Analysis of the Growth Dynamics and Structure of Modular Building Construction Industry

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ABSTRACT

The modular construction industry has made significant advances in the last two decades that qualifies it as a more efficient, greener and affordable alternative for delivering building projects. Modular construction depends on moving portion of the project work to off-site manufacturing locations where the building is manufactured in modules, transported to the site, and erected in the designed configuration. Currently, modular construction is a sizable industry that encompasses its own stakeholders, customers, vendors, and supply chains. However, there is no comprehensive understanding of the structure and growth dynamics of this industry that is necessary for predicting its future performance trends. Accordingly, this paper presents a comprehensive description of the modular construction industry structure and a preliminary analysis of previous growth trends and dynamics. Different aspects of the industry are described, in terms of its main stakeholders, supply chain interactions, logistical requirements, and economical attributes of manufactured modular buildings. The industry growth dynamics and trends are analyzed by examining available historical performance data of the modular construction industry that have been collected by the Modular Building Institute since 1994. The findings of this analysis should prove useful in developing future advanced models to help in designing efficient policies and measures to support the growth of the modular building industry.

INTRODUCTION

The construction industry is lacking behind other business sectors in terms of productivity gains and operations efficiency. Construction productivity fell by about 7% between 1995 and 2001 due to its slow adoption of information technology, robotics, and operations innovation (Triplet and Bosworth, 2004). Construction efficiency is negatively affected by internal waste factors, such as labor coordination and material management that result in 25 to 50 percent waste (Tulacz and Armistead 2007). As a reaction, the National Institute of Standards and Technology (NIST) collaborated with the National Research Council (NRC) on forming an ad hoc experts
committee to propose possible options of advancing the competitiveness and productivity of the U.S. construction industry. The committee identified five breakthroughs to improve construction efficiency; the third of them is the greater use of modular construction and offsite prefabrication (NRC 2009).

Modular buildings are made of sizable components that are volumetric in shape, constitute finished parts of the building, and include finishing different construction trades (structural, electrical, plumbing, finishes, etc.). These volumetric components are manufactured offsite, transported to the construction site, and installed in place after site work and foundation are already completed. Research and professional reports have consistently reported that modular construction has the great potential of improving construction efficiency, reducing project costs, and shortening schedule duration. A recent U.S. industry report stated that modular construction helped 66% of the respondents in decreasing their schedule durations, 65% to reduce project costs, and 77% to reduce construction waste (MHC 2011). Similar reports of modular and manufactured construction in England (Egan 1998, Kelly 2009), Canada (Neelamkavil 2009), Australia (Hampson and Brandon 2004), Hong Kong (CIRC 2001) reported additional benefits of reduced risk, improved quality, safer site conditions, and reduced traffic.

This paper presents a comprehensive analysis of the U.S. modular construction industry in terms of its structure and growth. The findings of this paper will be utilized in future research to predict future market trends and analyze the impact of industry policies and regulations on its growth. Accordingly this paper is organized in the following four main sections: 1) reviewing of previous research related to modular and prefabricated buildings; 2) modeling of the industry stakeholders, structure, and supply chain; 3) analyzing the finances and economics of modular buildings; and 4) studying the previous industry growth behavior and identifying demand and supply patterns and trends. The paper will be concluded with recommendations for future research based on the findings of this study.

PREVIOUS RESEARCH

Modular building construction was in the interest of researchers and national agencies to investigate and study cost-effective building systems and efficient construction methods. One of the early leading efforts of improving modular building construction was performed by the Partnership for Advancing Technology in Housing (PATH) program that was established as public-private partnership and operated for almost a decade before it was closed in 2008. Concurrently, relevant research reports were sponsored and published by the Office of Policy Development and Research (P&DR) at the U.S. Department of Housing and Urban Development (HUD). PATH and P&DR programs collaborated in sponsoring and publishing wide array of research studies that investigated three main topics. First, studies were performed to investigate different innovative building material and systems that would facilitate cost-effective and durable modular buildings. Investigated options of construction

SUPPLY CHAIN AND LOGISTICS OF MODULAR BUILDING INDUSTRY

The modular building industry is comprised of 8 main participants that interact through the supply chain of modular buildings. As shown in Figure 1, these participants include:

1) Customers: They are the project owners who fund and establish the demand of modular buildings. The decision to go for modular construction versus traditional stick-built is derived by different constraints, including: limited project time and tight budgets. There are two types of modular building demand: a) standard designs that are limited to the available models provided by the modular building dealer; and b) customized designs to satisfy specific spatial or functional requirements. Standard modular buildings can be installed as permanent on fixed foundations or as mobile assets. In case of mobile settings, the owner would have the option of either purchasing or leasing the units from the modular building dealer. Also, old standard mobile units can be returned back to the dealer to join the inventory of used modular building for future sale or lease.

2) Manufacturers: Offsite fabrication and assembly of building modules is performed at one or more of the manufacturer’s factories. The layout of manufacturer factory depends on the type of the fabricated modules. Fixed production lines are used to fabricate and assemble the standard models of the building modules (similar to car manufacturing), while laydown and fabrication yards are used for customized modules (similar to traditional stick-built construction). For standard modules, manufacturers react to dealers’ bulk orders in order to minimize or eliminate the stock of finished modules. For customized modular buildings, manufacturers work with the project architect/engineer through the design modularization and offsite fabrication.

3) Dealers: Stocks of standard building modules are stored, maintained, and sold by regional dealers who communicate with the customers to satisfy their spatial, budgetary, and timely constraints. It should be noted that minimal or zero stocks of
finished modules are stored in manufacturer site as a pull-system is majorly adopted between manufacturers and dealers.

4) **Integrated Companies**: Integrated companies are large business entities that combined both the manufacturing and marketing capabilities of modular building construction. These companies are usually large in size that has multiple manufacturing and sales locations that spread over wide geographic area.

5) **Suppliers**: Raw material and building components are provided to the manufacturers and integrated companies by specialized suppliers. On contrary to traditional stick-built construction, the relation between the supplier and manufacturer are usually more committed and long-term that can be materialized in the form of partnership agreements.

6) **Architect/Engineer**: In case of customized modular buildings, architects and engineers are the major decision makers in determining the number, shapes and size of building modules. The design team (architect and engineer) work with the fabricator to modularize the customized design by considering fabrication, transportation, and installation constraints in terms of dimensions and weights.

7) **General and Specialty Contractors**: Even with modular construction, there are still some onsite work that need to be performed before and after installing building modules, such as earthwork, foundation, and final finishes. These onsite work items are performed by a general contractors and/or subcontractors.

8) **Local Permit Agency**: Modular buildings are authorized for construction and occupancy by local permit agencies that ensure the compliance with building and construction codes. Similar to traditional stick-built buildings, permanent modular buildings are designed to comply with regular building codes. On the other hand, mobile units are subject to a dedicated federal building code called HUD-Code (US-HUD 2000) that can be enforced between the state premises.

**Figure 1. Supply chain and stakeholders of the modular building industry**

Off-site construction of modular buildings results in significant logistics benefits as well as transportation challenges compared to traditional stick-built buildings. Moving the majority of construction work from multiple jobsites to a single manufacturing site reduces vehicular traffic and transportation system.
disruption (MBI 2012-a). This is achieved by adopting fewer material supply deliveries of larger sizes to the manufacturing site instead of more deliveries of smaller sizes to multiple jobsites. However, the outbound supply of the finished modules from the factory to the jobsite usually requires large trucks and trailers, which impose additional overhead of logistics coordination. Module widths range from 8 ft to 14 ft, lengths can reach up to 70 ft, and heights can range from 11 ft to 13 ft (MBI 2012-b). Large modular sizes may require special traffic control measures, such as staging areas, traffic officer control, and parking bans (NMHC 2013). Accordingly, manufacturers and suppliers tend to strategically position their factories and yards close to major highways, as shown in Figure 2 that depicts the locations of 87 modular factory sites as a sample of industry logistical pattern. It should be noted that there is a higher concentration of industry firms in the east and south regions of the U.S. due to a combination of lower labor costs and higher market demand.

![Figure 2. Sample locations of modular building manufacturers](image)

**ECONOMICS AND REGULATIONS OF MODULAR BUILDINGS**

Although modular building industry is not clearly regulated by national and local statutes, it still offers significant financial benefits to investors and owners. It was reported in a previous study that almost 30% of the states have weak statutes to protect and promote the modular construction industry (US-HUD 2011). Furthermore, some existing regulations constitute serious barriers against modular buildings construction, such as permits, fees, and zoning. However, modular buildings started recently to be considered as a financially viable option, compared to traditional stick-built construction. First, overlap of off-site production of building modules and initial onsite construction (site and foundation works) results in significant time savings that can reach up to 30%, compared to stick-built approach (MBI 2012-a). These time reductions are directly monetized into lower construction project overheads, productivity gains, and earlier availability of the finished building
and its possible generated revenue to the owner. In addition, mobile modular building can result in remarkable tax benefits because of its potential to qualify as a personal property instead of real estate. Such tax classification improves the owner’s cash flow as it reduces depreciation credits period from about 40 years to 7 years. Most of local regulations determine the mobility of a building based on its support condition. A facility would classify as a mobile personal property if it is placed on a chassis, similar to trailers. Otherwise, it would be classified as a real property if it is supported by a permanent foundation system. Although mobile modular homes can improve tax-related cash flow because of its modeled personal property rapid depreciation, it imposes financing challenges for their owners. Financing of mobile homes is obtained through personal loans (or chattels), not traditional real-estate mortgage. Personal loans are usually characterized by it high interest rates and shorter repayment period, which increases financing annual expenses for the owner.

ANALYSIS OF INDUSTRY HISTORICAL DATA

Historical data of modular building industry was obtained, organized, and analyzed to generate better understanding of industry patterns and dynamics. These data are derived from the published reports of the Modular Building Institute (MBI 2013) that archive industry performance from 1994 to 2011. A total of 18 major historical data items were obtained by surveying the three major industry participants: manufacturers, dealers, and integrated companies. Examples of these data items include: mean gross revenue, age of dealer lease fleet, dealers market segments, and production. Preliminary investigation of the reports identified inconsistency in reporting some historical data due to the inclusion of exclusion of some survey items over the years. Early and later missing data are ignored, while intermediate missing data are interpolated to maintain the continuity of the historical series.

The analysis of the historical data revealed that the dealers are the industry participant that achieved the most revenue due to larger business portfolio. Figure 3 illustrates the average gross revenue per company for each of the three categories of industry participants. Between 1998 and 2008, dealers achieved more gross revenue than manufacturers and integrated companies. Higher revenue for dealers can be attributed to their larger business portfolio that includes four major functions as shown in Figure 4: sale of new units, sale of used units, lease of units, and facilities and services (i.e. setup, dismantle, and maintenance). A major business portfolio is the units’ lease, which contributed to the larger revenue of modular building dealers.
The analyzed historical data clearly illustrate the dynamics and interrelations between the participants of the modular building industry. For example, Figure 5 depicts the supply dynamics between the manufacturers and dealers in terms of the production (in 1,000 square foot) and the sales (in $ million) of modular buildings. Because manufacturers don’t hold inventory of produced modules, they wait for batch orders from the dealers that are predicted based on market profitability and sales. Accordingly, large dealers’ sales trigger new orders of modules, which in turn result in larger production volume of the manufacturers. Also, the figure shows the impact of the 2008-2009 financial and real estate crises that greatly impacted the production and revenue of the modular building industry by a harsh 70% shrinkage for both manufacturers and dealers.
SUMMARY AND FUTURE RESEARCH

This paper presents a comprehensive analysis of the modular building industry as a preliminary effort to better understand the dynamics of its major participants and historical growth. The major stakeholders of the industry are identified, including the customers (building owners), dealers, manufacturers, integrated companies, architects/engineers, suppliers, general contractors, and local permit agencies. Logistical attributes of the industry are presented by analyzing the geographic location of modular building manufacturers and transportation requirements. Finally, the previous growth trends and dynamics of the modular building industry are identified by analyzing the historical data that are published by the Modular Building Institute (MBI).

Future research studies are needed to overcome the limitations of the current work and further expand its investigation. Despite the wide scope and timeline of the MBI surveys, its data can be evaluated as biased because the surveys were performed by a major advocating organization of modular construction. Accordingly, additional historical data can be sought from third-party or governmental entities to eliminate bias possibilities, including the U.S. Census Bureau. In addition, other research studies can provide more rigorous and quantitative insights on the financial feasibility of modular buildings.

REFERENCES


Modular Building Institute (MBI) (2012-a). Improving Construction Efficiency & Productivity with Modular Construction. Report prepared by the Modular Building Institute, Charlottesville, VA.


