

# PREFACE

## BOOK ORIGINS

In 1990 I accepted my first (and only) academic position, as a faculty member in the Department of Industrial Engineering and Management Systems at the University of Central Florida. My first research assignment was to explore the use of innovative manufacturing technologies in prefabricated homebuilding. I pursued this research topic throughout my academic career, and I continue to pursue it today, in my retirement, serving the prefabricated homebuilding industry as a consultant. Before entering academia, I served as an engineering consultant for more than a dozen years, designing highly automated manufacturing and distribution systems for leading manufacturers in aerospace, automotive, defense, electronics and healthcare. I can still remember my initial overconfidence and oversimplification as I naïvely attempted to interest prefabricated homebuilders in the same advanced manufacturing technologies. In retrospect, the prefabricated homebuilding industry is one of the most complex manufacturing environments that I have ever encountered. There are many complicating factors: diverse product offerings allowing partial or even complete customization; building systems and materials developed for site-built construction; numerous sub-systems (structural, electrical, plumbing, HVAC, data/communications, finish) that must be integrated in the product; strict regulatory codes that vary by locale; large heavy components; and numerous manufacturing activities involving fabrication, assembly and finishing.

Over time, members of the prefabricated homebuilding community enlisted as partners in our research. They guided research direction, reviewed results and graciously opened their factory doors, allowing the factories to become working laboratories. Research efforts were enabled by continuous funding over two decades from the U.S. Department of Energy's Building America Program, the U.S. Department of Housing and Urban Development and the National Science Foundation. This book organizes and documents many of the resulting research findings.

## FOCUS

The focus of this book is modular homebuilding, one of the most promising approaches to prefabricated homebuilding. It uses large, three-dimensional, factory-built modules to build a home. Each module includes the floor, walls and ceiling/roof with plumbing and electrical systems installed and interior and exterior finishes applied. The modular home is usually 85–95% complete when it leaves the factory. Utilizing modern industrial technology, modular homebuilding offers the promise of building a higher quality home, faster and at a lower cost. In practice, however, modular homebuilders and homebuyers have found this theoretical promise to be elusive. This book examines the theory and practice of modular homebuilding, identifying its strengths and weaknesses and introducing a structured engineering design approach for configuring a high performance modular factory. The approach can be used for the design and operation of a new greenfield factory, the redesign of an

existing modular factory or the redesign of a general purpose facility for modular homebuilding. The book provides the first substantive discussion of factory design for modular homebuilding. My goal is to equip stakeholders inside and outside the industry – factory designers, product designers, operating managers, investors, and researchers – so they can design and operate high performance modular factories.

The key strengths of this book are an aggressive vision for a high performance modular factory and a structured engineering design approach for achieving it. Both are the result of integrating three disparate, but invaluable sources of knowledge:

- The practices and experience of current modular producers, many of whom are industry pioneers who helped create and develop the industry.
- Emerging best business practices, such as lean production and mass customization, that are transforming the industry.
- Current scientific research findings that provide insight about the industry.

This book is organized into five chapters:

- Chapter 1 – defines modular homebuilding, envisions its promise, and describes the present reality. Challenges that have eroded the success of modular homebuilding are identified.
- Chapter 2 – uses the key findings from Chapter 1 to develop a production strategy that guides factory design. Lean production and mass customization are prominent in the production strategy.
- Chapter 3 – describes the primary building elements used in modular homebuilding and the production processes used to produce them.
- Chapter 4 – introduces a six-step structured engineering design approach for configuring the modular factory.
- Chapter 5 – discusses the implementation of the modular factory.

The focus of this book is modular homebuilding in the U.S. All statistics are from the U.S. industry. It presumes wood frame construction, the predominant building system used by U.S. modular producers. However, the basic principles and methodology are robust and apply to prefabricated homebuilders throughout the world. For example, they can be used by modular producers using alternative building systems such as light gauge steel framing, structural insulated panels (SIPs) or other composite materials. They can be used by HUD Code home manufacturers in the U.S. They can also be used by producers of smaller-scale prefabricated components, such as bathroom modules or wall panels. Finally, they can be used by prefabricated homebuilders throughout the world. It is important to emphasize that even though this book does not address prefabricated homebuilding outside the U.S., this does not mean that international prefabricated homebuilders are irrelevant. In fact, visits to leading prefabricated homebuilders in Japan, Sweden and the U.K. have demonstrated that, in many ways, they are more advanced than their U.S. counterparts. They are very large and well capitalized, allowing them to become the most technologically sophisticated housing providers in the world and offering the best examples of automotive-scale business practices in homebuilding. They use their size and capital as leverage for vertical integration – encompassing research and development, marketing and sales directly to the homebuyer, manufacturing, field installation, and long term customer

service and follow-up. While their home designs are visually simpler than most U.S. designs, the design details are more complex to meet critical performance needs, such as energy efficiency in Sweden or earthquake and fire resistance in Japan. They are more likely to use advanced manufacturing technologies to enhance quality, increase productivity, and improve ergonomics. Several examples are particularly notable. Swedish factories emphasize ergonomics, utilizing production/material handling equipment and workplace design to minimize physical activity of workers and lifting heavy loads. This reduces worker fatigue and injuries, lowers worker turnover and allows homebuilders to retain older, highly skilled workers. In summary, factory workers are treated like factory workers, not construction workers. Japanese factories demonstrate this same emphasis on ergonomics, while placing additional emphasis on automation to improve quality and productivity. Prefabricated homebuilders in both Sweden and Japan place great emphasis on quality, and they are trusted by homebuyers to deliver excellent quality and service.

Given the many strengths of these international homebuilders, it is reasonable to ask why U.S. homebuilders should not simply clone their production strategies. Some insight can be gained from U.S. industry executives who shared their thoughts during plant visits to Sweden and Japan. They expressed great admiration for the achievements in quality and ergonomics. However, they were openly skeptical about the extensive capital investment required to attain what appeared to be only modest gains in production capacity and productivity – in other words, how can these staggering investments pay for themselves, particularly in the U.S. market with its wild and unpredictable demand cycles. Their skepticism was reinforced by recent events in the U.S. homebuilding industry, particularly the failure of the most advanced prefabricated housing factory in the U.S. [1] Pulte Homes, one of the biggest site-built homebuilders in the U.S., created Pulte Home Sciences (PHS) to prefabricate large-scale shell components for its homebuilding operations. Prefabricated components included pre-cast concrete foundation walls, floors built using open web steel trusses, SIPs for exterior structural walls and interior walls built using light-gauge steel framing. PHS used advanced CAD modeling to design, engineer and drive its highly automated production processes. The PHS factory had a capacity of 2,000 homes per year. The predominant reaction to Pulte's effort from both financial analysts and competitors was skepticism and can be summarized in the following quote from a Wall Street housing analyst [2]: "This is still a cyclical business, and the reason [builders] hire subs is so they can get rid of them during slower periods." In January 2007, three years after the PHS plant was opened, Pulte management announced the plant's closing [3]:

*"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."*

Consequently, this book is not about how to clone the production strategies of international homebuilders for use in the U.S. Instead, it focuses on how to add value for the homebuyer using the inherent advantages of prefabrication, in a way that is cost effective and sustainable in the U.S. These principles should be useful for all prefabricated homebuilders, even advanced homebuilders, anywhere in the world.

## **INTENDED READERS**

This book is directed to several groups:

- Industry professionals that are responsible for owning, designing and operating a modular factory.
- Advanced undergraduate and graduate students that are studying residential construction, construction science, construction management, building technology or industrial engineering and who are enrolled in courses addressing prefabricated homebuilding. The book is most likely to be used as a supplemental text, but could be used as the primary text for a more tightly focused course.
- Faculty and students that are engaged in academic research involving prefabricated homebuilding.

## **REFERENCES USED IN THE PREFACE**

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