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# *International Journal for*
# HOUSING SCIENCE and ITS APPLICATIONS

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## TABLE OF CONTENTS

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**Housing Science and Its Applications**

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International Journal for
# Housing Science and Its Applications

## AIMS AND SCOPE

The world is facing a major dormant housing crisis. It will create economic, social and political changes. It is time to give a high priority to housing studies, planning and production in the development programs of every nation. The uncontrolled population increases, migration from rural to urban areas, and decay of existing housing units are the major reasons behind the urgent need for more and better housing. This is a universal trend which is affecting every community.

The prediction of an United Nations study is that during the next thirty years, the world's population will increase by 3.5 billion. Assuming five persons per family, this growth in population will translate into 600 million new homes next thirty years, or twenty million per year. This is a difficult task to achieve. Housing science will be the base of all innovations needed to establish a successful approach to a permanent solution.

The *International Journal for Housing Science and Its Applications,* with its multi and inter-disciplinary concepts, is dedicated to achieve the objective of providing better living environment through the dissemination of scientific and technological knowledge

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# INNOVATION IN THE U.S. INDUSTRIALIZED HOUSING INDUSTRY: A TALE OF TWO STRATEGIES

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## ABSTRACT

This paper examines the current state of the U.S. industrialized housing industry and two recent industry efforts to innovate. The first approach takes a revolutionary approach, investing heavily in new designs, materials, and production technologies. The second effort takes an evolutionary, continuous improvement approach based on lean production principles. The success of each effort is summarized and conclusions given.

Key words: Homebuilding Innovation, Benchmarking, Automation, Lean.

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## Introduction

As shown in Figure 1, after a five year period of astounding growth, housing starts in the U.S. dipped by 15% in 2006. In many of the hottest markets the decrease is now approaching 50%. Three related reasons are frequently cited: a rise in mortgage interest rates, resetting of Adjustable Rate Mortgages (ARMs) and problems in the sub-prime mortgage market. Subprime loans, made to borrowers with a history of missed payments or untested credit, and ``Alt-A" loans, which require little or no documentation, account for about $2.5 trillion of the $10 trillion in outstanding mortgages (4). The delinquency rate on subprime mortgages rose from 11.6% at the end of 2005 to 13.3% at the end of 2006, driven largely by the high rate of ARMs resetting due to rising interest rates and the end of 'teaser' introductory rates. As a result, sub-prime mortgage companies failed, ripples spread throughout the mortgage industry (and the entire economy) and mortgage money became harder to get – especially for less qualified homebuyers. Rough estimates suggest that one-third of foreclosures will wind up back in housing inventory during the next year, with the remaining loans being restructured to make them current. This increase of foreclosed homes in the market further depresses new home sales.

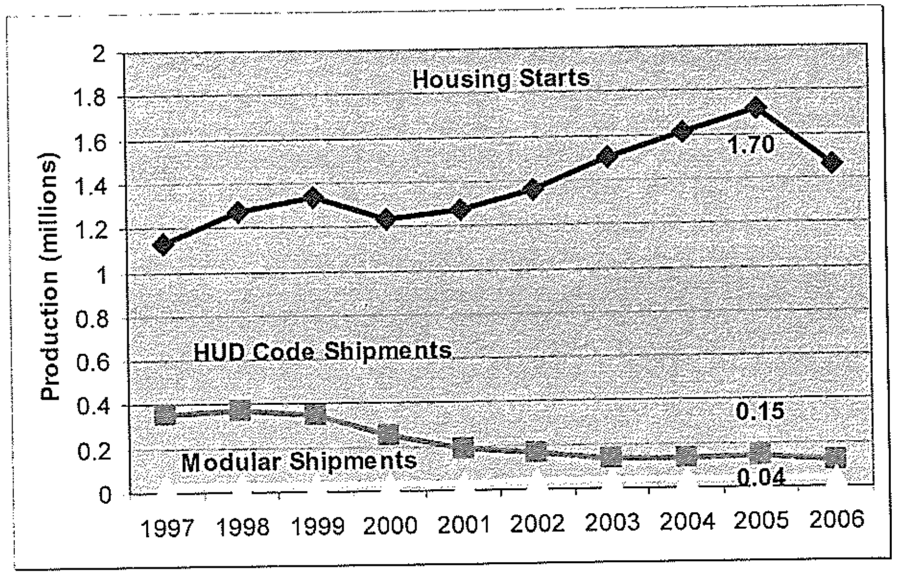

FIG. 1
U.S. Homebuilding Statistics (1,2,3)

Industrialized housing production, represented in Figure 1 by HUD Code and modular shipments, was also affected. HUD Code shipments dropped by 20% and modular shipments dropped by 11%. Thus, HUD Code market share continued to erode, while the modular industry actually improved market share slightly in the down market.

Continued deterioration in the HUD Code market has resulted in a major shift for some of the largest industrialized housing companies. Three of the largest HUD Code manufacturers are now the top three largest modular producers (5). The largest modular producer produced 40 percent of their $1.4 billion revenue in 2006 from the modular business compared to just five percent in 2002 (3).

A profile of new home construction by homebuilding technology is shown in Table 1. 55% of homes were stick built on the construction site using conventional wood frame construction. 14% were site-built using concrete block. 13% were built using prefabricated panels – primarily low value added, open wood frame panels. Insulated concrete forms (ICFs) and removable concrete forms were used to build 4% of homes. Steel framing was used to build 2% of homes. Non-traditional, innovative technologies, such as structural insulated panels (SIPs), were used to build a total of less than 2% of all homes

TABLE 1
Profile of Homebuilding Technologies
(1,2,3,6,7,8,9)

| Technology | Market Share |
|---|---|
| Stick-built | 55% |
| Concrete masonry | 14% |
| Panelized | 13% |
| Insulated Concrete Forms | 4% |
| Steel Frame | 2% |
| Structural Insulated Panels | <1% |
| Other | <1% |
| HUD Code | 9% |
| Modular | 2% |

The two primary industrialized homebuilding technologies, HUD Code and modular, were used to build about 11% of the homes – 9% and 2% respectively.

Recognizing the serious challenges that it faces, the industrialized housing industry recently launched a multi-year, industry-wide effort to boost production performance. Working collaboratively, the Manufactured Housing Research Alliance (MHRA) - the industry's research and development arm – and the University of Central Florida Housing Constructability Lab (HCL) completed an important preliminary task, documenting the industry's current production performance. A comprehensive survey was distributed to 275 U.S. and Canadian housing factories. The survey included questions concerning product offerings, production levels, productivity, worker satisfaction and customer satisfaction. Over 50% of the factories responded. Results were published (10) and disseminated to provide an industry baseline, allowing the industry to track improvements industry-wide and encouraging each factory to benchmark themselves against competitors. A finer breakdown of findings by industry segment (HUD Code versus modular) and by region were provided to participants to enhance benchmarking relevance. Key findings are summarized below.

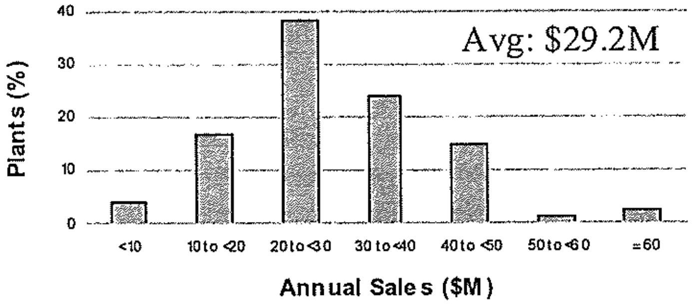

FIG. 2
Profile of Annual Sales

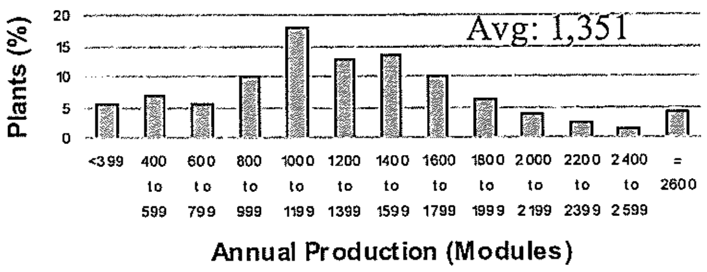

FIG. 3
Profile of Annual Production (Modules)

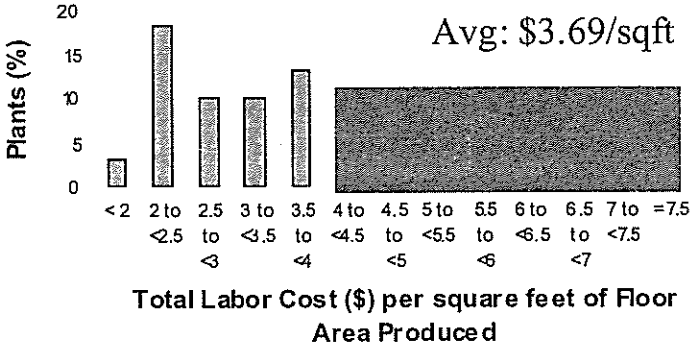

FIG. 4
Profile of Labor Cost per Sqft

Annual sales from each factory averaged over $29 million (Figure 2) with production over 1,300 modules (Figure 3) – equivalent to about 5 modules or about 2 homes per day. Labor cost averaged $3.69 per square foot (Figure 4) or about 15% of the total sales $ (Figure 5). These metrics are important measures of labor productivity. Note that many factories had much higher labor cost. Those factories with labor costs in the "red zone" should look closer at their costs for improvement opportunities. Service costs, the cost to repair quality problems discovered by the customer, averaged 3.8% of total sales (Figure 6). Some factories had much higher service costs, over 7% of sales. Labor turnover averaged over 60% annually with some factories over 100% (Figure 7). Turnover is a critical indicator of worker satisfaction. When labor turns this fast, the factory never develops the skilled workforce needed to deliver a high quality product with factory efficiency. Instead, the workforce resembles day labor on a construction site. Customer satisfaction averaged 89% with many factories reporting satisfaction less than 85% (Figure 8).

In summary, findings from the benchmarking study clearly indicated opportunities for industrialized housing producers to improve performance. When considered against the backdrop of current market conditions, this opportunity for improvement becomes an absolute imperative for organizational survival. Thus, the only question is how to improve. In general, there are two manufacturing improvement strategies that are widely used across most industries. The first is a capital intensive approach that is based on revolutionary change, often incorporating new plants, technology and automation. The second strategy relies on more evolutionary, continuous improvement using lean or 6 sigma techniques to effect change. Neither strategy is used appreciably in the U.S. industrialized housing industry. This paper serves as a comparative case study of recent attempts by the industry to adapt and utilize these strategies.

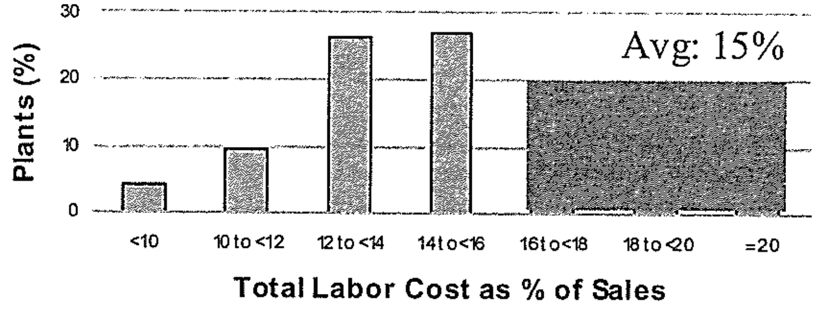

FIG. 5
Profile of Labor Cost as % of Sales $

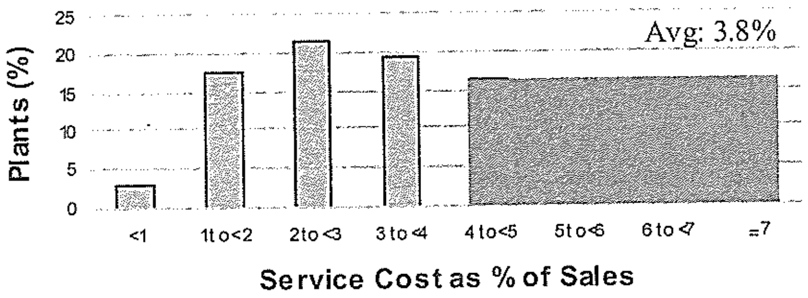

FIG. 6
Profile of Service Cost as % of Sales $

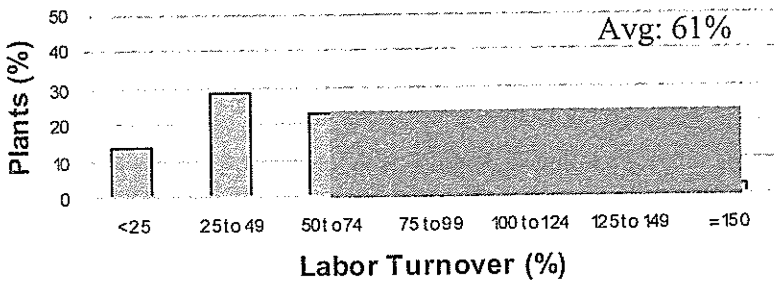

FIG. 7
Profile of Labor Turnover

Strategy 1: Revolutionary Change

The strategy of using revolutionary change, often incorporating new plants, technology and automation, has been widely used across most industries to drive production improvements. The automotive and electronics industries have been highly successful in developing and implementing new technologies that enhance both the functionality and customer appeal of their products as well as improve the quality and productivity of their manufacturing processes. Although this approach has not been widely used by homebuilders, a recent U.S. Department of Housing and Urban Development (HUD) study (11,12) chronicled several innovative efforts by homebuilders. This section describes the most highly visible of these efforts, Pulte Home Sciences. Pulte Homes is one of the biggest homebuilders in the U.S., producing over 40,000 homes in 2005. Like other large production builders, Pulte uses subcontractors to stick-build most of their homes on the construction site. In 2003 Pulte announced a growth strategy to double their sales over the next 5 years. That strategy had 5 major components: manage land assets, diversify products, satisfy customers, develop employees and, finally, vertically integrate construction processes. This discussion focuses on the last component.

To vertically integrate, Pulte created a new division, Pulte Home Sciences (PHS). The cornerstone of PHS was a new 108,000 square foot factory that opened in December 2003 in Manassas, VA. The factory produced large-scale shell components – foundations, floors and walls. It had a capacity of 2,000 homes per year (8 homes/day) and produced a typical home size of 4,200square feet. PHS used an advanced parametric CAD modeling system to design, engineer and drive automated production processes. The cross-domain integration allowed information to flow consistently from design to engineering to production. The CAD system was supplemented with web-based process scheduling.

With the exception of readily available roof trusses, the large-scale shell components that comprised the new, highly integrated building system were all produced in the PHS factory. High density, pre-cast concrete foundation walls were formed on casting tables that used lasers to position bulkheads, inserts and holdouts.

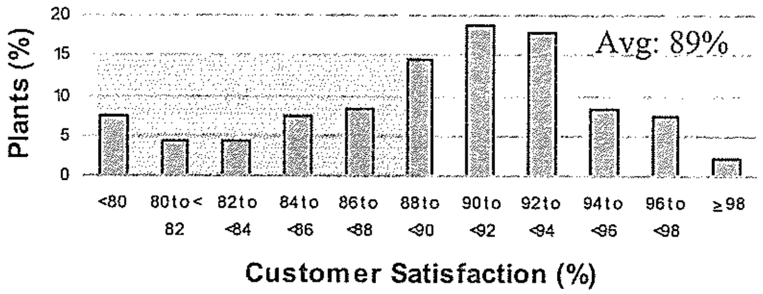

FIG. 8
Profile of Customer Satisfaction

Open web steel floor trusses were fabricated and assembled in the factory. Floor trusses were used to frame floor panels up to 45' long. CAD information guided numerically controlled tooling to assemble the floor panel and precut holes for pipes, HVAC ducts, and registers in the floor deck.

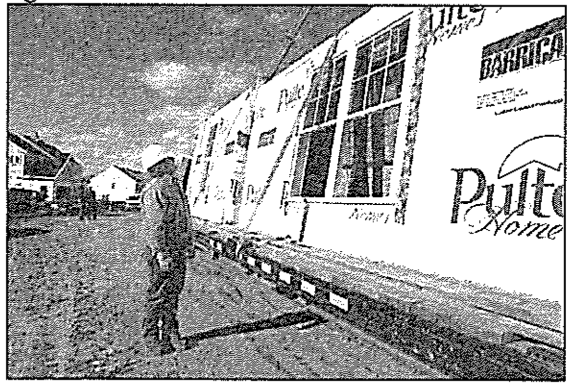

FIG. 9
SIP Walls Delivered to Building Site

PHS produced structural insulated panels (SIPs), which were used for exterior structural walls (Figure 9). Jumbo (8' x 24') sheets of oriented strand board (OSB) were pulled from inventory, squared, and delivered just in time for the numerically controlled equipment to pick them up and place them on a moving assembly table. Adhesive was automatically sprayed on the OSB sheets, expanded polystyrene (EPS) foam blocks with pre-cut electrical raceways were dropped onto each sheet, another layer of adhesive was sprayed on the insulation, and a second jumbo OSB sheet was installed to complete the sandwich panel. The assembly was then pressed while the adhesive cured. Finally, a numerically controlled router cut rough openings for doors and windows. The SIP panel then moved to a vertical rack where flashing and windows were installed.

Light-gauge steel studs were roll formed at a workstation fed by a galvanized steel coil, automatically precut to length using CAD data, and then assembled into interior partition panels. Throughout the plant, components were labeled with the project, location, and component identification to increase field erection accuracy and speed.

The advantages of the PHS building system were substantial. Quality was improved by the use of the large scale building elements that reduced seams and joints, providing a tighter envelope, less settling and cracks, and reduced customer service calls. Cycle times were reduced – shell dry-in time was reduced from 10 to 3-4 days with the overall cycle time shortened from 120 to 100 days. Although overall labor levels were similar, the new system required fewer skilled trades in field.

There were two opposing views of Pulte's innovation. The first was very positive and was reflected in a report from the U.S. Department of Housing and Urban Development (11) that called it: "one of the most significant developments in the systems approach to housing." The opposing view, which was also the predominant view of both financial analysts and competitors, was that vertical integration is risky because of its fixed costs. This view is summarized in the following quote from Greg Gieber, housing analyst at A.G. Edwards: "This is still a cyclical business, and the reason [builders] hire subs is so they can get rid of them during slower periods." (13)

In January 2007, three years after the PHS plant was opened, Pulte management made the following announcement (14):

> "Due to current market conditions, the plant was operating at about 25 percent capacity by the end of 2006 and on [Jan. 26] we reached the decision to close the facility .... Longer term, pre-manufacturing and transporting sizeable, heavy components to a geographic area limited to within 125 miles of the facility proved economically unviable, especially under current market conditions .... Overall, costs were higher and that was something that Pulte Homes could not pass on to home buyers."

Unfortunately, Pulte was not the only innovative casualty in the current housing downtime. The same HUD report that chronicled the PHS system (11) also cited an innovative whole house building system and the use of light gauge steel framing for residential construction. In summer 2007, the only factory producing homes using the whole house building system closed, as did one of the most innovative new steel frame panelizing operations. Clearly, even very sophisticated, well financed innovators have found it difficult to successfully utilize a capital intensive, revolutionary strategy in the highly cyclical U.S. housing market.

### Strategy 2: Continuous Improvement using Lean Production Principles

The second manufacturing improvement strategy is based on evolutionary, continuous improvement using lean or 6 sigma techniques to effect change. This paper focuses on a case study involving the use of lean production. Originating with the Toyota Production System (15), 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 (16). Other industries have followed the automobile industry's lead, achieving similar results (17). The goal of lean production is to satisfy the customer by delivering the highest quality at the lowest cost in the shortest time. This is accomplished by continuously eliminating waste. All forms of waste are targeted by lean production initiatives: defects, overproduction, transportation, waiting, inventory, motion and processing. Lean refers to a general way of thinking and specific practices that emphasize using less of everything (18). Dennis (19) summarizes lean production concepts in Figure 10.

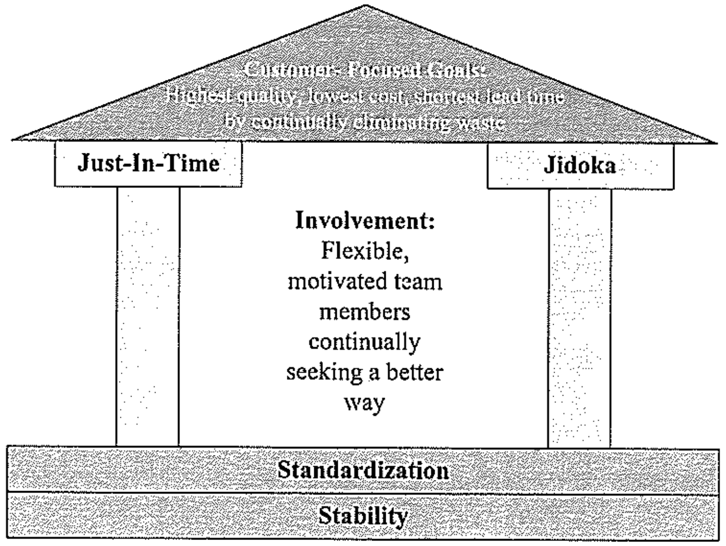

FIG. 10
Lean Production Concepts (19)

The foundations of lean production are stability and standardization. Stability seeks to bring order to the chaos that is an inherent part of the manufacturing enterprise. Stability and standardization are mutually supportive. Standardization provides stability to the workplace and stability is required for a production system to meet standard (expected) levels of performance. Standardization refers to the intentional design of both products and processes to achieve greater commonality and repeatability. Standard manufacturing processes (e.g., process equipment and methods) are the safest, easiest and most productive ways of doing the job. They are also the baseline from which improvements are continually made, and thus are transitory.

The two supporting walls for lean production are just-in-time delivery of parts and jidoka, automation with an intelligent mind. The over-riding objective of Just-in-time (JIT) is customer satisfaction - providing what the customer values when the customer wants it – i.e., producing the right part at the right time in the right quantity. JIT begins with the identification of what the customer values, often called the voice of the customer. JIT then seeks to provide a continuous flow of work to create this value, which simultaneously eliminates all waste and provides quick response to the customer. It should be noted that JIT and continuous flow rely on stability and standardization in the workplace as well as a capable, multi-skilled workforce. Jidoka, automation with a human mind, refers to intelligent workers and machines identifying errors and taking quick countermeasures. The objective is to make processes defect-free by automatically identifying and containing defects.

At the core of lean production is an empowered workforce, focused continually on seeking a better way. The objective is to nurture and utilize the vast potential of production workers to improve their own operations while simultaneously improving the organization's prospects for long-term success.

As mentioned previously, the industrialized housing industry recently began a multi-year, industry-wide effort to boost production performance. The second phase of this effort, called the Lean Initiative, began in March 2006. Nine plants representing eight different companies volunteered to participate in the effort, including several of the largest in the industry.

To kick-off the effort, two lean advocates from each plant participated in one week of centralized lean training. The advocates then returned to their plants, trained their associates, and began a series of kaizen Rapid Productivity Improvement events or RPIs. Lean experts from Senco (an early lean adopter) and the UCF Housing Constructability Lab participated in at least three events at each plant.

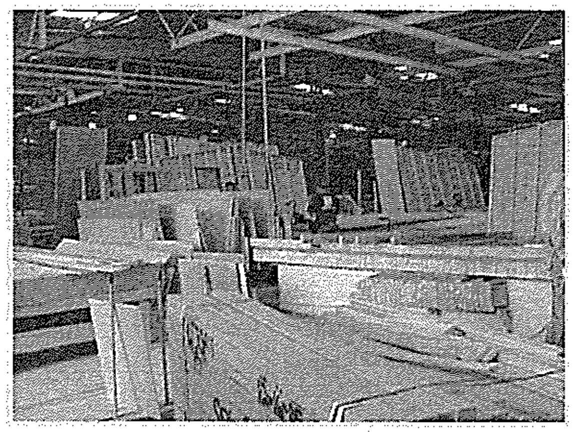

FIG. 11
Interior Wall Department

The RPI in an interior wall department (Figure 11) was typical. The department appeared cluttered and disorganized and repeatedly delayed the main production line. Workers walked long distances to get materials and were often delayed by other workers or haphazardly placed materials. Finished walls were pulled through the shop by hand. The primary objective of the RPI was to improve the activities and flow in the area by rearranging the layout.

RPI team members were intentionally selected to include associates from both inside and outside the area and to include specific functions that might be involved in implementation. Participants included: Production Manager, Assistant General Manager, Audit Manager, Maintenance, Area Supervisor, and several other associates from the area.

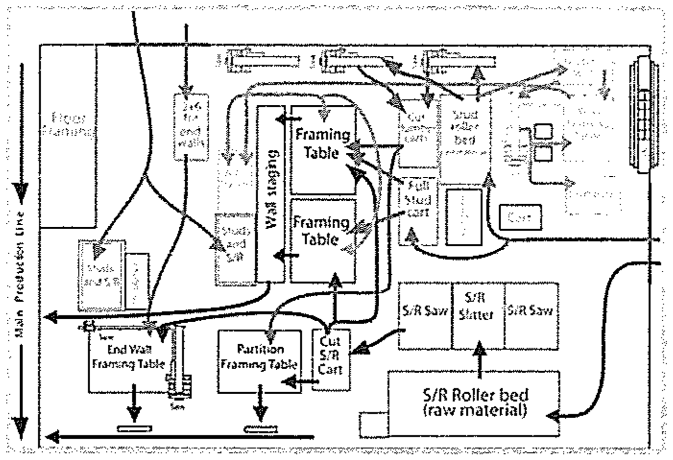

FIG. 12
Spaghetti Chart Showing Material Flows

Most RPI team planning activities took place over two days. The lean advocate began the discussion by presenting the objectives of the RPI and some initial ideas for improvement. The team then conducted a more thorough observation of activities in the area and developed material and information flows. The spaghetti (material flow) chart (Figure 12) indicates many long material movements, often crossing each other. All team members then discussed possible alternatives and developed a comprehensive plan to improve the area.

Follow-up and implementation activities took place over several months and included involving other area workers in planning discussions, procuring materials, fabricating needed elements, rearranging the layout, evaluating the number of workers and work load based on the new layout, balancing the work load, relocating workers, and evaluating the performance of the reconfigured area.

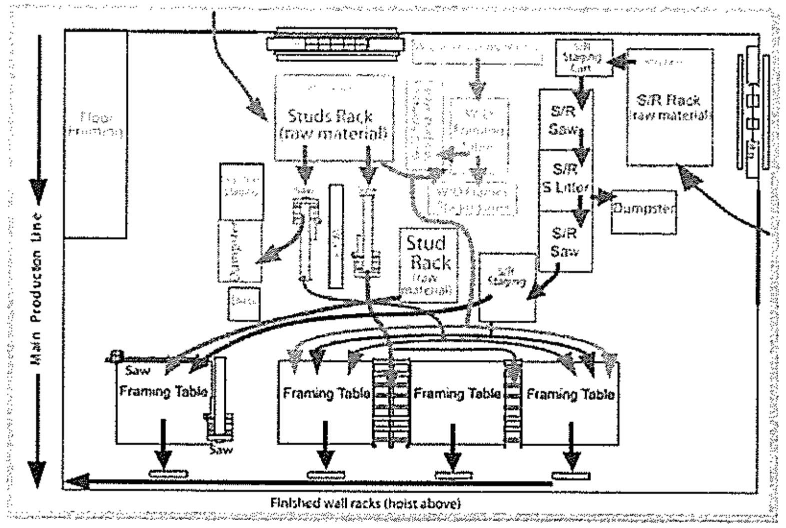

FIG. 13
Spaghetti Chart Showing New Material Flows

Results were encouraging. The new flows (Figure 13) were short and logical. The new area was neat and orderly (Figure 14) – the associates can see it to manage it. Cranes were extended to minimize pulling completed panels through the area by hand.

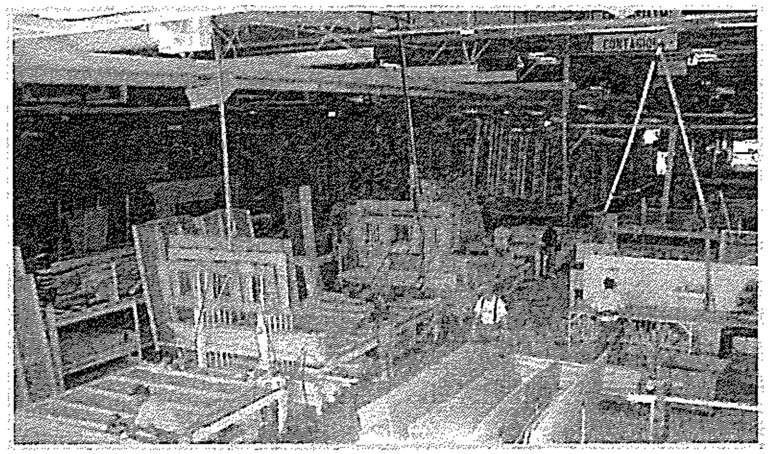

FIG. 14
Reconfigured Interior Wall Department

In January 2007, advocates from all nine plants reconvened to report their results to industry executives. The results were remarkable. For the wall department, the most important accomplishment was that the department was able to keep up with the main production line. Space was reduced by 12%; drywall damage was reduced by 10%; and labor was reduced by about 30% - a labor savings of over $70,000 annually. These workers were transferred to other departments with labor needs, eliminating the need to hire and train three new workers. Other plants reported similar hard results – they simply were able to use less of everything to meet their customers' needs. Soft results were equally striking. Selected comments from team members included:

- "Taps into worker commitment to the company"
- "We can make our workplace better"
- "Morale in department very high"
- "Wide range of RPI participants"
- "Strong support of plant management"
- "Spread lean company-wide"
- "Workers understand production as a system"
- "Forces company to confront critical issues"
- "Provides forum for management to converse with workers"

Based on the strong results and contagious enthusiasm generated by the Lean Initiative, participating plants made substantial commitments for the future by assigning Lean Directors at the corporate level, assigning full time lean advocates at each plant and training their associates and accelerating the pace of kaizen RPIs. A report to HUD (20) summarizes the Lean Initiative and individual plant presentations are available at the MHRA website (21).

## Conclusion

Once again, technically sophisticated and well financed industrialized homebuilders have failed in their attempts to utilize a capital intensive, revolutionary strategy to effect production improvement. Although the highly cyclical U.S. housing market certainly played a key role in these failures, it is important to ask whether they were inevitable or whether other factors increased risk unnecessarily. Perhaps the first place to look is the planning processes that resulted in the unsuccessful systems. A fundamental axiom of automation planning is that existing (often manual) processes should be optimized (eliminated, simplified, or combined) before considering automation. This axiom underlies one of the fourteen principles identified by Liker (22) that define the Toyota Production System, Toyota's version of lean production. Toyota uses only reliable, thoroughly tested technology that serves their people, processes and values. In practice, Toyota introduces a new technology only after it is proven through direct experimentation with a broad cross-section of their associates and has been found to provide added value to their people, their processes and their culture. For Toyota, lean processes are a prerequisite for technology. Only then, will the decision maker understand the true value of the technology being considered. This true value extends beyond financial return on investment to include the impact on flexibility to accommodate different products, manageability of the process, acceptability of the process to associates, and technical and business (market and competition) risk. Future research should include a comprehensive post mortem of the PHS failure and the lessons learned.

It is still too early to assess the mid to long term impact of lean on early adopters participating in the Lean Initiative, much less the long term success of lean throughout the industrialized housing industry. However, it is clear that it is capable of having an substantial impact - both hard and soft benefits have been noteworthy. Further research should continue to support and document lean progress in the early adopters and encourage more companies to begin the lean journey.

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# BEYOND SHELTER: A DESIGN FRAMEWORK FOR REMOTE INDIGENOUS HOUSING IN AUSTRALIA

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## ABSTRACT

This paper reports on the development of a design framework for improving housing conditions in remote Indigenous communities in Australia. The first section of the paper outlines the nature of the housing crisis in these communities and briefly reviews recent policy changes that have the potential to facilitate major improvements in the number and quality of houses to be built in the communities in coming years. The second section defines the concept of 'design framework' used in this paper and the process of research that was undertaken in three case study communities to elicit stakeholder views of an appropriate design framework for remote Indigenous housing in Australia. The final section of the paper provides an overview of the design framework that was developed with a particular emphasis upon how a 'Triple Bottom Line' view of sustainability was used to guide the development of an integrated and balanced set of guiding principles for the planning, design, construction and maintenance of remote Indigenous housing.

Key words: Housing, Australia, Indigenous, Design.

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