The On-Site Housing Factory: Quantifying its Characteristics

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Abstract

US citizens are among the best housed people in the world. The US housing finance system has become a mainstay of the economy, providing continuous access to mortgage credit on favorable terms. Housing matters in the US. Better housing has led to better outcomes for individuals, communities, and American society. While the US housing industry shines, the housing production system still offers substantial opportunities to markedly increase its performance. The production system is firmly entrenched in a fragmented, outmoded and inefficient construction methodology that presents substantial barriers to the introduction of innovations and new technology. This paper describes important characteristics of existing production system and identifies several of many barriers to change. Suggestions for fundamental research aimed at substantially increasing productivity within the production system, leading to reduced cost, higher quality, more durable housing, and increased safety on the construction site are presented.

Keywords: Home building industry, residential construction, production management, project management, trade contractor coordination.

Introduction

The US housing industry has performed brilliantly in the past few years, being one of the few bright spots in the US economy. Buoyed by historically low interest rates and powered by cash seeking a safe haven from the storms of the US equity market, the industry in 2002 produced the largest number of new homes in the past 24 years (US Census Bureau, 2003) and carried US homeownership rates to their highest levels ever, reaching 68.3 percent in the 4th quarter of 2002. But the economy will not remain stalled forever, and when competition for investment dollars renews between the US equity markets and the securities markets and interest rates rise, the "truth will out". Rising prices and rising interest rates will increase the squeeze on lower income families, including teachers, office workers, nurses, and many others seeking decent, safe, and affordable housing.

Home prices are driven by many factors, including the cost of land, the cost of financing, the cost of necessary government approvals, sales and marketing costs, and the costs of the actual construction. The Arizona Housing Commission (2000) studied the distribution of costs for single-family residences in Arizona and found that actual construction costs, including the builders' overhead and profit, comprise 60 to 70% of the cost of a new single-family dwelling.

With the cost of construction being such a large percentage of the total cost of providing housing, construction cost reduction represents a good opportunity for reduction of the initial cost of housing. The affordable housing sector of the housing market has made substantial effort to reduce the cost of housing, but these efforts have generally focused upon finding ways to

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subsidize or write down land costs, waive government fees, and reduce long-term financing costs. Reducing construction costs has been focused upon reducing architectural and design features. There has been little or no effort focused upon systemically reducing the cost of construction of new homes.

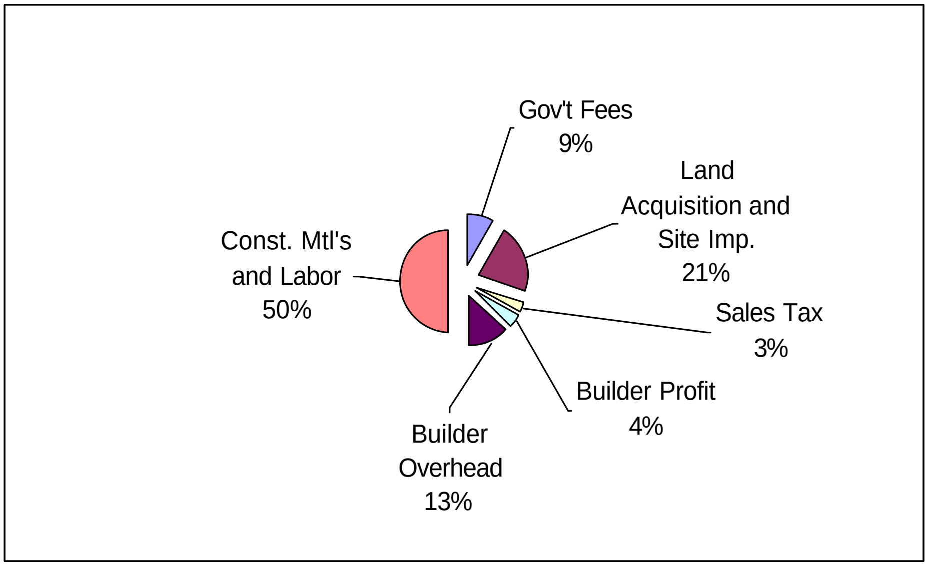

Figure 1: Distribution of Housing Costs in Arizona
Source: Arizona Housing Commission, 2000

Backdrop for the Position Paper

Large homebuilders, defined herein as homebuilders who construct more than 300 homes per year, currently construct more than 35% of the new homes constructed in the US, and this percentage is rising every year (Popp, 2002). These large homebuilding companies, called production builders, construct large numbers of similar homes, typically in tracts of 50 or more. The metropolitan Phoenix, Arizona residential construction market provides an example of an active housing production system, where more than 35,000 new homes have been constructed in each of the last 5 years. The area is on target to construct about 42,000 new homes in 2003. These homes are constructed in 400 to 500 different tracts scattered throughout the metropolitan area.

Characteristics of the Phoenix Housing Production System

A significant feature of the Phoenix housing production system for the purposes herein is the methodology employed for actually completing the construction work. Most builders in the Phoenix area subcontract all housing construction work to trade contractors. For instance, if Builder A is planning to construct 100 new homes in a new Tract 1, Builder A will solicit proposals from at least several trade contractors in each of the 30 to 35 trade categories required to complete the work. The builder will then select one trade contractor for each trade category and award contracts to these selected trade contractors to perform all of the work for the 100 homes in the tract. With so many active tracts and so many trade contractors, rarely will the exact same slate of trade contractors be employed at two or more tracts, and virtually all trade contractors work in multiple tracts for multiple builders at the same time.

The homebuilders provide a site superintendent at each tract during the construction process. The site superintendent is responsible, among other things, to schedule the trade contractors in proper succession to complete the work in a timely fashion. This scheduling of trade contractors requires extensive communication between the site superintendent and the trade contractors. A typical home requires about 135 separate activities to be completed, and the site superintendent must notify the responsible trade contractor when the home is ready for each of the activities to be performed. In addition, the site superintendent must notify building inspectors at the appropriate times for inspections, and in the case of failed inspections, notify the responsible trade of the necessity to fix whatever caused the inspection to fail. Thus, a typical home requires at least 150 communications, and a tract of 100 homes would require about 15,000 communications. If the 100 homes in the tract were to be built over a 1 year time period containing 250 working days, an average of 60 communications are necessary every day. These communications are typically made by telephone. Substantial effort has been made over the past few years by several of the production builders to develop information technology applications to ease the burden of this substantial communication effort. As of this date, these efforts have not produced a product that works efficiently. Communication failures are commonplace, and confusion between trade contractor crews and site superintendents frequently occur, resulting in inefficiency, lost time and waste.

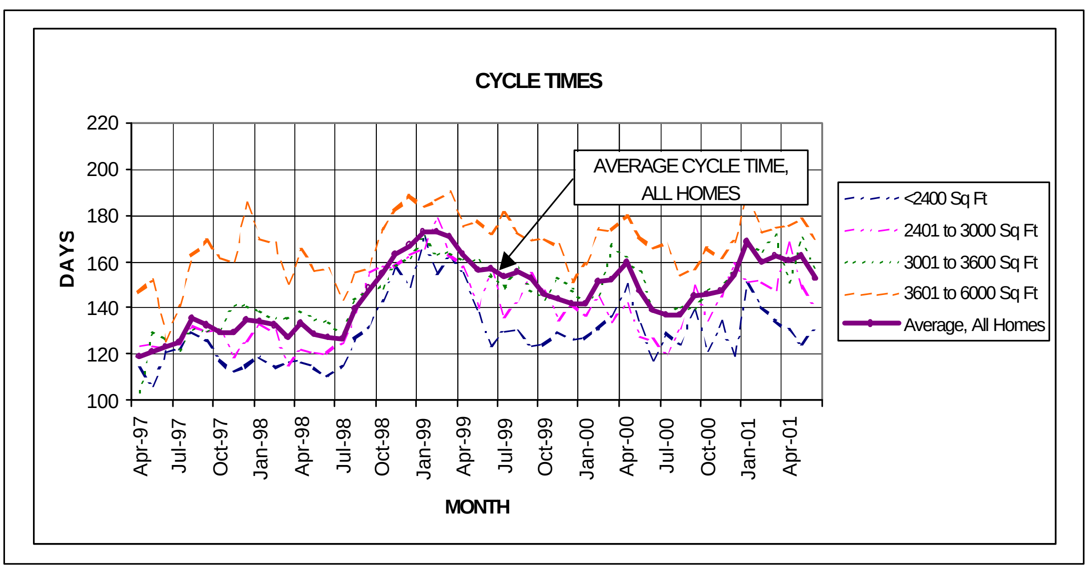

FIGURE 2: Housing Construction Cycle Times
April 1997 – April 2001, Chandler, Arizona

The production system does not contain a mechanism to accurately predict the amount of time required for construction of homes. Bashford, et al (2003) present the graph shown in Figure 1, which shows the amount of time required to construct single family homes in the City of Chandler, Arizona over time. The graph shows the variation in the average time required (computed monthly) to construct more than 10,800 homes during the 50-month period from April 1997 through June 2001. Average cycle time for each month for all homes completed during that month ranges from a low of about 120 days to a high of nearly 175 days. Clearly, there are factors in play causing these large differences in construction cycle time other than changes in work quantities or production rates of workers.

The Current State of the Phoenix Housing Production System

The Phoenix housing production system is clearly capable of producing large numbers of houses. And, according to the most recent J.D. Powers study, new home buyers in Phoenix are more satisfied with their homes than any other area studied in the US. In spite of this positive news, improvements can still be made. Some of the areas ripe for improvement are highlighted herein.

Wasted Time During Construction. Referring to the graph in Figure 1, it can be seen that construction time for houses in Chandler, Arizona, ranged from 120 to 180 calendar days for the time included in the study. It is the researchers' sense that this is typical for the Phoenix metro area, and matches reports of others. The researchers have been studying home building operations in the Phoenix metropolitan area for several years, and records accumulated through time-lapse photography and through direct on-site observation show that actual construction operations only take between 25% to 40% of the time that lapses between the start and finish of construction, based upon an 8 hours per day, 5 days per week work schedule (AzPath, 2001). This means that houses actually sit idle, with no work being performed, for well over 50% of the available work time.

Huge Quantities of Work-in Process. Additional studies performed using the City of Chandler, Arizona, building permit data revealed that completion of about 300 homes each month required an average level of work in process of about 1400 homes, which is reflective of the long cycle times. Annualized, this amounts to a ratio of about 2.5 to 1, completions to work in process. The researchers were interested in further investigating this trend. Copies of the 2001 fiscal year SEC filings for all 23 publicly traded homebuilders in the US were obtained and analyzed. These 23 homebuilders collectively completed and sold 193,515 homes during fiscal year 2001, with a sales value of $43.78 billion, for an average sales price of $226,250. For purposes of comparison, the US average sales price for new homes constructed in 2001 was $213,220, and 908,000 new homes were constructed. At the fiscal year close of these 23 companies, they collectively held 81,011 houses under construction, with a stated value of $13.93 billion. This amounts to a ratio of about 2.4 to 1, annual completions to work in progress, which is remarkably similar to the Chandler Arizona statistic. Using Little's Law of production (Hopp and Spearman, 2001) for the aggregated amount of work in process and home completions for the 23 companies, average construction cycle time for the new homes completed in 2001 is 152 days, nearly the same as the average observed for the first 6 months of 2001 in Chandler, Arizona.

The significance of these findings lies in the enormous amount of work in process, and hence capital requirements, necessary to support the number of completions annually. $13.9 billion of work in process was necessary to support the production of 193,515 new homes for the 23 publicly traded companies. Extending the value of this work in process from the 193,515 new homes of these 23 companies to the 908,000 new homes produced during 2001 in the US results in an average value of work in process throughout the year of about $68.1 billion, which is a direct result of wasted time in the construction process. If construction cycle time could be reliably reduced, the value of the work in process necessary to support the construction of the

908,000 new homes constructed in the US would proportionately be reduced. This tremendous savings would come only by use of the time for construction operations that is now needlessly frittered away.

Lack of Implementation of New Technology. There have been few significant changes in residential construction practices since the introduction of platform framing in the late 1800's. In recent years numerous new products and processes have been developed which could bring significant change and improvement. However, due to the fragmented nature of the residential construction industry, change is difficult to accomplish. The fact that virtually all of the construction work is performed by trade contractors who have individual interests concerning the performance of their individual tasks is a major barrier to innovation and adoption of new technology. This resistance is not without reason. Often, changes or improvements in the work practices of trade contractor A can have ripple affects upon the necessary work practices of one or more other trade contractors who receive no benefit from trade contractor A's changed work practices. Obviously, the affected trade contractors will object to the new work practices of trade contractor A, and frequently the objection takes the form of increased cost, thereby completely negating the potential improvements that may have been received from the changed work practices of trade contractor A. However, changes or improvements in the work practices of trade contractor A that do not affect other trade contractors can and are frequently made.

Trade contractors in the residential industry exist to perform an activity or set of activities that fit into the overall residential supply chain in ways proscribed by tradition and the existing building systems. As a consequence, product or process substitutions that affect only one trade are relatively simple to deploy, as expected based on the categories offered by Cox (1997). However, any innovation that affects more than one trade is difficult or impossible to deploy, as it requires multiple agents within the supply chain to modify their plan of work, carry different products in their standard toolkit, and generally slows down the overall process. This situation is exacerbated if only one potential customer uses the new system; many trade contractors would then choose to avoid that client in preference for other clients whom they can satisfy using existing systems at existing productivity levels (Bashford, et al, 2002).

Walsh, et al (2002) provide a cogent example of this point. They studied energy efficiency technologies in the Phoenix, Arizona market, and the cost effectiveness of these technologies. Interestingly, the innovations that were most commonly encountered in the marketplace were not those that could be shown to be the most likely to produce significant energy efficiency benefits for a given expenditure. Rather, the most likely technologies to be adopted in practice were pure product substitutions requiring no change by any other subcontractor. So, for example, higher efficiency windows and air conditioning units were very common, because these technologies require only that the relevant trade contractor install a different item, and all other trades need do nothing different. Even less expensive technologies, such as slab edge insulation for example, which affected the work of more than one trade, were not present in the marketplace.

This problem plagues the market penetration of many new technologies in the housing industry. We take as one example here the many residential building envelope systems that are presented as potential panelization candidates. Such technologies include, for example, structural insulated panels (SIPs), insulated concrete forms (ICF), Aerated Autoclaved Concrete (AAC), among others. All of these products provide different, and in most situations substantially improved, performance characteristics when compared to framed systems. All of these systems are marketed as if they were *product innovations*. That is, these technologies are marketed as if it were a simple matter to use existing wood framed walls, SIP walls, or ICF walls interchangeably. Product literature includes information about how insulative the material is, and how rapidly it can be erected in comparison to existing methods. However, use of these products for wall systems substantially impacts the way in which other trade contractors must perform their work.

In fact, in current usage the wall system is a nexus point for a great many of the trade contractors involved in the home. The concrete contractor prepares the foundation to a set of tolerances and with a set of anchor bolts appropriate for wood framing, and would have to operate differently to support SIPs (and yet differently again if the wall were ICF). The framing contractor has crews trained and equipment available appropriate to the wood framing operation, not to the erection of SIPs. All of the services (electrical, plumbing, communications, and HVAC) are installed inside the existing framed walls while the access is very good prior to installation of the drywall. But, the alternative wall technologies, being solid walls rather than open walls, do not readily accommodate these services without significant changes in the actual work conducted. All of the finishes which connect to the walls (drywall, cabinetry, fenestrations, millwork, for instance) require different connection systems, and each is provided by a different trade contractor. *In spite of the enormity of the conflicts created by alternative home envelope technologies, virtually all of these problems are deferred to the installer to work out!* In fact, it is clear that the implications of these systems are so profound that completely new supply chains must eventually be developed in order to accommodate them.

Future Research Directions

The current construction method begins with the erection of the structural frame, and is characterized by work conducted almost exclusively at the site. Threaded into, under, around, and through this structural frame are the components of the building services (principally electrical, mechanical, water and wastewater, and telecommunications), most of which were not even contemplated when the structural system itself was developed. The entire set of systems is covered up with finishes at the end. This combination of building a house by having separate tradesmen and contractors, each responsible for their own system, working primarily on site, has led to a long, linear, sequential construction process. The outcome is marked by inefficiency, long cycle times, large quantities of work in process, poor quality products, ever increasing prices, a dismal worker safety record, a target for trial lawyers and an industry forsaken by the insurance industry. This is not in the best interests of the consumers.

In spite of the importance of the housing resource, and in spite of the many product innovations that have been attracted to this huge sector of the economy, very few changes in production method have actually occurred. This great paradox is the central issue for consideration. The vision of our research efforts must be to devise methods to disentangle and separate the various building service systems from the house structural system and from each other. The construction process must be redesigned, with a view towards creating a modular framework for all of these systems. Development of such a modular framework whereby as many systems as possible are disconnected and separated will remove major barriers and roadblocks to innovation and change in the housing industry. The end result will be the opportunity to create much larger, standardized interchangeable parts, which will be the key to facilitating greater use of manufactured components in the housing construction process. This will be a major step forward in achieving the goal of providing better homes at a reduced cost, resulting in vastly decreased construction time, costs and environmental impact, higher durability and reduced maintenance costs, higher quality, enhanced worker safety, and increased options for homebuyers.

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