, multi-disciplinary team for an intensive, multi-day series of workshops that focus on developing and implementing improvements in an area. This requires that team members be relieved from regular production jobs for the duration of the RPI. In many industries it is possible to substitute workers or temporarily shut down a department. Three of the nine participating plants used this approach, substituting utility staff or ‘floaters’ for team members or pre-producing in the affected area. However, most home building plants find it difficult to pull people off the production line due to short staffing caused by perpetual absenteeism and hiring problems. Nevertheless, plants have met the challenge of conducting RPI events by using a variety of methods, including:

- Having the complete RPI team gather for a series of shorter meetings (one to three hours) for a number of days over the course of a week and then conduct a longer intensive implementation blitz, perhaps on a non-production day
- Using a core group of three to four RPI team members (including the lean advocate) to do preparatory work and develop preliminary solutions; involve production workers from the area and other impacted employees individually or in small groups for brief meetings to get their feedback and buy-in.
- Using non-production days to accomplish the bulk of the RPI and pay production workers overtime

Some RPIs were conducted over longer periods, due to extensive preparation required for implementation (e.g., moving mezzanines and overhead cranes, purchasing new equipment, and building fixtures). Other RPIs were completed in a week or less.

### **3.3 MANAGEMENT SUPPORT AND LEAN ADVOCATES**

While there are a variety of strategies to conduct RPI events and map value streams, successful lean initiatives have one thing in common: a lean advocate(s) on site with the time and management support to drive the process. This, not surprisingly, is proving to be the most important ingredient in deriving value from lean methods. Almost every plant began with a part-time lean advocate. However, after struggling to keep the effort energized, most plants learned that a full-time lean advocate in their plant was essential.

# APPENDICES

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The pages that follow profile the efforts to adopt lean manufacturing at five of the nine plants participating in the MHRA pilot. The plants followed the same general plan for applying lean methods, but as evident from these case studies, moved in different directions indicative of their differences in product type, manufacturing methods, business objectives and company culture. The case studies are intended to demonstrate that the same set of tools applied in five different environments yield results that are often quite different although in all instances lean philosophy is a powerful catalyst for positive change.

# A

## R-ANELL HOUSING GROUP, LLC

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R-Anell Housing is a producer of primarily modular residential and commercial structures based in North Carolina. Their residential operation based in Denver, NC was the focus of their lean initiative in 2006.

R-Anell's residential division markets primarily mid-range homes to builders in the Southeast states. Production operations employ about 240 associates located in two adjacent facilities, each of which contains a portion of the production line.

R-Anell approached their lean initiative in a comprehensive manner, developing an overarching lean management strategy, a rigorous education campaign for both management and production associates, a comprehensive five S campaign and a highly structured process for conducting major RPI events. This appendix describes each of these elements of R-Anell's lean strategy and detailed examples of one of their five S events and one of their major RPI events.

### A.1 LEAN MANAGEMENT STRATEGY

R-Anell's lean strategy was implemented by a full-time lean engineer who was responsible for much of the research, preparation, follow up, and organizational work required to conduct lean events in the plant, and a director of process development with extensive lean manufacturing experience who oversaw the lean initiative and reported directly to senior management, including the president of the company. The company president provided visible support for the lean initiative.

However, R-Anell's commitment to lean production has not been without its difficulties. A number of managers resistant to lean methods left the company during the initial stages of implementation.

R-Anell has developed a rigorous and thorough plan for implementing lean production as part of a renewed corporate strategy developed early in 2006. This strategy started with developing a vision for the company and will proceed through the following nine steps:

1. **Develop the Vision:** define core values and purpose statements and vision of the future R-Anell and get buy in from upper management.
2. **Share the Vision:** get input and commitment from department managers and share vision with customers.
3. **Plan, Assign Roles and Responsibilities and Develop Standards:** develop complete job descriptions for all company employees; introduce the lean strategy company-wide; hire a lean engineer; complete MHRA lean training program and bring that training back to R-Anell executives using lean simulations; conduct supervisor lean simulation and initial supervisor six S and kaizen events.
4. **Implement Plan and Review:** Implement the lean plan and review initial improvement activities with a small group.

5. **Create Stability:** implement a comprehensive organizational-wide six S program (R-Anell has added a sixth S for safety).
6. **Convert to Continuous Flow:** change to smaller lot production and in-line production layout; develop standard operating procedures for production and non-production tasks that include built-in quality; reduce in-line buffers and inventory.
7. **Synchronous Production:** run production to takt time with one piece flow and daily production schedules; entrench the kaizen philosophy and visual management throughout the company.
8. **Pull System:** establish min/max levels, implement kanban systems and just-in-time (JIT) systems.
9. **Level Production:** improve flexibility of processes and operators to enable predictability of production.

R-Anell's management strategy includes effective communication between all levels of the company in an effort to foster a lean culture. Elements of this communication strategy include:

- Lists of lean management behaviors provided to senior leadership and to manufacturing supervisors/team leaders
- Laminated pocket-sized cards with the basic lean manufacturing concepts distributed to employees
- Recognition banners hung over work areas that have completed kaizen events
- Poster boards documenting before and after photographs and achievements posted in areas that have conducted six S and kaizen events
- Weekly plant meetings covering, among other topics, news about lean events (six Ss and kaizens) delivered by area supervisors
- Presentations to customers to describe R-Anell's reasons for and goals of its lean transformation

R-Anell's lean implementation strategy began with detailed value stream mapping, followed by a series of frequent and ongoing six S events throughout the plant coupled and continued with several major kaizen events that resulted in major reorganizations of production areas. Both six S events and major kaizen events incorporated intensive education and training components.

**Figure 1 Plumbing department supervisor explaining poster boards documenting the area's six S event**



## A.2 EDUCATION AND TRAINING

Extensive education and training occurs with every kaizen event (six S event or major kaizen). This includes training modules on the lean basics (seeing waste and the six Ss), value stream mapping, and layout planning.

A half-day role-playing simulation workshop called the *pipe factory* demonstrates major lean principles such as takt time, standard work, incremental improvement, breaking down departmental barriers, product flow, poka yoke (in process quality checks), stability, inventory reduction, and value stream focus. This pipe factory was conducted with management groups (including senior management and sales), and with every group of production workers that goes through a kaizen event.

## A.3 FINAL FINISH SIX S EVENT

R-Anell's six S campaign ran through the entire plant, with a first pass through each area completed by the summer of 2006. Six S events are run by area supervisors, who were trained during the first event in the final finish department.

Participants in the final finish six S event included ten supervisors and two production workers. R-Anell's lean engineer prepared for the event by collecting data on materials needed in the area, making inventory labels for racks, and developing an agenda. The agenda, stretching over three days, consisted of the following parts:

- Two and one-half hours in the classroom where lean basics and the six Ss were taught
- A Q&A session and a walk-through of the final finish department
- Participants reorganized and cleaned the area and set up systems of visual management

In a fortuitous coincidence, all the supervisors had been reassigned approximately three weeks before the event so while they were familiar with their new areas, they were not wedded to the old systems of organization. Additionally, the plant had a new production manager who was highly supportive of lean philosophy.

Figure 2 shows the final finish area before the six S event. Racks are stacked high with large amounts of poorly organized materials. Clutter on the floor encroaches on the space between the racks and the aisle, restricting movement.

**Figure 2 Final finish area before the six S event**



The photos in Figure 3 were taken during the event. All materials were removed from the racks and laid out on the floor for sorting. Figure 4 depicts the final finish area after the six S event. Materials are neat and organized on the racks. Equipment on the floor all has designated “parking” spaces marked with yellow lines. Visual management is facilitated: if a parking spot is empty or if something is in an aisle, it is immediately obvious to any passing manager or worker.

**Figure 3 Final finish area during the six S event**



**Figure 4 Final finish area after the six S event**



So much material was removed from the area (see Figure 4) because it was obsolete or not needed by the department that one entire section of rack was dismantled, permitting the opening up of a bay door that had been sealed for years. The jacks can now move through this new access point to the yard where they are used to lift homes onto carriers rather than being rolled along the narrow and previously cluttered passageway between the home and racks to a more distant doorway.



**Table 2 Materials removed from the final finish area during the six S event**

Item	Qty removed	Reason
Oak rosettes	Approx 150	Removed from rail assemblies when not used in home
Oak bull nose stair riser assembly	40	Not used in final finish area; used at partition wall set
48" stair post	10	Not used by R-Anell (delivered in error by supplier)
Metal pull down attic stairs	1	Obsolete
Mantel, Oak Gilford, acorn pattern	11	Obsolete
Mannington transition moulding	2.5	Obsolete
Various quarter round moldings	236	Obsolete

## **A.4 KAIZEN EVENTS**

In addition to frequent six S events, R-Anell conducts major kaizens in targeted areas. R-Anell has developed a guideline called the 12 Steps of Kaizen Event Planning for organizing and conducting their major kaizen events. These steps provide a general guideline for event planning and a list of steps to consider when developing a detailed timeline for a specific event. While all kaizen events do not need to follow these steps precisely, they should follow the PDCA cycle commonly used in lean production: Plan, Do, Check, Adjust. The steps are:

### **Plan**

1. Decide on the area
2. Set expectations for the project in terms of desired results
3. Develop a project timeline
4. Collect data and prepare materials for use by team, including:
  - Record list of steps in the process
  - Establish space constraints
  - Map spaghetti diagrams
  - Prepare plans of area and paper cut outs
  - Measure walking distances with wheel
  - Draw process maps
  - Create proposed new layout with an obvious error to stimulate involvement
5. Create/modify training program specific to the area
6. Complete training and mapping with department personnel
7. Brainstorm improvements for the future state

### **Do**

8. Make physical changes to the area

### **Check**

9. Track progress on first day of production
10. Report by department to executive team



## **Adjust**

11. Two week adjustment period (while trial production is preferred, most of the time, evaluation is done and adjustments are made during regular production)
12. Follow-up and documentation

After the team has run production and is satisfied with the new procedures, they conduct an executive report out (Step 10). The report out allows associates and executives to speak with each other directly. Associates feel valued through the attention during the event and the executives get to see the pride and understanding exhibited by the associates.

R-Anell's experience illustrates the potency of empowering the workforce in a lean implementation. The way their kaizen events and report out are conducted is a substantial investment in the associates, visibly demonstrating management's commitment to lean production.

As with any plant, it is a difficult decision to pull workers off the line to participate in lean events. However, R-Anell's production departments are accustomed to dealing with absenteeism of approximately 10% (20 to 30 production associates are absent on any given day), so they handle the loss of someone to a lean event just as they normally do with someone who is absent. Additionally, the plant operates four 10-hour days per week, leaving Fridays open for maintenance, miscellaneous minor production operations, and other activities affecting the production facility such as implementing kaizen or six S changes.

## **A.5 DORMER AREA KAIZEN**

R-Anell constructs dormers as complete units (Figure 5) in a dedicated section of the plant employing eight associates (Figure 6). Dormer units are connected to homes by installation crews on the home site.

**Figure 5 Completed dormer**



The dormer area kaizen event was R-Anell's first major kaizen. There were several factors that led to selecting the dormer area as the first major kaizen, including:

- The area was consistently not meeting the daily production requirements
- This in turn meant that overtime was ongoing and the answer from the team and supervisor was that they needed another person
- The area supervisor had a positive attitude and was open to new ideas
- Dormer build is an off-line operation, so it would have minimal impact on the main production line

The main goal of the dormer kaizen was to improve the productivity of the area. The secondary goal was to provide space for large gable dormers to be built in the plant instead of on-site.

Planning for the RPI commenced in July 2006. The lean engineer developed a detailed timeline for the dormer kaizen, based on R-Anell's 12 Steps of Kaizen Event Planning, but tailored to the specific needs of the area. The event was conducted in one week with implementation, evaluation, and adjustment continuing through the subsequent two weeks. A second phase of the dormer RPI was conducted at the end of the next month with additional changes being made at that time.

**Figure 6 Dormer area before the RPI**



The detailed timeline for the event was as follows:

**July 26-Aug 4: Preliminary lean mapping and data gathering.** Developed spaghetti charts and current state value stream map, took before photos of area, observed and recorded procedures. Procured prints of the dormer area and surrounds and used them to examine material and associate movements and the flow of parts and assemblies. Made template sets and used blank layouts to make proposed layouts. Talked with associates and listened to problems and concerns. During the gather data step it was readily apparent there were many causes to the low production rate.

- Extensive walking to obtain materials and to use the equipment
- Indirect product and material flow
- Batch cutting of parts, contributing to congestion
- Staging the same material in multiple locations with the area
- Equipment located far from the point of need
- Lack of a table saw in the area, requiring sheet goods to be taken to the far corner of the plant to be cut

**August 3-4: Lean training of area associates.** Simulation exercise and introduction to lean classroom training.

**August 8-9: Determine area for gable dormer construction and method.** Lean engineer developed proposed location and process for constructing the large gable dormers.

**August 10: Value stream mapping.** Conducted classroom training on value stream mapping, followed by moving to the plant floor to develop a current state value stream map of the dormer area. The class was divided into three groups to create maps. Back in the training room each group completed their map and presented it to the rest of the class. The entire class compiled the three maps into one and discussed it.

**Figure 7 Dormer area workers developing an area value stream map (left) and planning changes (right)**



**August 11: Develop and implement future state layout.** Reviewed current state value stream map and collaboratively developed a future state map. This involved brainstorming the needs of the area, listing and prioritizing concerns and incorporating most of the high priority needs into the future state map. Items that could be implemented immediately were incorporated in the area reconfiguration. The lean managers presented a straw man proposed layout to the group and requested that they find problems with the proposed layout and correct them. The group discussed layouts, developed a modified solution and then went to the plant floor to physically reconfigure the area. Management recorded the event with photos during the process (Figure 8) and after completion (Figure 9).

**Figure 8 Dormer area during the RPI**





**August 14: Executive report.** R-Anell’s executive management team visited the area to review the changes and to see team members report on the previous state, the changes, and measured improvements. The executive management team congratulated the dormer associates on their hard work. After the presentation, the dormer associates celebrated the completion of the event by raising a success banner (Figure 10).

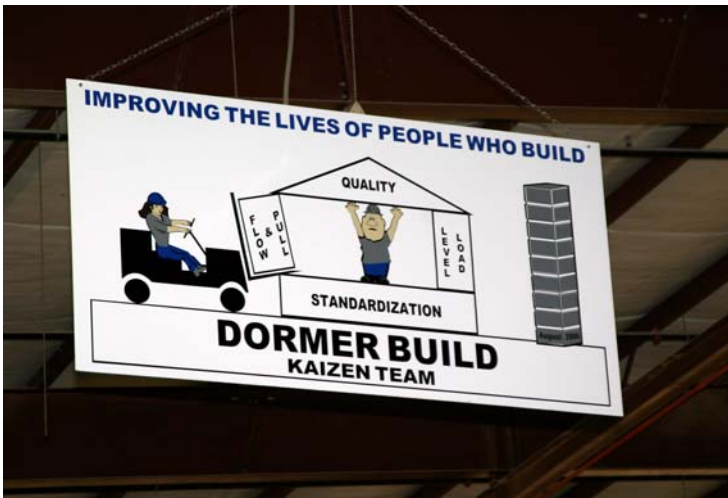
**August 14-16: Gable dormer trial.** Completed trial build in the reconfigured area, gathered labor time data, and costing information. Conducted a team review to discuss concerns, improvement ideas and to prioritize suggested changes.

**August 16: Implement changes.** Implemented changes and roped off the space freed up for the future gable dormer area to avoid sprawl into the open area.

**Figure 9 Dormer area after the RPI**



**Figure 10 Banner over dormer build area recognizing the team’s accomplishments**



**August 21: Build first production dormer.** After production commenced, conducted another team review to discuss concerns and improvement ideas and to prioritize additional changes.

**August 22-25: Implement changes.** Implemented additional changes based on second team review.

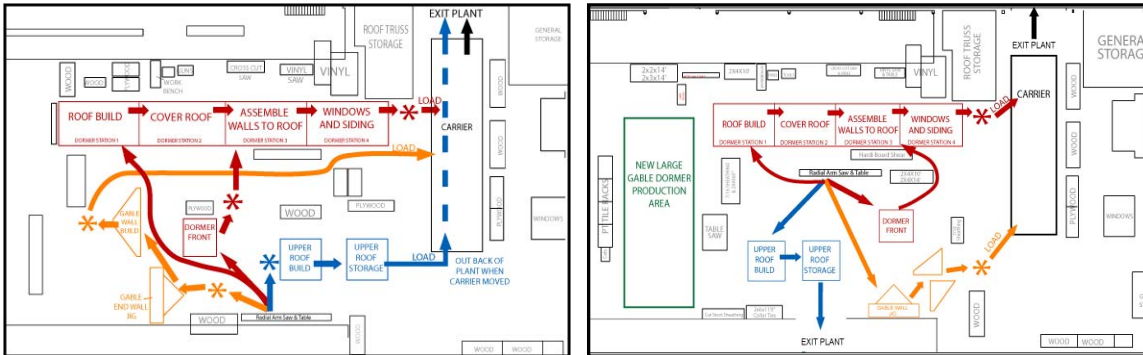
**August 25: Document process.** Record all procedures and develop written job instructions.

**August 28: Begin with new layout.** Recorded concerns, changed processes and revised team instructions.

Three primary products were built in the dormer area prior to the kaizen: gable walls, dormers and upper roof sections. The area layouts before and after the kaizen event are shown in Figure 11, color coded by product type. In the *before* diagram the upper roof sections (blue) were completed behind the carrier location and had to wait for the carrier to move before exiting the plant. The gable walls (orange) were completed on the opposite end of the area from the carrier upon which they were loaded. The saw was located on the edge of the area (bottom of figure) resulting in long travel distances to the dormer build area (red).

As seen in the *after* diagram, products are completed at the point of need or at an exit from the area. Material storage is reduced due to centralized staging and equipment locations. The saw is centralized to minimize the distance to areas it serves. The dormer build production line has been compressed. A new large gable dormer production area (green) has been created.

**Figure 11 Area layouts before and after**



The reduced travel distances are dramatically evident by comparing before and after layouts of the dormer area. Table 3 summarizes the area and travel distance changes achieved by the reorganization.

**Table 3 Data before and after dormer kaizen**

Metric	Before	After	Improvement
Upper roof build area	38 x 36 (1,368 sf)	29 x 30 (870 sf)	Reduced 498 sf
Travel distance to remove roofs from plant	500	200	Reduced 300 ft
Sheathing cut procedure	<ol style="list-style-type: none"> <li>1. Get material</li> <li>2. Load onto a cart</li> <li>3. Push to table saw</li> <li>4. Wait for saw to be available</li> <li>5. Cut material</li> <li>6. Load cart</li> <li>7. Push back to work area</li> </ol>	<ol style="list-style-type: none"> <li>1. Get material</li> <li>2. Step to saw</li> <li>3. Cut material</li> <li>4. Get pieces from saw</li> <li>5. Step to table and aside</li> </ol>	Eliminated two steps
Sheathing travel distance per occurrence	341 ft	21 ft	Reduced 320 ft
Gable wall build area	34 x 46 (1,564 sf)	28 x 32 (896 sf)	Reduced 668 sf

<b>Metric</b>	<b>Before</b>	<b>After</b>	<b>Improvement</b>
Distance to load gable walls on carrier	158 ft	30 ft	Reduced 128 ft
Dormer side wall build area	24 x 44 (1,056 sf)	22 x 20 (440 sf)	Reduced 616 sf
Distance to move dormer side walls to assemble dormer	44 ft	48 ft	Increased 4 ft
Dormer window wall area			No change
Distance to move dormer window walls to assemble dormer	35 ft	32 ft	Reduced 3 ft
Dormer build area	30 x 100 (3,000 sf)	30 x 84 (2,520 sf)	Reduced 480 sf
Travel distance saved per dormer build	282 ft	21 ft	Reduced 255 ft
Gable dormers build area	Non-existent		Created new area 40 x 60 (2,400 sf)
Relocated dormer miter saw and lumber; lumber positioned closer to and in-line with saw	342 ft 10 times per week	14 ft 10 times per week	328 ft 10 times per week (96% reduction)
Modified carts used to move cut lumber; reduced material handling and excess carrying of materials	60 ft round trip 40 times per week	60 ft round trip 15 times per week	Eliminated 1,500 ft per week (63%)

The kaizen team also applied the six Ss to the fastener storage area, removing inventory items no longer used in the area, repairing and cleaning shelves, and labeling items with part numbers, descriptions, and weekly usage.

Following is a comprehensive list of recommended changes and needs provided by the team. A star (\*) indicates items corrected during the event; others were slated for later consideration and approval before implementation.

1. Provide carrier loader safety harness with hooks in front instead of in back\*
2. Instruct associates to not leave pieces with nails and staples on the floor (safety issue)\*
3. Move gable end walls closer to carrier\*
4. Reduce the waiting time at the saw (will assign a dedicated saw operator after cross training associates)
5. Sharpen the truss area radial arm saw
6. Prevent errors on prints – these currently take much time to question and resolve (engineering has begun a new procedure to help eliminate mistakes)
7. Repair leaking hydraulic system on truss gang nail press
8. Locate saw and materials so material can be pulled into the saw easily\*
9. Provide a cart with serial number labels to place and move cut lumber – this will reduce trips and bending\*
10. Add a radial arm saw with miter ability that can cut up to ten 2-by-6s
11. Make required tools available at each workstation
12. For roof build operation, provide adjustable work platform for rafter sistering, provide a glue system, and enlarge the current work area

13. Add a larger saw in the vinyl area to cut polar wall siding
14. Devise a method to cut angles on Hardi Plank siding that is faster than using nippers
15. Purchase lumber for 6-in-12 pitch roofs precut, as is currently done for 9-in-12 pitch
16. Investigate whether precut collar ties can be sourced for less cost than cutting them in-house (factoring in material waste)
17. Get more air flow in dormer area of plant to keep it cooler during summer
18. Move a table saw into the work area\*
19. Locate window inventory closer to point of use
20. Swap miter saw in dormer build with another that has compound miter and 2-by-6 cutting ability
21. Eliminate cords and airlines on the floor (safety issue)
22. Get a jig to speed up first build of trusses
23. Improve the durability of the tape application around windows – perhaps use a heat-gun instead of spray adhesive
24. Improve labor allocation to provide assistance at process bottlenecks\*
25. Improve the material replenishment process to prevent running out of nails, staples and windows
26. Move 2-by-8s and 2-by-10s closer to the carrier load area from the current location outside
27. Better balance inventory so it does not run too high or too low as often
28. Locate trusses closer to the dormer build area
29. Enable truss fabrication in the area
30. Create a cart to leave dormer roof on so it is raised off the floor for roofing\*
31. Add the capability to cut and bend flashing in the area rather than going to the east plant when needed
32. Purchase flashing precut
33. Provide cut-off machine for roofing paper

By correcting the flow of product through the area, reducing duplicative material inventory (for example OSB was reduced from three bundles to one) and compacting work centers, enough space was freed up to provide room for the large gable dormer area which R-Anell now builds in the plant. The value of the manufacturing space freed up is \$108,000.

The reduced travel distances and other efficiencies eliminated the need for the additional associate (overtime in the area has been largely eliminated), saving \$27,300 annually. A summary of the major results is in Table 4.

**Table 4 Dormer kaizen major results**

<b>Item</b>	<b>Then</b>	<b>Now</b>	<b>Change</b>
<b>Floor area</b>	6,988 sf	4,726 sf	Reduced by 2,262 sf
<b>Travel distances</b>	13,027	2,848	Reduced by 2 miles per day
<b>Employees</b>	9	8	Reduced by 1

Typical of major kaizen events, a number of additional opportunities were identified but not addressed in the initial dormer kaizen event. The following items were slated to be addressed in a subsequent dormer area kaizen:

- Truss and knee wall fabrication
- Ganging of roof trusses
- Carrier load area
- Dormer truss storage location
- Window inventory location

## **A.6 GOING FORWARD**

R-Anell is aggressively moving forward with its lean transformation. Plant managers have requested an accelerated training schedule to provide the balance of the associates with lean training. Through the master plant value stream map, managers know the areas of constraint that affect production flow and will begin to concentrate on these areas with future kaizens. Lean principles are being utilized as R-Anell plans a move to another manufacturing facility; and lean training will be included in the orientation of all new associates.



# ***B***

## **SOUTHERN ENERGY HOMES**

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Southern Energy operates seven plants in the Southeast. At Southern Energy (SE), lean production is championed by the assistant general manager of the Alabama division with visible support from the CEO and other senior company leaders. A full-time lean advocate at the corporate office coordinates lean activities at SE and is charged with spreading information and success stories to all plants, which by the end of 2006 each had their own full-time lean advocate.

This appendix describes a major RPI event conducted in the Southern Estates plant to reorganize the end and partition wall department.

### **B.1 END AND PARTITION WALL RPI EVENT OBJECTIVE**

The Southern Estates plant is part of SE's headquarters complex in Addison, Alabama. It has been in operation producing moderately priced HUD-code homes for the Southeast market since 1982. Its daily production is about five to six floors, with some customization.

The partition and end wall department at the Southern Estates plant supplies interior and exterior walls up to a maximum of about 16 feet long to the main production line. Walls are framed (with openings for windows and doors), sheathed with gypsum wallboard on one side, and insulated if exterior.

SE managers selected the interior wall department for one of the first RPIs because the area was having difficulty meeting the production needs of the main line. Prior to the RPI, production required workers to do excessive walking to get materials, material flow was random, materials did not have fixed staging locations, and finished walls had to be pulled through the shop by hand. The objective of the RPI was to increase productivity by rearranging the equipment layout and material locations to rationalize the flow of materials through the area.

### **B.2 RPI PROCESS**

SE's RPI team included the plant production manager, the division assistant general manager, SE's lean advocate, the area supervisor, a maintenance employee, and representative workers from the area.

Because of the extensive construction (including the relocation of a portion of a mezzanine) that would be required to implement the changes envisioned by the team, the RPI was conducted in three phases:

1. Planning and initial design (May 2006)
2. Finalizing the design involving area workers and making physical changes (June–July 2006)
3. Evaluating and refining the new area (August 2006)

### **B.2.1 Planning and initial design**

During the first RPI meeting, the team reviewed a preliminary proposal for a revised area layout that was prepared by management to stimulate discussion. The team conducted detailed observations of the activities, material and information flow, and equipment. Participants then discussed alternatives for improving the area layout and material flow, and developed a revised department layout. The team also analyzed the effects the department has on the flow of the main production line. Finally the team developed a plan going forward consisting of the following steps:

1. Get input and feedback on the proposed new design from additional area workers
2. Procure materials and fabricate needed elements
3. Physically rearrange the layout
4. Evaluate the number of workers and work load of each major activity based on new layout in order to balance work loads and allocate labor
5. Once the learning curve stabilizes, explore changing the takt time from 65 to 46 minutes for the partition and end walls area

### **B.2.2 Finalize design and make changes**

During June and July the SE team carried through on the plan, completing necessary reconstruction and implementing the new arrangement.

### **B.2.3 Evaluate and refine**

On August 1, the team reconvened to observe and document the activities in the reconfigured area. The assessment revealed that wall framing activities on the tables were a bottleneck and work load across the tables was not balanced: framers at one table were completing walls for a given house and commencing building walls for the next house before the remaining tables had completed the walls they were working on for the first house. The team met to discuss the new layout and potential revised activity arrangements in light of these issues. Associates were open and enthusiastic about the new changes and recommended some further improvements for the area. A subsequent evaluation in September confirmed that these recommendations had been implemented and were working well.

## **B.3 RPI CHANGES**

The partition and end wall area was completely reconfigured with the guiding principle that materials should flow from outer storage areas towards the main production line with a minimum of travel distance and detours. The area layout and material flow prior to the RPI is shown in Figure 12. The arrows indicate the primary flow of materials (blue: studs, orange: window and door frames, red: wall board). Materials were not stored logically near where they would be needed as can be seen by the criss-crossing of lines of various colors. The post-RPI material paths are shorter and more direct with practically no intersections of different material flows until they reach the wall framing tables where all materials come together for final wall assembly.



**Figure 18 Old wall tables**



**Figure 19 Framing jig**



Before the RPI, the wall build tables were merely flat platforms that depended on the skill of the worker to assemble walls accurately (Figure 18). There were many opportunities to make mistakes. The RPI team increased the use of jigs and fixtures to error-proof and standardize work (Figure 19).

Prior to the RPI, mistakes were made when information about which walls to build was not transmitted properly. Carts of materials (Figure 20) were easily misplaced or misidentified. Now a system of labels and racks organizes the flow of information along with the flow of materials (Figure 21). There is “a place for everything and everything is in its place.” Specific changes made to the area during the RPI include:

- Relocated half of the mezzanine to open up floor space for the revised area layout (Figure 22)
- Built shelves for gypsum board that hold six different colors and installed it under the mezzanine
- Relocated the sheet rock cutters (two saws and one splitter) to smooth material flow and created a staging area for cut-to-size sheetrock (Figure 23)
- Relocated the door/window frame assembly area
- Relocated two of the partition wall framing tables to allow walls to be staged adjacent to the tables and moved by crane to the line
- Relocated the two stud saws and lumber staging rack to underneath the mezzanine to provide in-line flow
- Built stud racks for cut studs and installed these racks between the framing tables (Figure 24)
- Implemented a labeling system for the stud racks so all studs for a given house are grouped together and tagged by house; this reduced writing required of the stud cutters (they no longer need to label each stud by house number) and facilitated the sorting of studs for the wall framers
- Created new fixture to cut studs to size, reducing the amount of measurements performed by the stud cutters (Figure 25)
- Created a new rack system for raw gypsum board and studs (Figure 21)



- Created a new staging area for wall board near the wall building tables, keeping framers close to their framing tables most of the time
- Balanced the work at the framing tables to avoid bottlenecks; the production manager and the area supervisor arrange a work schedule to balance complex walls with less complex walls to ensure that all the walls of a specific house are ready on time for the next activity

**Figure 20 Lumber and cut part carts**



**Figure 21 Cut stud rack between wall tables**



## **B.4 RPI RESULTS**

As result of the changes, productivity improved. The department is meeting the needs of the main line while wall workforce was reduced from 9 to 6.5 people. Importantly, no one lost their job because of lean activities; rather, experienced workers were transferred to other departments where they were needed due to normal attrition. Other benefits include space savings of 12% and wallboard damage reduction of approximately 10%. Southern Energy invested \$25,786 in labor and materials for this RPI, which was a major commitment by management. The investment paid for itself in less than four months as annual labor savings amounted to \$73,200 plus the savings of not needing to hire and train 2.5 new workers from outside the company.

**Figure 22 Split and relocated mezzanine**



**Figure 23 Gypsum board cutting station and new storage rack for cut gypsum board**



**Figure 24 New racks for cut and labeled studs and temporary labeling of the rack**



**Figure 25 Fixture to cut studs to size, reducing manual measuring**



**Figure 26 New rack system for gypsum board and studs**



## **B.5 GOING FORWARD**

Participants in this RPI team included a wide range of people from the company president to maintenance workers. All necessary people were present to understand issues, procure resources, and fix problems. The production manager at the plant enthusiastically endorses lean production and facilitates lean improvements. Workers have been very appreciative of the efforts to improve their work environment. Several months after the wall RPI they are still enthusiastic about the changes and the process.

Southern Energy has held 32 major RPI events and 23 five S RPI events at six plants. Each plant has assembled a lean team lead by a full-time lean advocate. Each plant began lean implementation with five S events and value stream mapping.

The commitment to lean production by SE's senior management is evident in the appointment of a dedicated director of lean production who follows up on the progress of lean activities, provides guidance, and disseminates successes. Management permits teams to take time to work on improvement activities and SE invests in the changes recommended by the teams. Management takes seriously the suggestions of workers and senior managers are closely involved in many of the lean activities.

# C

## CHELSEA MODULAR HOMES

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The Chelsea Modular Homes housing plant was selected to use as a case study for applying lean production techniques to a factory home building facility. The goal was to develop and recommend changes to the plant's production system and product design, improving production efficiency and product quality.

The case study team consisted of industrial engineers and plant management. The team worked together in a collaborative process to identify opportunities to improve the efficiency and productivity of the manufacturing operations.

### C.1 INTRODUCTION TO THE CASE STUDY PLANT

Chelsea Modular Homes is a manufacturer of primarily single family detached wood-frame modular residential buildings. Chelsea's single production facility is located in Marlboro, NY in New York's Hudson River Valley (Figure 27). Their homes are sold through a network of builder-dealers in the Northeast US. The builder-dealers often maintain model home centers and are responsible for selling the homes to the end-customer and installing the home.

**Figure 27 Chelsea's plant, interior and exterior**



Chelsea has been in its present facility since opening in 1986 and has produced over 5,000 homes. Most of the homes are highly customized multi-section homes with some homes consisting of a dozen or more modules. Approximately half of Chelsea's production is multi-story.

Chelsea's 118,000 square foot facility is configured in center-line production arrangement and produced approximately 3 to 4 floors per day in 2006. All component assembly and pre-cutting is accomplished off the assembly line. These components are then distributed throughout the facility by material handlers to assemblers on the main production line.

Chelsea has consistently had a strong order file and production level. Product quality is high, but at a significant cost. Production challenges include:

- High level of customization (80% of homes produced are highly customized and 20% of homes produced are totally custom)



- The occasional very large, extremely detailed and highly customized homes cause massive disruptions to the production line
- Change orders to homes in production cause confusion and further disrupt the flow of production
- Revisions of shipping dates of homes under production that cause frustration among the workforce
- Difficulty maintaining stable workforce in high labor-cost market despite having low turnover of 10% and a low absenteeism rate of 3%

Production operations are headed by a plant manager reporting directly to the company president. Three production line supervisors report to the plant manager and supervise group leaders of each department of two to ten workers. In early 2006, management began to focus on stabilizing and getting better control of plant operations. At this time they began their lean production initiative.

## **C.2 CHELSEA'S RPI PROCESS**

As part of their lean initiative, Chelsea hired a manager with the dual responsibilities of safety manager and lean advocate and provided him with strong backing from plant and corporate management. With the guidance of MHRA, this manager commenced a series of workshops for production workers, supervisors, and selected office employees. Each workshop lasted approximately 20 hours spread over three to five days. Participants were taught the basics of lean production, including recognizing waste, the five Ss, and value stream mapping. Following the instructional portion of the workshop, participants focused on a specific production issue that was pre-selected by management. The first workshop developed current and future state value stream maps as well as recommendations for modifications to the production line. Subsequent workshops focused on specific process improvements in the plant.

Chelsea RPI events are typically structured as follows:

1. Form a team of about six people representing a cross-section of the plant and including key people from the target area or areas
2. Meet every day for half a day over the course of a full week; the week begins with training on lean basics, and then focuses on investigation of the issues in the target area; the team divides its time between the plant floor and the lean conference room to brainstorm solutions
3. On the final day, the team presents its findings and recommendations to management, including the plant manager and the president of the company; in many cases, approval to go forward with recommendations is granted immediately
4. Team members take responsibility for and are given authority to see that approved recommendations are implemented

This report describes Chelsea's value stream mapping workshop and three RPI events.

## **C.3 VALUE STREAM MAPPING**

From May 8 to 10, 2006, a value stream mapping workshop was conducted at Chelsea Modular Homes.



The goals of the workshop were as follows:

- Train a team of Chelsea employees in the basics of lean production and value stream mapping
- Collect data for a current state value stream map
- Develop a current state value stream map
- Develop a future state value stream map
- Identify rapid process improvement events whose completion will allow the plant to achieve the future state

Eight Chelsea employees participated in the workshop including the lean manager, a foreman, the receiving supervisor, the quality control manager, a representative from the engineering department, and three production workers from various departments.

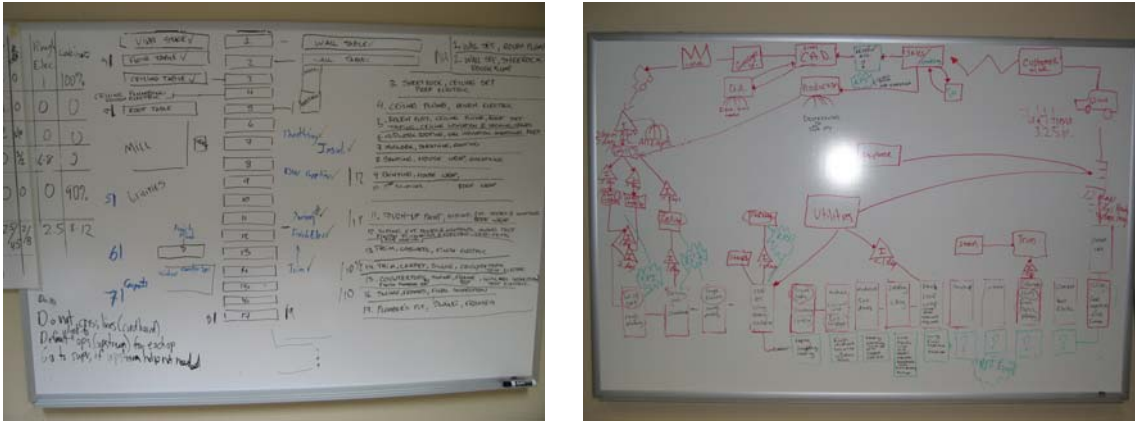
The first day of the workshop was devoted to reviewing the objectives of the workshop and training the participants in the basics of lean production. Days two and three focused on current state and future state value stream mapping respectively. At the end of day three, the team presented their work and conclusions to the chief of production.

This team worked for three days to develop the current and future state value stream maps. The team walked the floor in two groups to record the production process steps and re-convened in the lean training room to construct a rough outline of the current state value stream map (Figure 28 and Figure 29).

**Figure 28 The team on the production floor (left) and in the lean training room (right)**



**Figure 29** Rough diagrams created by the team during the value stream mapping process



The first task of the workshop, following training, was to develop a schematic value stream map showing the material and information flow driving production, as well as major inventory locations. Once the schematic map was completed, the team selected the data that would be most meaningful for visualizing the production process and identifying opportunities for improvement.

Six items were selected:

1. Material shortage frequency
2. Time spent on rework because of change orders
3. Time spent on rework because of errors
4. Time spent idle waiting for line moves
5. Number of times forced to work out of assigned line station
6. The average and maximum time spent on a module

To best provide insight into opportunities, the team decided to collect production data at the component assembly level (e.g., rough plumbing, wall build, etc.) rather than at the workstation level. The first cut of the data was obtained by identifying 15 key processes (those likely to have opportunities for improvement) and asking the process lead operators questions about assembly operations based on production experience over the most recent two-week period.

This data was then verified by having process teams collect selected data for each module they completed. A summary of the data is presented in Table 5 and Table 6. The completed current state value stream map is shown in Figure 30.

**Table 5** Production data - cycle times

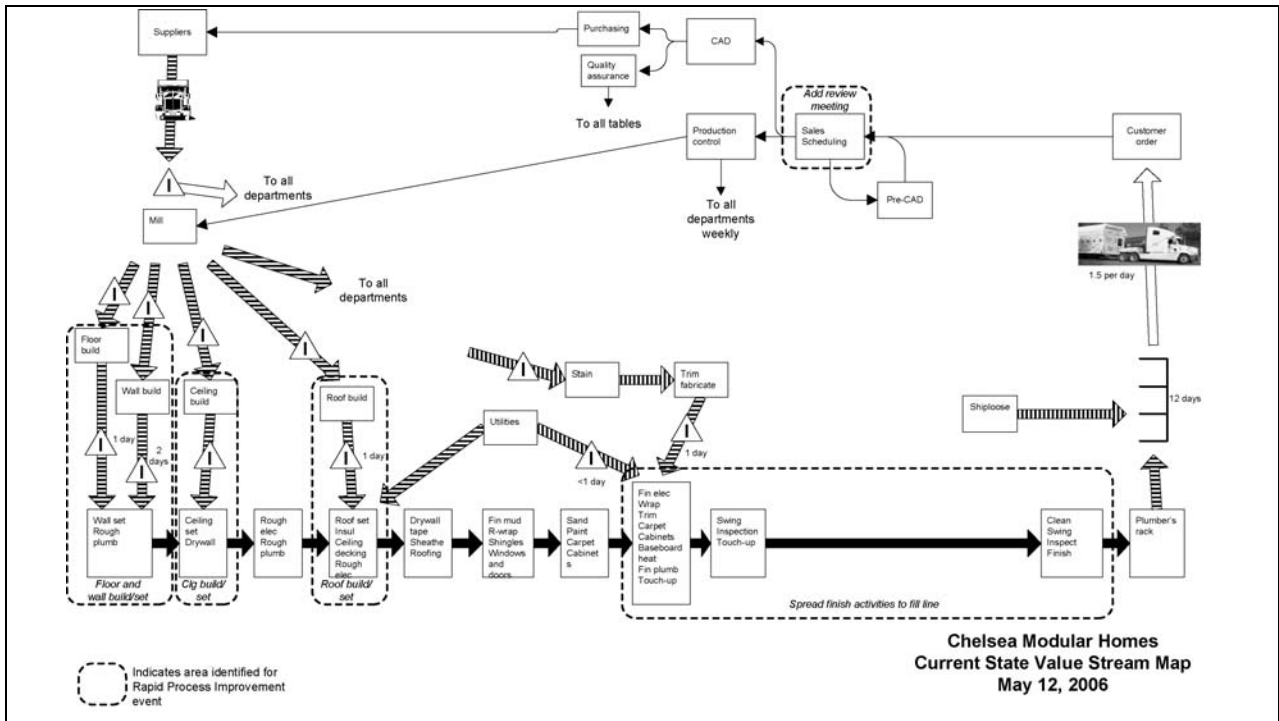
Department	Hours per module (Data collected April and May 2006)															Avg.	Min	Max
Floor	3.3	2.3	2.3	2.4	5.2	5.2	5.3									3.7	2.3	5.3
Wall Set	3.3															3.3	3.3	3.3
Ceiling	4.3	3.3	2.2	2.5	2.5	3.0	3.2	3.3	3.3	5.4	5.4	4.5	3.5	3.5	2.5	3.5	2.2	5.4
Rough Electric	2.8															2.8	2.8	2.8
Roof	2.2	2.0	1.5	3.4	3.4											2.5	1.5	3.4

**Table 6 Production data - survey results**

	Department														
	Floor build	Wall build	Clg build/set	Rough elec	Roof build/set	Tape	Sheathe	Mill	Wall set	Siding, win, door	Countertop	Trim	Cabinets	Fin elec	Swing
No. times ran out of materials	0	0	0	1	0	0	0	2	5	2	0	3	5 (100%)	4	1
Rework time due to change orders (hours)	2	1	0	0	2	0	0	4	0	0	0	0	0	0	0
Rework time due to errors (hours)	2	1	1	small	3	3	0	2	4	0	5-6	8	few	2.5	10
Downtime waiting for line move (hours)	0	0	0	6-8	30%	0	10	0	5	10	0.5	0	some	n/a	90%
No. times forced to work out of station	0	0	0	0	50%	4	0	0	0	100%	0	0.9	90%	flexible	100%
Avg. time spent on a module (hours)	4	2.5	3	2.5	2	3	2.5	2.5	3	2.5	2	2.5	8	1.75	3.5
Max. time spent on a module (hours)	6.5	5	6	6	8	5	3	4.5	5.5	5	8	4	12	5	6

Data collected May 5, 2006. All data pertains to most recent two week period.

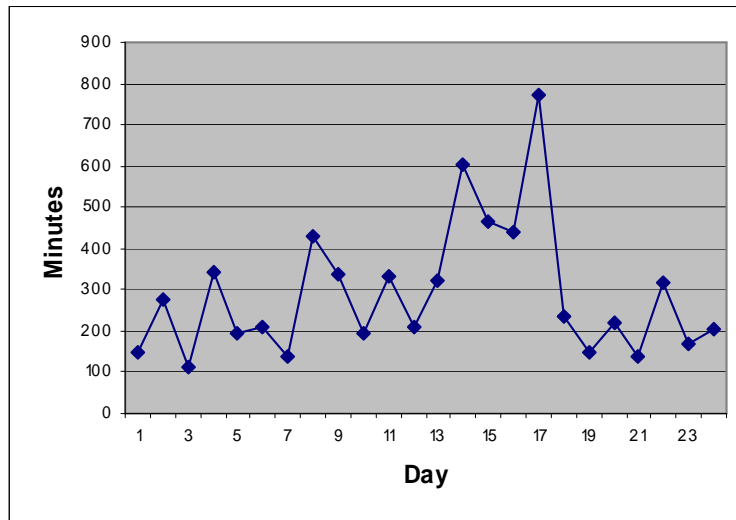
**Figure 30 Current state value stream map**



In addition to process level data collected for the value stream map, Chelsea collected three weeks of data on line pulls (when all modules are simultaneously pulled down the line from their current workstation to the next workstation). From April 17 through May 8, the line was pulled 24 times for an average of approximately 1.5 times per work day. The time between line pulls varied from a low of 110 minutes to a high of 770 minutes (not counting breaks, lunch and non-

work hours). The average line pull time was 290 minutes. Figure 31 shows the variation of line pull times.

**Figure 31 Line pull times**



### **C.3.1 Identification of opportunities**

Based on the current state value stream map and other data collected, the workshop team drew the following conclusions:

- Line pull times vary widely due to product variation, line imbalance and other factors
- Framing is a bottleneck for certain units
- Finish activities are crammed into upstream framing activities- because framing is often a bottleneck, finish workers migrate their activities upstream into framing stations when they complete the downstream units; this causes congestion and resulting quality problems

The workshop team analyzed the data to identify problem areas and opportunities for improving operations through the application of lean production practices. A goal for a consistent line pull time was established. This goal was calibrated to the takt time (takt time is a representation of customer demand, e.g., if the plant is selling two modules a day, then the takt time in minutes should equate to two line pulls daily). Based on current and projected demand, the takt time goal was established at 195 minutes.

In order to achieve this goal, productivity would need to increase. Five rapid process improvement opportunities events were identified:

1. Finish activities at end of line: spread out these activities to fill in currently empty slots on the production line
2. Scheduling process: create a scheduling review meeting and have engineering receive house plans two weeks rather than two days before commencing production on that house
3. Wall/floor framing area: improve efficiency, flexibility and flow
4. Roof framing and set area: improve efficiency, flexibility and flow

5. Ceiling framing and set area: improve efficiency, flexibility and flow

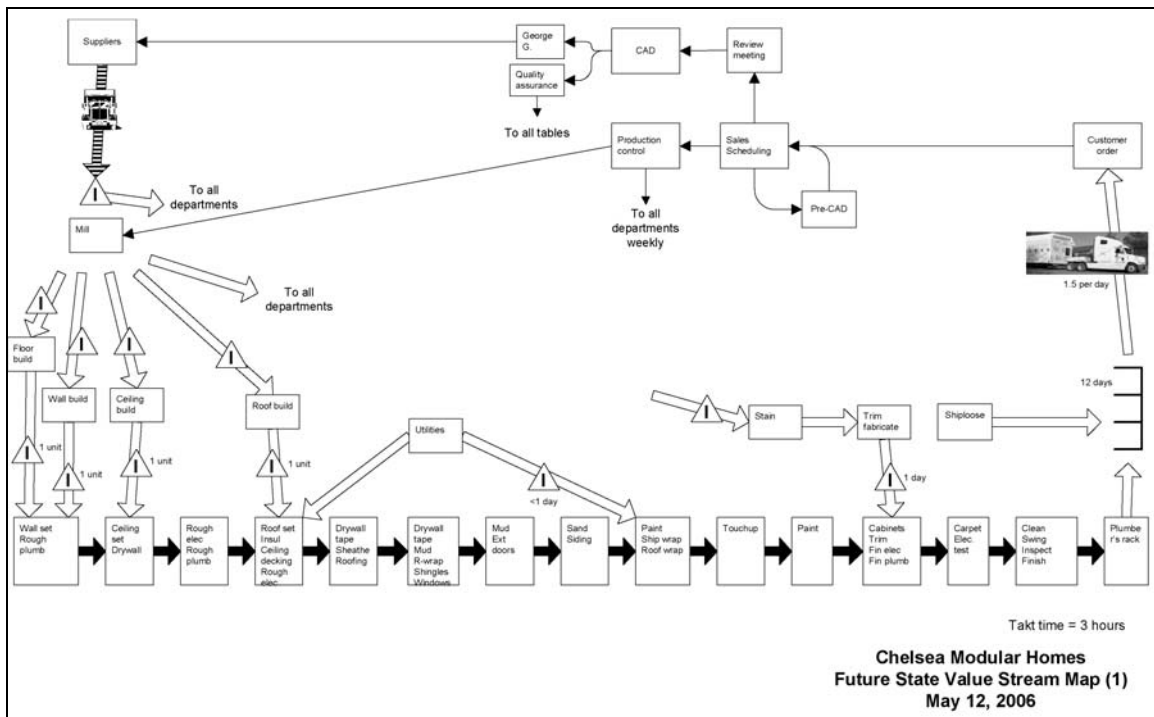
The future state value stream map (Figure 32) shows the target value stream assuming the completion of the five RPI events. In addition to the tangible results of the Value Stream Mapping Workshop (value stream maps, data, RPI plans), the workshop participants reported that the exercise forced them to think of the production line as a system rather than simply a series of individual operations. Most significantly, from a production flow standpoint, the exercise ingrained into the minds of the participants the concept and vital importance of takt time as the heartbeat of the production line.

### C.4 END OF LINE RPI

The first and most critical RPI identified by the value stream mapping workshop team was determined to be the finish activities RPI. This RPI was given the highest priority because finish activities must be spread out to their appropriate line stations in order to stabilize the line flow prior to addressing the individual workstation RPIs.

The objectives of this RPI were to spread the finish activities (wallboard taping, mud and painting; trim; cabinets; finish electrical; etc.) across modules at workstations on the back half of the production line, which is currently largely empty (Figure 33). Implementation of this RPI consisted primarily of enacting and enforcing a pair of work rules governing the production process.

**Figure 32 Future State Value Stream Map**



- **Rule 1:** A finish activity cannot move upstream past its respective signboard (the team demarcated with signboards where certain finish activities should take place), but the worker is expected to move upstream to help complete earlier activities. The worker can then follow the module downstream. This rule requires cross-training of

- workers and coordination by supervisors and leads to make sure workers move to where they are needed.
- **Rule 2:** Line pulls will happen at takt time (starting with a three hour takt time), regardless of whether roof has been set. If the roof has not been set, all stations downstream will move, leaving a gap in the line (and costing a unit of production). Maintaining takt time was deemed worth the risk of this substantial penalty.

The team also recommended that Chelsea conduct more frequent and earlier engineering reviews so the production floor can receive complete working drawings for a module well in advance of start of its production.

The proposed rules for the end-of-line RPI are controversial, particularly cross-training and risking production loss if the roof is not completed on takt time. The workshop team accepted responsibility to teach other line workers the value of the new procedures, and to make it work. The line workers on the workshop team made clear to management that in return for their efforts and commitment they expect to share in the rewards gained by these changes. Researchers and the plant manager questioned and critiqued the plan, but the workshop team was not dissuaded and won over the confidence of management. The plan was scheduled to be implemented the following week.

**Figure 33 Empty workstations at the end of the line**



**Figure 34 Hanging signboards**



### **C.4.1 Results**

After one week of operating under the new procedures, plant management reports that the changes are working well. Specific findings include the following:

- Overtime was being used to fill empty line stations (one time only in theory)
- Foremen were moving operators around to smooth production
- Engineering was now getting plans two weeks in advance rather than two days to improve scheduling
- Product review meetings were occurring more frequently

## **C.5 WALL DEPARTMENT RPI**

This RPI included the wall framing area, including interior and exterior walls. Four workers including the team leader work in the area. Three of the workers have less than one year of experience. A floater and several hours of overtime daily are routinely used in the department and the area still fails to meet line production requirements.

### **C.5.1 Objective**

The objective of this RPI was to improve capacity and productivity in the wall department. Even with floaters and overtime, the area routinely failed to meet target production levels. Several other key challenges were noted: communication at all levels; raw material quality (bad studs were stacked to the side taking up valuable space); delivery (mill products were not available when needed by the department); location of materials (plate material located outside the building became covered with ice in winter; and the location of the table saw (blocking an electrical panel box creating a safety issue) and the gang nailer location (created interference with overall plant traffic and material flow).

## C.5.2 Process

The RPI team met each day of the week for a full week, from noon until 3:30pm. Each morning Chelsea's lean manager and MHRA researchers observed the wall production process and prepared for the afternoon meetings. Six Chelsea employees participated on the RPI team including the lean manager, the wall department foreman, the wall department team leader, and three production workers from other departments.

**Monday July 17, 2006.** In the morning, MHRA researchers and the lean manager reviewed plans for the week, the material to be covered and the participants' backgrounds. They met with the supervisor of the front of the line, including the partition wall area. He believed that the wall department team leader was spending too much time overseeing the work of others. The group conducted a plant walkthrough and reviewed the current state of product flow. The line was not moving as scheduled. Framing stations appeared to be waiting for roof set to move the line. A roof was staged for set, but the set crew was waiting for electrical and insulation to be completed in the ceiling. Framing stations, including walls, appeared to be keeping pace with line movement.

During the afternoon RPI meeting the plant manager issued his charge to the RPI team. The team reviewed lean production training materials including the seven wastes, the five Ss and value stream mapping.

**Tuesday July 18, 2006.** In the morning, researchers observed the wall build process from the start of production and developed an area layout with removable templates representing equipment and staged materials.

During the afternoon RPI meeting, the team completed reviewing the training materials and developed a value stream map of the wall department (see Figure 35), and a detailed activity list (see below).

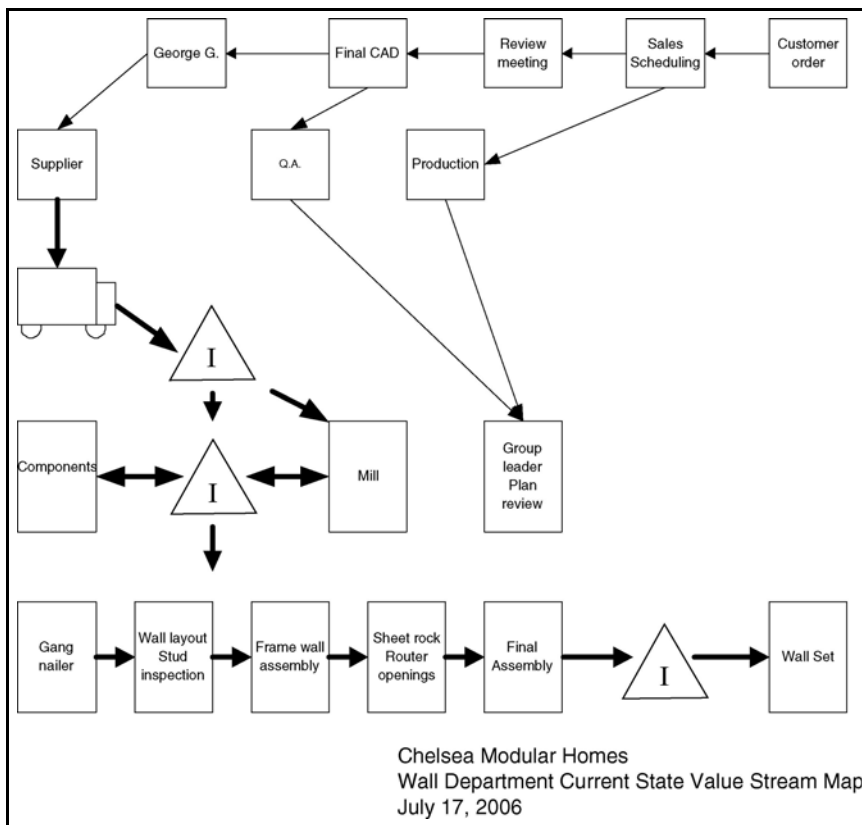
Detailed wall build process sequence (current state as of July 18, 2006):

1. Move material for plates to the gang nail area
2. Gang nail lumber together to create plates
3. Carry the plates to work area
4. Mark plates for assembly
5. Carry studs to table
6. Inspect studs for walls (orientation and quality)
7. Mark the name of the wall
8. Assemble wall (frame)
9. Carry other building material (blocks & headers) to proper area
10. Install framing for components (i.e. windows/doors) and double top plates
11. Tighten-up (squeeze) the table and square the walls
12. Add strapping to walls (excluding gable walls)
13. Identify no-drywall areas
14. Cut drywall when necessary
15. Lay drywall in proper location



16. Raise drywall and support with lumber
17. Glue studs and components
18. Lower drywall and tack in place
19. Screw drywall
20. Push up bottom half of drywall tight to top half
21. Screw off all drywall top and bottom
22. Check quality of work and replace if necessary
23. Route out the component (i.e. window/door) openings and edges
24. Drill holes in plates for fitting and install lifting eyebolts
25. Lift wall partway to staple strip to back of wall assembly
26. Using the hoist. remove the walls from the table and put them on the proper cart or rack

**Figure 35 Value stream map of wall department**



**Wednesday July 19, 2006.** In the morning, researchers studied the location of the gang nailer. Fourteen-foot long lumber was being manually carried from an outside shed. When the top and bottom plates were assembled, they were transported by two people to the wall table. The plates were over 40 feet long and difficult to carry. They presented a hazard when staged near the break room. Several different layout changes were discussed for the wall area.

During the afternoon RPI meeting layout changes were discussed using the templates. The discussion focused on the location of the gang nailer and material staging locations. The day

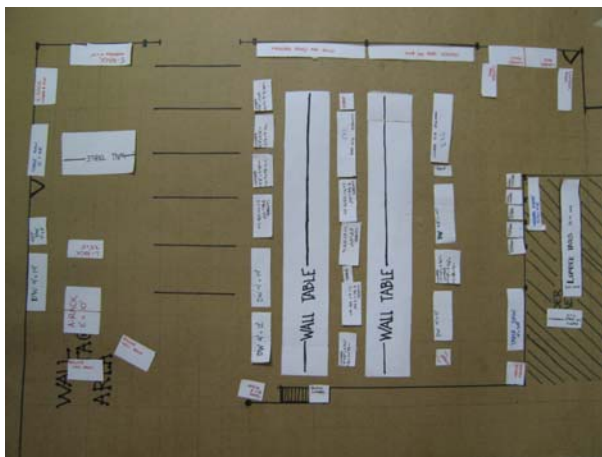
concluded with a frank discussion on the lack of communication between the supervisor and the team leader in the area, as well as the lack of communication between the team leader and his workers.

**Thursday July 20, 2006.** In the morning quotes were obtained for mobile gang nailers that can be placed adjacent to the wall framing tables. Researchers brainstormed the issue of proper management, leadership and teamwork. The outcome of the session was summarized in a Wall Build Code of Action.

During the afternoon RPI meeting participants identified the need for proper communication between workers and developed a set of guidelines. They then completed formulating their recommendations and developed the presentation format for the final day.

**Friday July 21, 2006.** In the morning researchers observed the sidewalls area. It was a heavy production day and the area was struggling to keep pace. During the final afternoon RPI meeting, the team presented their findings and recommendations to the chief of production and the company owner and president. The RPI team’s recommendations are summarized in Table 7 below and in the proposed revised area layout included in Figure 38. Implementation and evaluation was planned for a later date to be determined

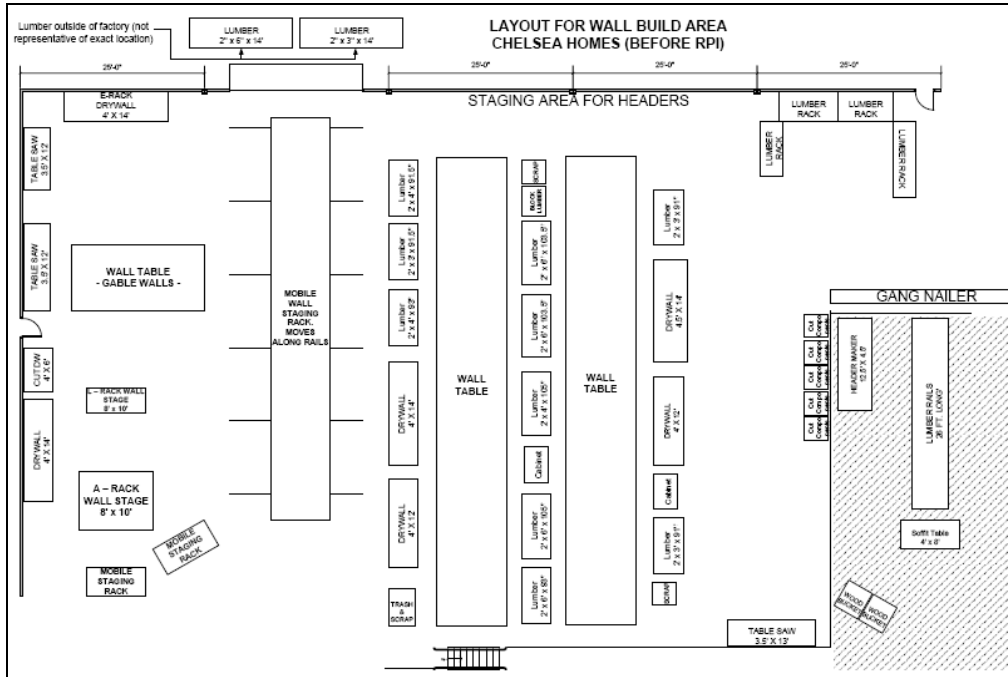
**Figure 36 Template plan of wall department**



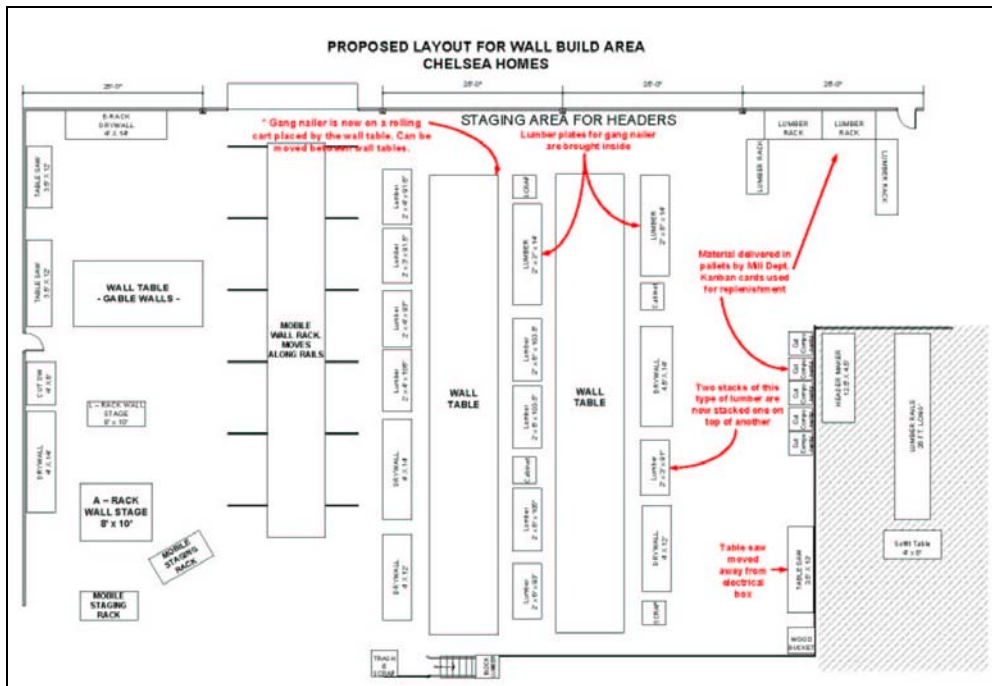
**Table 7 Summary of recommendations**

Issue	Recommendation
Location of table saw blocks electrical panel box creating safety hazard	Relocate table saw
Location of gang nailer is far from materials and wall tables and blocks plant traffic	Purchase small, mobile gang nailer that can be placed adjacent to the wall table
Location of lumber for plates is outside and far from gang nailer	Make space for lumber inside and near the wall tables
Lack of communication between Team Leader and Supervisor	Report every morning and provide status report before or after each break
Mill fails to deliver material in time. Workers make repeated calls and often are forced to cut their own materials	Implement a kanban system for mill material replenishment
Other workers walking through the work area around the small wall table interrupt the work flow	Reverse the hinge on the nearby door to the offices so traffic is guided away from the work area

**Figure 37 Wall department layout - current**



**Figure 38 Wall department layout - proposed**



**C.6 SPACKLING RPI**

By September 2006 Chelsea’s lean initiative had lost some momentum as other priorities had sapped the lean initiative’s resources and the earlier RPI’s sustainability faltered.

Earlier RPIs in wall build and end-of-line work rules had been identified by value stream mapping as critical to improving line flow and addressing the strategic goal of increasing plant throughput. But these RPIs met with limited sustainable successes. The lean initiative needed a high visibility home run. In a change of focus, management targeted spackling where numerous small cross-departmental issues added up to major quality problems easily visible to all plant employees. The end result was poor quality at inspection, requiring expensive rework to achieve Chelsea's high-quality end-product, and as a result, creating a bottleneck in the rework area.

The spackling RPI was conducted from September 25–29, 2006. It covered the drywall finishing operations, which employed a crew of four tapers, two sanders and two painters distributed among five line stations, and three touch-up workers working farther down the line reporting to a different group leader.

The objective of the RPI was to increase the quality of work delivered down the line and reduce the number of delays caused by incomplete work or the need for rework. Chelsea managers were aware that spackling had numerous problems contributing to poor productivity and low initial quality, but they had never thoroughly catalogued and analyzed them with the mindset that they were fixable. The RPI provided Chelsea with a process to solve them. Some of the major issues included:

- Poor communication across departments and a lack of cross-departmental coordination and cooperation
- Lack of accountability – teams not taking responsibility for the quality of their work
- Rigid mindsets regarding responsibilities leading to a “not my job” attitude
- Numerous seemingly minor process and product issues that added up to major problems at the end of the line
- No systematic process to address and solve these issues

The bottom line was that defects, unintentionally caused by many people and affecting many others, were requiring time-consuming and expensive rework at the end of the line in order to maintain the high quality of Chelsea's finished product.

### **C.6.1 RPI process**

The RPI began on a Monday. The lean manager established the goals of the RPI and the plant manager presented his expectations to the team. Lean manufacturing training including the five Ss, the seven wastes and value stream mapping was conducted. Six Chelsea employees participated on the RPI team including the lean manager, the spackling team leader, the foreman over the spackling area, a production worker from the sidewall department, a member of the touch up crew and the yard supervisor who was also responsible for final quality checks.

On Tuesday the lean manager further defined the issue with a slide show presentation and video clips of problems in the department. The team then moved out onto the production floor to look for problems and their causes. On Wednesday and Thursday the team researched problems on the floor and discussed preliminary solutions. Problems identified included:

- Sheetrock not being installed on time
- Poor quality of sheetrock coming into the spackling department (missing or damaged wallboard, large crude punch-outs for ceiling penetrations, screws not fully set, screws not hitting studs, glue seeping through seams in ceiling)

- Tapers sometimes set raised screw heads by hitting them with a hammer (Figure 39), causing damage to the wall or using a screwdriver with difficulty (Figure 40)
- Insufficient drying time (the department is supposed to have five dedicated line workstations for drywall finish/sand/paint, but this has been reduced due to shipping commitments)
- Lumps of mud in bottom of corners caused by wiping mud “up to down” (Figure 41)
- Inconsistent mud mix
- Line workstation assignments not being adhered to
- Attitude issues (“not my job”)
- Lack of unity and team spirit in the department
- Communication barriers between workers and supervision
- Congestion in modules where sanding and painting are done (often simultaneously)
- Inadequate and uneven sanding in corners
- Untrained and unmotivated workers

**Figure 39 Hammer mark from setting screw**



**Figure 40 Taper setting screws by hand**



**Figure 41 Mud lump in bottom of corner**



On Friday the team discussed other plant-wide problems affecting the drywall department, including:

- People working out of station (causing congestion and worker stress)
- Workers cutting through paper intended to protect the floor, leading to flooring damage
- Lack of proper training when workers are assigned to a new area
- Orders being pushed through the line when they have been sitting in offices for months
- Revising transportation dates when the house is not ready

Finally, the RPI team prepared, rehearsed, and delivered their presentation to the plant manager and company president, and identified team member responsibilities for implementing approved changes.

## C.6.2 Recommendations

The spackling RPI team made 22 recommendations for changes. The team recommended product changes, such as using wider tape to prevent glue seepage through drywall joints, maintaining a supply of one-quarter-inch sheetrock and switching to reverse nail electrical boxes where they were not already being used. They also suggested process changes, including routing wall tops to ensure a flush surface for the ceiling to set on and using a hole-saw rather than a hammer to make holes for plumbing vents. Equipment improvements suggested by the team were minor, but important; padding on racks and carts to reduce damage were the most important. Some of the most significant changes were in work rules: making departments responsible for quality and correcting mud defects before painting. The team recommended standardizing mud mix procedures by marking water levels on the mud mix barrels, and making some organizational changes to better align responsibility with accountability and permit the area team leader to come down off his stilts so he could better supervise his team.

All of the changes were based on simple lean principles and common sense. While many may seem obvious, the fact was that Chelsea was living with these problems for a long time prior to this RPI and it took the lean initiative to provide a process to solve them. And coming from the plant workers, the recommendations have a much greater chance of being sustained than if they were a dictate from management. Table 8 summarizes the complete list of recommendations and their disposition.

**Table 8 Spackling RPI recommendations**

Recommendation and purpose (responsibility)	Disposition
1. Switch from ¾-inch to 2-inch wide tape for sealing ceiling drywall joints against glue seepage	Implemented during the RPI, subsequently approved by management after questions on sustainability were addressed (ensuring that this tape will be ordered going forward)
2. Cut ceiling openings for vent pipes with a hole-saw rather than punching with a hammer, which creates overly large and imprecise openings, requiring extensive spackling repair (Figure 42). A worker from ceiling set will need to go down to the floor and route the ceiling from the bottom up.	Approved. Ceiling workers hesitant at first but quickly realized the benefit to the operation. The additional time to cut holes is vastly outweighed by benefits to the spacklers. Electricians are also now cutting openings from the bottom up instead of top down to reduce paper tear-out (Figure 43).
3. Wrap wall rack pipes with foam and straighten them to prevent damage to completed walls (Figure 44)	Approved. If pipes cannot be straightened then replacements are approved.
4. Install new carpet padding to short wall carts to prevent damage to completed walls	Approved.
5. Make group leaders over wall department and sheet rockers responsible for ensuring sidewall screws are fully set	Approved. Screws are now mostly being properly set.
6. Mark mud buckets with levels for water, mud mix	Completed. Mud consistency improved dramatically.
7. Combine touch-up with taping, sanding and painting as one department	Touch-up not approved to join. Other departments combined.
8. Install a new 3 ft by 13 ft work table to score and snap sheetrock in the wall department to prevent workers from using the sheetrock bundle as work table and damaging wallboard	Approved.
9. Combine sheetrock and wall set as one department to instill accountability for wall quality	Approved. There are three slots open for new people at this department. Once they are hired, they will work together as

<b>Recommendation and purpose (responsibility)</b>	<b>Disposition</b>
	both wall setters and sheet rockers.
10. Initiate new procedure to properly inspect walls and correct mud defects before painting or do not paint	Former painting group leader now responsible for pre-paint inspection. Additionally walls being dusted before painting as part of standard procedure.
11. Bring spackling department group leader down from stilts as much as possible so he has the mobility to get around to manage the group	Hired another spackler for stilt work and dismissed one sloppy spackler. Group leader now mostly off stilts and managing his workforce in spackle, sand and paint areas.
12. Initiate new policy that each department cleans up their mess when their work is completed	Management wanted to broaden recommendation to "Each department cleans the box out once they are finished," not just their mess. Group leaders are now being held accountable to supervisors for cleanliness.
13. Wall department to route off excess drywall extending above sidewall top plates so ceiling lies flat on walls	Now part of standard procedure.
14. Use reverse nail receptacle boxes so they can be installed flush to wallboard	Approved. Reverse double and triple boxes are on order and reverse singles are being used.
15. Consistently apply ½" shims around showers and tub walls to account for the thickness difference between green board and standard wallboard	Approved. Now part of procedure.
16. Reduce the number of people cutting protective floor covering paper or folding it back. Deep cuts are damaging the vinyl underneath.	Cutting paper restricted to individual who is supposed to do it.
17. Hire an experienced sheet rocker	Still looking to hire.
18. Purchase ¼-inch sheetrock supplies	Approved and purchased.
The following issues/recommendations were not directly related to the spackling department but affect production generally.	
19. Working out of station causes confusion, poor attitudes and ultimately affects quality	Trying to minimize but still a problem caused by customer demands for variable product complexity.
20. Lack of proper training when assigned new area	New training procedure in place. New workers work directly with group leader or his/her designee to train. Manuals and training videos planned for development.
21. Individual orders being pushed through the line and revising transportation dates causes confusion and struggling on the line	Customer demands and financial considerations make eliminating this difficult.
22. Resume monthly group leader meetings	Have been reinstated. The first meeting went very well and many of the spackling RPI issues were discussed.

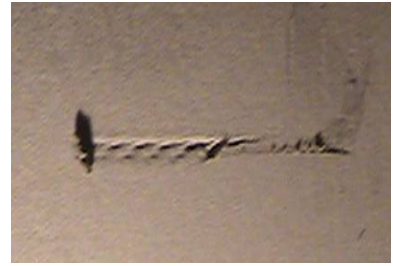
**Figure 42 Vent pipe punch out**



**Figure 43 Paper tear in ceiling panel**



**Figure 44 Damage from wall rack**



### **C.6.3 Results**

As a direct result of the RPI, wallboard finish quality at the inspection station improved dramatically. Defects and rework were reduced by 85% through improvements that were made with little-to-no cost. Often only one of the three touch-up workers was required after the RPI, with the other two performing other tasks. The quality inspector was able to focus on other relatively minor quality issues that were previously ignored because most of the major problems were eliminated.

In order to sustain these impressive gains, the new procedures must be documented in standard work sheets by department and the lean advocate, plant manager, and supervisors need to hold group leaders and production workers accountable for compliance with new procedures.

In addition to the gains in product quality, mindsets have also been affected. Workers gained an understanding of production as a system and more fully realize the impact of how cutting corners in one area can adversely affect another area (for example, not fully setting screws and punching oversized vent holes with a hammer made the mudder's job difficult). Better communication and active involvement by employees in problem solving resulted in improved morale and a more positive work attitude. The results are so dramatic and visible to the entire plant that it gave Chelsea's lean initiative a much needed boost.

## **C.7 ADDITIONAL CHELSEA LEAN INITIATIVES**

Between the lean advocate training in early April, 2006 and the value stream mapping exercise in May 2006, Chelsea implemented a number of lean changes including the following:

Reduced inventory of raw materials throughout the plant. Examples include:

- Fastener inventory cut from three months to three days at some workstations
- Ceased buying gypsum board in bulk. Gypsum board inventory was reduced from fifteen foot high stacks to less than six foot high stacks and as a result, material handlers no longer need to unstuck and re-stack bundles to pull from the bottom (see Figure 45).
- Ceased buying doors in bulk
- Removed old corner bead (had over a one year's supply, some of which had been crushed flat by the weight of material above it). Moved most stock outside and retained only a few weeks of inventory in the plant



**Figure 45 Previous wallboard inventory (left) and leaner wallboard inventory (right)**



- Cleaned up the production floor
- Removed worker shanties under catwalks to make work areas visible and clean
- Removed and red tagged 2.5 pallets of unneeded materials and placed it near a side door for future disposition (see Figure 46)

**Figure 46 Red tag area**



- Conducted an informal five S RPI in the door build area (Figure 47). The RPI was initiated by area workers mainly because traffic through their area was constantly interfering with production. Changes included:
  - Re-arranged tables into an L-configuration to reduce conveyance and motion
  - Built overhead tool bridge for compressed air tools
  - Removed unneeded materials from area
  - Improved the work area ergonomics
- Conducted an informal RPI in the drywall mud/tape area at the request of area workers. Changes, based on workers' suggestions resulted in re-arranging line stations to provide the area with three wet stations followed by two dry stations, the second of which is where painting would begin
- Modified mill procedures to cut blocking from scrap lumber rather than full 12 footers, resulting in a more efficient use of materials and eliminating the time wasting practice of carrying 12 footers back and forth to mark and cut

**Figure 47 Door build area after RPI reorganization**



- Made initial moves to start spreading out production activities to more fully utilize the open work stations at the end of the line
- Initiated daily accountability meetings four mornings per week attended by the production manager, line supervisors, service, QC and transportation departments; at each meeting, the group reviews production targets. If targets are missed, the team probes the reasons to discover the root causes. One meeting resulted in the discovery that downstream workers (tapers) were idle while upstream workers (sheet-rockers) were missing their production targets. The solution discussed at the meeting was to have idle tapers assist the sheet-rockers when necessary.
- Revised plant cleaning procedures so that each worker is responsible for cleaning their own area and directed house cleaners to move upstream to clean the production floor when they are not needed to clean finished modules at the end of the line; as a result, Chelsea did not need to replace three sweepers who resigned over the course of a few weeks
- Shut down the mill for one week to reduce inventory of cut parts. Directed mill workers to assist in other departments such as the wall build area; as a result, did not need to replace one worker who resigned from the wall build department.

# D

## HI-TECH HOUSING

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Hi-Tech Housing is a single-plant operation producing high-end manufactured homes for Saddlebrook Farms, a large manufactured home community that is a sister company; manufactured and modular homes for independent retailers; and commercial buildings.

The plant's lean advocate is the assistant production manager, who enjoys strong corporate support and a great deal of enthusiasm from the production group leaders.

Through its value stream mapping process, Hi-Tech identified three top priorities to begin their series of RPI events.

- Partition build: reorganize by thoroughly applying the six Ss (Hi-Tech has added safety as a sixth S)
- Sidewall build: reorganize by thoroughly applying the six Ss
- Roof set and sheathing area (a major line bottleneck): design and build a "ceiling tunnel," a specialized jig that elevates the ceiling assembly to permit drywall finishing to take place underneath simultaneously with electrical and insulation above in a safe manner; this major RPI would include balancing the line through the roof set area

This section describes the partition RPI event.

**Figure 48** Reviewing Hi-Tech's value stream map



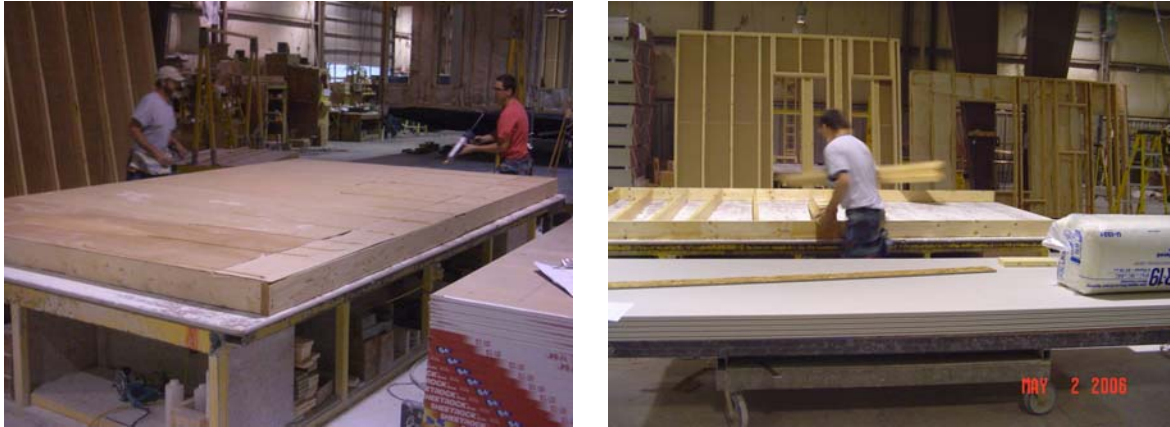
### D.1 PARTITION RPI EVENT

In the partition wall build area walls are framed using precut lumber provided by the mill, sheathed and, if exterior walls, insulated. Two production workers worked full time in the department prior to the RPI.

The two main reasons management selected partition build for the first major RPI event were:

1. Value stream mapping made clear that partition build was taking too long – it was lagging partition set, causing the set crew to wait for walls
2. Partition build would be a good demonstration area because of its high visibility in the plant – in an open area near the entrance to the office and break areas

**Figure 49 Partition department prior to the RPI**



The objectives of the RPI were to increase productivity by improving material flow and correcting poor ergonomics (lifting and toting large sheets of wallboard; reaching to fasten in the center of walls; hunting for tools).

### **D.1.1 RPI process**

The RPI event was conducted from June 1–9, 2006 with implementation continuing for a number of weeks afterward. Hi-Tech devised an RPI process that minimizes disruption to production activities. A series of brief meetings are spaced apart over the course of a week or two to give workers time to think about ideas while they work and then bring them back to the group. The meetings include a brief overview of lean basics and have a strong focus on improving the area in question.

For the partition RPI, eight production workers and supervisors and all top plant management were present at all three meetings, conveying the importance management placed on the event and the lean initiative in general.

During the initial one-hour meeting, the lean advocate introduced the concepts of kaizen and lean manufacturing and the effect these concepts could have on the wall department. The lean advocate asked participants to think about the six Ss as they worked in their area, focusing on ways to make it more efficient, and to write down their ideas prior to the next meeting, which was scheduled for the following week.

During the second meeting the team held a one-hour brainstorming session where all ideas were recorded and voted on by the group. Selected ideas were prioritized and developed further.

On Friday, June 9 the team had their third meeting to finalize recommendations and develop an implementation plan. Participants used a scale drawing of the plant to visualize and experiment with revised layouts.

Implementation was completed on a non-production day after needed materials and equipment was received.

## **D.1.2 Recommendations**

The team recommended the following changes to the area, all of which were implemented:

### **Wall framing tables**

- Move the two wall framing tables together under the hoist system and weld them together as one jig. A single larger wall framing table will improve the flow of the interior wall layouts by focusing production resources (such as tools and material replenishment systems) on one area.
- Add space for tool storage under the wall framing table with wire steel mesh doors for tool inspection at the end of the day
- Put a new top on the wall framing table and paint the steel yellow
- Add an I-beam to extend the existing hoist system over the entire length of the extended wall framing table

### **Material replenishment**

- Move the drywall cart closer to the wall framing table (to within three feet) and mount the drywall cart on a steel track secured to the concrete floor, and install new ball bearing wheels on the cart so it can be rolled beside the jig; this will improve the ergonomics of handling drywall
- Build racks to hold insulation bundles to keep a better control of cleanliness in the department
- Install a pair of drive-in/flow-through structural pallet racks for lumber and bolt them to the floor so they can be moved in the future; lumber will load from the back and flow thru to the front of rack; set the lowest rack location at six inches above the floor so workers will not have to reach too high to retrieve lumber from the top of the upper bundle; install rollers on the racks to enable workers to easily move the bundles of lumber
- Move the white glue barrels closer to the jig and get an air pump; prior to the RPI workers had to walk approximately 125 feet to get white glue

### **Procedures**

- Have the parts department build ceiling trays and soffits rather than the partition department, thereby reducing the inventory of parts needed in the partition department. The swing/parts department already has the material near their saw to make these items

### **Tools**

- Move the chop saw to a central location alongside and within three feet of the wall framing table
- Purchase retracting reels for air hoses and electrical cords

### **Visual management**

- Clean the floor and reseal the concrete to keep things cleaner
- Paint everything to foster a clean environment and as a visual cue to spot problems



### D.1.3 Changes

The changes to the area can be seen by comparing before and after pictures in Figure 50 and Figure 51, respectively. Before the RPI, materials had no designated staging locations and so material handlers did not know where to put them or when supplies were needed (Figure 50 left). After, everything has a place and needs are visible to the material handler when they drive by (Figure 51 left). The department is now rarely short of materials.

Before, there were two wall jigs; one was rarely used and taking up valuable factory floor space (Figure 50 center). Now, production resources are focused on one expanded jig (Figure 51 center). Note the drywall cart in the foreground – it is now mounted on tracks so that one person can move it along to where they are working and it slides out to the forklift aisle for replenishment.

Before the area looked disorganized, like nobody cared (Figure 50 right). Now everything is clean and painted. Workers are proud of it and maintain it on their own initiative (Figure 51 right). When things are out of order, it is immediately obvious to any worker or supervisor.

### D.1.4 Results

Initial results include the following:

- The one-time cost of materials and labor for the RPI event was \$8,000
- An unrelated increase in plant production volume after the RPI would have required adding one worker to the department at an annual cost of approximately \$35,000; improved efficiency rendered this unnecessary.
- Space requirements were reduced by consolidating wall jigs and placing raw materials in racks; this space is initially being used as a red-tag area, but eventually will be used to store wallboard that is currently outside

**Figure 50 Partition and end wall department – before the RPI (panning left to right)**



**Figure 51 Partition and end wall department – after the RPI (panning left to right)**



## **D.2 GOING FORWARD**

There is strong enthusiasm among team leaders and production workers at Hi-Tech. Hi-Tech has an ongoing six S program that will encompass the entire plant and is conducting numerous other major RPIs: sidewalls, roof tunnel, ceilings, countertops, cabinet shop, and inventory procedure.

Additionally, Hi-Tech is working with suppliers to implement an RFID tag and scanner system that will automatically notify them when material is used. For example, when a bunk of lumber rolls through the flow-racks from the rear to the front position where it will be used, the supplier will automatically be notified for a reorder of the appropriate item and quantity. And Hi-Tech is working with plumbing and electrical parts suppliers to develop in-plant “stores” where materials will be stored on-site at the Hi-Tech plant.



# *E*

## **PALM HARBOR HOMES**

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Palm Harbor Homes in Albemarle, NC is a unit of Palm Harbor Homes, a multi-plant manufactured and modular home producer with headquarters in Texas. The Albemarle plant produces both HUD-code and modular homes, mostly in the middle price range with moderate customization. It typically runs four floors per day and serves the central eastern states.

During the latter half of 2006 the lean initiative at Palm Harbor Albemarle struggled to get attention and maintain momentum without a full-time lean advocate and with constant labor and management staff shortages. Nevertheless, Palm Harbor has been able to achieve some notable successes and thereby demonstrate the value of their lean initiative. This appendix describes two efforts, both of which netted the plant immediate, quantifiable and recurring monetary gains: a plant-wide red tag process and an RPI event in the shingle department.

### **E.1 RED TAG PROCESS**

The Albemarle plant is small and was congested. Obsolete, damaged, and excess material and unneeded equipment was scattered throughout the plant, and needed materials were generally poorly organized. This condition persisted because there was no system in place to flush these items from the plant. Managers felt that freeing up space would improve productivity.

Management's objective was to reduce these items while recapturing their maximum value and preventing the elimination of needed items, and to establish an ongoing process to continually clear out such items. Managers decided to focus on developing and implementing a red tag system as one of the plant's first lean initiatives.

#### **E.1.1 Process**

Management formed a team of key individuals; set aside an area in a highly visible location demarcated by red flags; established an ongoing process with written procedures and responsibilities; and rolled it out to the entire plant. Importantly, a written standard operating procedure was established to institutionalize the red tag process, enabling it to be sustained indefinitely. Employees involved in the development and operation of the red tag process (Palm Harbor's Lean Manufacturing Team) included the production manager, purchasing manager, assistant purchasing manager, quality assurance manager, inventory control supervisor, special projects manager and the supervisor of the cabinet, door and trim departments.

The red tag process devised by the team consists of the following steps:

1. Each plant department puts together a list of obsolete, damaged, excess or otherwise unneeded materials in their department and submits a material return request to a designated administrative office
2. The Lean Manufacturing Team prioritizes the lists and arranges for the materials to be relocated to the Red Tag area

3. The administrative office prepares a list of all items in the red tag area including the material description, count, and estimated dollar value and distributes the list to the Lean Manufacturing Team
4. Every Friday morning the Lean Manufacturing Team meets in the Red Tag Area to examine each item and make a decision as to whether the material can be returned to the vendor, used in another application, cut down, scrapped or sold; fast action is possible because the team contains all the key people needed to make decisions
5. The team's decision is carried out as soon as possible
6. The process is repeated every week and will continue indefinitely; Figure 52 shows the red tag area on two different dates and an example of the tags

**Figure 52 Red tag area on June 28, 2006 (left), red tag area on October 12, 2006 (center) and red tags (right)**



## E.2 RESULTS

Examples of materials that have passed through the red tag process and their disposition include:

- Obsolete molding (2,094 pieces). The material was originally slated to be discarded and written off prior to being moved into the red tag area. The team concluded that all 2,094 pieces could be ripped down to a 3 inch window jamb and used. The team arranged for a table saw and clamps to rip the material and scheduled the work. The plant used the reworked materials in the production line, saving the purchase price of an equivalent amount of 3" window jamb: \$7,602.52.
- Obsolete wall and floor ceramic tile (original value of \$3,377.75). The team concluded that the best means of recovering any value was to sell the tile to a local distributor at 50 cents on the dollar, for a net recoupment of \$1,688.87.
- Obsolete light fixtures likewise were sold at a discount for \$1,760.

The total savings from June 2006 to January 2007 was \$21,282. There is also a clear improvement in the cleanliness and organization of a number of areas in the plant that have been most affected by the red tag process: welding, plumbing, ceramic, trim, and final areas are less cluttered and more organized.

A benefit of locating the red tag area in a visible location is that it helps close the loop for purchasing and sales – whenever they walk by the area they can see what products did not sell and what was otherwise wasted due to damage or for other reasons.

The red tag process, because it is open to all departments in the plant, empowers people to improve their work areas. It increases involvement in the lean process as the company just begins to introduce it to the workforce, and it's a good teamwork exercise for managers.

### **E.3 SHINGLE AREA RAPID PROCESS IMPROVEMENT EVENT**

This RPI event, conducted during August 2006, involved a portion of the shingle department where two workers cover the completed roof with shipping protection consisting of plastic sheeting applied from rolls and heat shrink it with torches.

Before the RPI event, workers climbed a narrow rolling stair (Figure 53) carrying heavy rolls of plastic and other equipment (including a torch for heating the shrink wrap plastic) on their shoulders. They stepped from the stairs onto the roof. The rolling stair was only a few feet wide, and because it was time-consuming and inconvenient to climb down, shift it sideways and climb back up, workers were in the habit of reaching far out to the side from the top of the stairs, a precipitous position (Figure 54).

Once they were on the roof with the plastic, workers rolled it along the roof to unfurl it, kicking it with their foot to move it along. Occasionally the roll would get out of control and roll off the far end of the roof, potentially causing injury to workers below.

**Figure 53 Old rolling stair**



**Figure 54 Lifting a roll onto the roof**



The objective of the RPI was to create a safe and convenient work procedure involving a new stable platform for workers to use in this area.

#### **E.3.1 Results**

A team was assembled to develop and implement a better procedure that would address these shortcomings. The result is a simple, but spectacular improvement. The team created a large stable platform with railings the full width of a floor with space for material staging on the platform and access for easy replenishment of plastic and battens from a fork truck (Figure 55). Each item on the platform has a designated location. Plastic rolls are mounted on a large spool. Workers can now pull plastic off the roller as they walk down the roof (Figure 56). The entire platform is on wheels so it can adjust to the home length.

**Figure 55 New platform**



**Figure 56 Roll spool on new platform**



While the platform cost \$10,000 in materials and \$3,000 in in-house labor, it has also boosted productivity. Using the new platform, the cycle time for applying the roof protection has been reduced by an average of 20 minutes. Additionally, fewer workers are required to complete the task (1.5 instead of 2). One worker now has more time available to assist in shingling, typically a bottleneck activity. So the investment has more than paid for itself in labor savings alone in less than half a year.

In hindsight, the platform may seem like an obvious fix to an obvious problem. However, with the needs of daily production requirements pressing on them, workers rarely focused on these sorts of improvements until the plant became involved in lean production. In the words of the production manager, “we could not see the forest from the trees.” They were not taking advantage of the knowledge and wisdom present in the lower levels of the organization, where critical process knowledge often resides.

## **E.4 GOING FORWARD**

In the short term, the Albemarle plant managers are considering additional similar platforms for other line stations. They are planning five S events for electrical, tile, and drywall departments and continue to manufacture racks, jigs, and fixtures to improve processes.

# F

## GLOSSARY<sup>4</sup>

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### **Cycle Time**

How often a part or product is completed by a process, as timed by observation. This time includes operating time plus the time required to prepare, load, and unload. The appropriate calculation of cycle time may depend upon context. For example, if a paint process completes a batch of 22 parts every five minutes, the cycle time for the batch is five minutes. However, the cycle time for an individual part is 13.6 seconds (5 minutes x 60 seconds = 300 seconds, divided by 22 parts = 13.6 seconds).

### **Kaizen**

Continuous improvement of an entire value stream or an individual process to create more value with less waste. There are two levels of kaizen: (1) System or flow kaizen focuses on the overall value stream and (2) process kaizen focuses on individual processes.

### **Kanban**

A signaling device that gives authorization and instructions for the production or withdrawal (conveyance) of items in a pull system. The term is Japanese for sign or signboard.

### **Lean Production**

A business system for organizing and managing product development, operations, suppliers, and customer relations that requires less human effort, less space, less capital, and less time to make products with fewer defects to precise customer desires, compared with the previous system of mass production.

Lean production was pioneered by Toyota after World War II and, as of 1990, typically required half the human effort, half the manufacturing space and capital investment for a given amount of capacity, and a fraction of the development and lead time of mass production systems, while making products in wider variety at lower volumes with many fewer defects. The term was coined by John Krafcik, a research assistant at MIT with the International Motor Vehicle Program in the late 1980s.

### **Poka Yoke**

Japanese term which means mistake (or error) proofing. A poka yoke device is one that prevents incorrect parts from being made or assembled, or easily identifies a flaw or error. Error-proofing is a manufacturing technique of preventing errors by designing the manufacturing process, equipment, and tools so that an operation literally cannot be performed incorrectly.

### **Production Lead Time** (also Throughput Time and Total Product Cycle Time)

The time required for a product to move all the way through a process from start to finish. At the plant level this is often termed door-to-door time. The concept can also be applied to the time

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<sup>4</sup> Some of these definitions are taken from the **Lean Lexicon**, Lean Enterprise Institute, [www.lean.org](http://www.lean.org).

required for a design to progress from start to finish in product development or for a product to proceed from raw materials all the way to the customer.

### **Takt Time**

The available production time divided by customer demand. For example, if a widget factory operates 480 minutes per day and customers demand 240 widgets per day, takt time is two minutes. Similarly, if customers want two new products per month, takt time is two weeks. The purpose of takt time is to precisely match production with demand. It provides the heartbeat of a lean production system.

### **The Five Ss**

1. **Sort:** Remove everything from the workplace that is not needed for current production.
2. **Set in Order:** Arrange items so they are easy to find and return and locate items to minimize motion waste.
3. **Shine:** Keep everything clean and in top condition, so that it is ready to be used.
4. **Standardize:** Ongoing maintenance of Sort, Set in Order and Shine.
5. **Sustain:** Create the conditions or structures that will help sustain commitment.

### **The Seven Wastes**

1. **Excessive inventory:** Supplies in excess of what is required for continuous flow production.
2. **Overproduction:** Producing more than the customer needs.
3. **Unnecessary conveyance:** Transporting materials farther than necessary.
4. **Waiting:** Idle time.
5. **Excessive motion:** Actions that do not add value.
6. **Over processing:** Work elements and procedures that do not add value from the customer's perspective.
7. **Corrections:** Scrap and rework due to defects.

### **Value Stream**

All of the actions, both value-creating and non-value-creating, required to bring a product from concept to launch and from order to delivery. These include actions to process information from the customer and actions to transform the product on its way to the customer.

### **Value Stream Mapping (VSM)**

A simple diagram of every step involved in the material and information flows needed to bring a product from order to delivery. A current-state map follows a product's path from order to delivery to determine the current conditions. A future-state map shows the opportunities for improvement identified in the current-state map to achieve a higher level of performance at some future point.

### **Waste**

Any activity that consumes resources but creates no value for the customer.