## *Industrial Revolution*

*Every home that is built is a representation of compromises made between different and often competing goals: comfort, convenience, durability, energy consumption, maintenance, construction costs, appearance, strength, community acceptance, and resale value. Consumers and developers tend to make tradeoffs among these goals with incomplete information which increases risks and slows the process of innovation in the housing industry. The slowing of innovation, in turn, negatively affects productivity, quality, performance, and value. This department piece features a few promising improvements to the U.S. housing stock, illustrating how advancements in housing technologies can play a vital role in transforming the industry in important ways.*

# Panelization: A Step Toward Increased Efficiency in Homebuilding

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## Abstract

*This paper examines the current use of panelized components in homebuilding in the Oklahoma City (OKC) and Dallas-Fort Worth (DFW) areas. Panelization is a type of prefabrication in which certain framing components are built off site and then transported to the site for assembly. This technique has been reported to make homebuilding more efficient and affordable. Further, panelization may be one strategy to cope with the growing labor shortage. However, adoption in the United States varies and is relatively limited. To better understand the benefits and challenges of panelization, semi-structured interviews were conducted with 10 production homebuilders from the OKC and DFW metropolitan areas. Although most of the benefits (faster, more consistent, and less waste) and challenges (cost, logistics, and labor issues) were consistent with previous research, new benefits related to warranties and new challenges relating to transportation and delivery were identified. In addition, the study concludes that national and regional production builders differ in their priorities and perceptions of panelization: national builders are trying to increase their use of panelization, whereas regional builders are moving away from it.*

## Introduction

*Panelization* is a variation of factory-built construction (interchangeably referred to as *prefabrication*) in which components are produced in a factory setting and transported to the construction site. Unlike modular construction, in which nearly complete units are produced, panelization produces only components. Panelization typically refers to roof trusses, floor joists, and wall panels but may also include assembled floor or roof systems. In fact, the term *panelization* comes from *wall panels*. Unlike traditional stick framing, in which individual pieces of dimensional lumber are measured, cut, and fastened one piece at a time, panelized components are assembled in a factory and transported to the construction site, where they are installed (Boafo, Kim, and Kim, 2016; Lopez and Froese, 2016). For a home framed traditionally, each wall would be assembled piece by piece on site, whereas a panelized home has walls that arrive on the site already assembled and ready to be moved to the correct location and fastened in place on the basis of the floorplan.

Some potential benefits to panelization are that onsite framing crews spend less time, less staffing, or both on each home, allowing for increased crew production and shorter build times than stick framing. Those efficiencies result from components arriving at the site ready for installation, without the need for measuring, cutting, and fastening each component—which also results in less job-site waste. By comparison, traditional methods require that each piece of lumber be measured and cut to fit the need. By limiting the need for measuring and cutting on site, panelization can also reduce the demand for skilled trades (Bernstein and Gudgel, 2011; Tam et al., 2007). Further, panelized homes reduce permit costs and construction time. According to Emrath (2017), the median permit value of a panelized single-family home was $69 per square foot compared with $89 per square foot for traditionally constructed homes, and construction time went down from 6.6 months to 5.8 months with panelization. Despite those potential advantages, according to the 2015 U.S. Census, only 3 to 4 percent of new, single-family homes (nonmanufactured homes) used panelized components (Steinhardt and Manley, 2016).

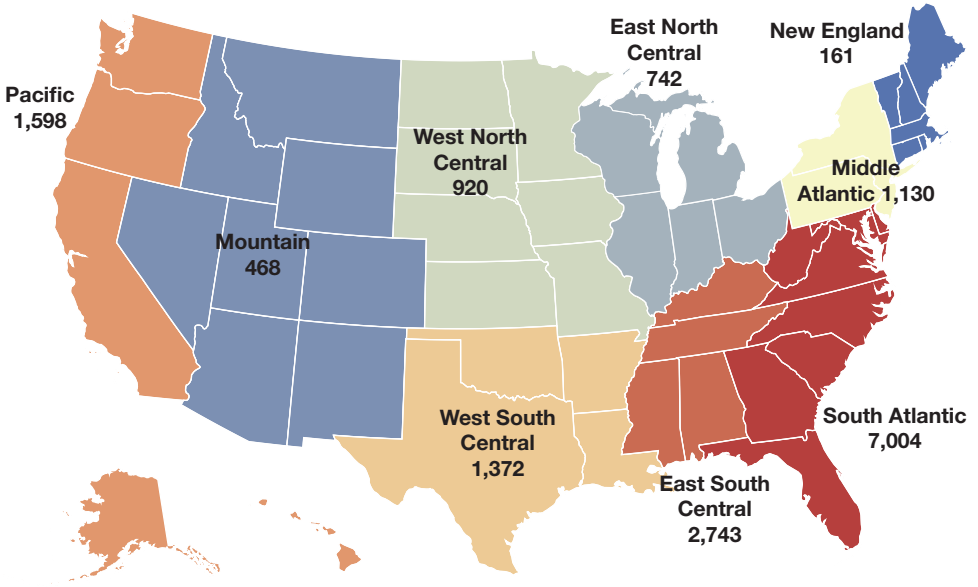
Prefabrication has a long history in the United States. In the 1600s, the English brought prefabricated wooden houses with them to Cape Ann, Massachusetts. In the mid-19th century, numbers of imported prefabricated homes continued to rise, especially during the California Gold Rush (Albert Farwell Bemis Foundation and Kelly, 1951). Housing was also mass produced in factories during the Great Depression and World War II to provide easily transported homes for soldiers (Fisher and Ganz, 2019; Musa et al., 2016). American companies such as Pacific Systems Homes, Inc. in Los Angeles and Sears, Roebuck, and Co. (Sears) were on the frontline of supplying prefabricated kit homes across the United States. Sears sold about 75,000 homes between 1908 and 1940 (Albert Farwell Bemis Foundation and Kelly, 1951; Redshift, 2019). By the 1990s, however, overall consumer interest in prefabricated homes declined due to overstandardization. Only a limited number of floorplans and elevations were available, limiting homeowners' ability to customize their homes or make changes (Mortice et al., 2019). Although prefabricated homes provided affordability, limited choices and inability to make changes turned away prospective buyers, particularly as demand grew for unique and personalized homes.

In 2017, there were 16,138 single-family panelized or pre-cut homes built in the United States. As seen in exhibit 1, adoption varies by region, with the South Atlantic region building the most

homes this way, followed by the East South Central region. On the other hand, the New England and Mountain regions build the fewest.

**Exhibit 1**

Panelized/Precut Homes Started in 2017




*Source: NAHB, 2018*

According to a survey conducted by the National Association of Home Builders (NAHB, 2018), builders cited the following barriers to greater adoption of panelization:

- One-half indicated—
  - They would lose subcontractors.
  - It does not allow enough customization.
- Nearly one-third indicated problems with—
  - Customer perceptions.
  - Cost.
  - Reliability of delivery.
  - Insufficient information about methods.
- Almost one-fourth indicated—
  - Lack of trained workers.

- Excessive cost.
- Insufficient manufacturing capacity.

Those results from the NAHB survey are consistent with findings reported by Alazzaz and Whyte in 2015 and Tam and colleagues in 2007, suggesting that panelization has changed little in the past 14 years.

Despite the barriers reported in the survey and previous research, 66 percent of homebuilders in the NAHB (2018) survey would implement more panelized construction if the construction costs were lower. Further, 55 percent reported that the quality and consistency of products encourage use. The body of research points to many advantages of panelization, but seemingly contradictory results (lower cost based on permit value are reported, but homebuilders say the cost is actually higher) suggest that inconsistent adoption throughout the country should not be surprising. That study explored the extent of use of panelization and the perceptions of builders on the subject to identify challenges and benefits that could confirm or refute previous research results and better understand why builders adopt or reject panelization.

## Methods

This study investigated the Oklahoma City, Oklahoma (OKC), and Dallas-Fort Worth, Texas (DFW), markets to explore the subject of panelization from a builder's perspective. This study asked the following research questions:

- What is the extent of panelization among production homebuilders in these regions of the United States?
- What are the perceived benefits of panelization to production homebuilders in these regions?
- What are the perceived challenges of panelization to production homebuilders in these regions?

Unlike custom homebuilding, in which each home is unique, a production homebuilder uses defined sets of home plans with limited options to gain economy of scale. Production homebuilders are often classified by the scope of their organization. National builders operate in multiple markets across the country and may build tens of thousands of homes yearly, whereas regional builders are usually confined to a single market or region and thus build fewer total homes each year. A single market may have regional builders with greater volume than the national builders in that same market, however. Both regional and national production builders were included in this study.

A qualitative research strategy using data collected through structured interviews with production homebuilders was used to address those research questions. Representatives of both national and regional production homebuilders in the DFW and OKC markets participated. The builders recruited for this study build more than 400 homes a year, and the representatives interviewed were all considered decisionmakers in their respective organizations. Upon completion, interviews were transcribed, and the researchers used thematic analysis to identify and code themes that

emerged from the data. Open coding was used to form the initial themes. Once the initial themes were identified, the researchers conducted confirmatory analysis by reviewing the interview transcripts a second time. A different member of the research team conducted a third pass to provide interrater reliability on the identified themes.

The sample included 10 production homebuilders, of which 3 were regional homebuilders in the OKC area, 3 were production builders in the DFW area, and 4 were national builders who also build in the region. Participants were chosen through convenience sampling based on the researcher's professional network. Nevertheless, with 10 unique homebuilders interviewed, the sample should be considered representative of the region. These data were collected in late 2019, so recent developments in homebuilding resulting from the COVID-19 pandemic did not affect the data.

## Findings and Discussion

The first research question—*What is the extent of panelization among production homebuilders in this region?*—yielded mixed findings. The extent of panelization among the participating homebuilders varied between regional and national builders and by the state in which they build. All four of the national builders who participated use panelization. Three of the four builders base the extent of use on the market, whereas the fourth uses it on all homes. In contrast to the national builders, only two of the six regional builders currently use panelization. All three regional builders in Dallas-Fort Worth have used panelization, and two continue to use it. On the other hand, in Oklahoma City, two have tried it, but none currently use it. Exhibit 2 displays the results related to this question.

**Exhibit 2**

Extent of Use of Panelized Components

| Company | Full Use | Some Use | No Use |
|---|---|---|---|
| Regional Builder 1, OK | | Past | X |
| Regional Builder 2, OK | | | X |
| Regional Builder 3, OK | | Past | X |
| Regional Builder 4, TX | | Past | X |
| Regional Builder 5, TX | X | | |
| Regional Builder 6, TX | X | | |
| National Builder 1 | | Market Dependent | |
| National Builder 2 | | Market Dependent | |
| National Builder 3 | X | | |
| National Builder 4 | | Market Dependent | |

*Note: Regional Builders 1, 2, and 3 operate in Oklahoma, and Regional Builders 4, 5, and 6 operate in Texas.*
*Source: Authors' compilation based on interviews conducted for this study*

The second question this study sought to address was, *What are the perceived benefits of panelization to production builders in this region?* Analysis of the interviews resulted in 55 responses on the benefits of panelization. From those responses, the following themes emerged: time savings, labor

savings, cost savings, and improved quality. Most of the benefits were consistent with previous research, but some unique findings surfaced.

Saving time and cost of construction were themes consistent with previous research. All respondents reported that panelization is faster and results in shorter construction times. One builder reported that panelized framing required 3 to 4 days, whereas stick framing requires 5 to 7 days. Although all 10 builders reported time savings, cost savings were not as consistent. Four builders mentioned cost savings related to materials from panelization, and three indicated savings on labor.

Beyond time and cost savings, quality was another benefit. Quality was reported in three different ways. Seven builders reported better consistency, six reported less waste, and two indicated that panelization gave them a better warranty. Greater consistency and less waste have been reported previously, but a better warranty is a benefit to panelization that was not found in previous research. One of the national homebuilders explained: "We tend to have much fewer warranty issues … we tend to have less cracking, less nail pops, less movement in the system, so it's a better warranty for us." Exhibit 3 displays the benefits that emerged from the interviews and their frequency.

**Exhibit 3**

Identified Benefits of Panelization

| Benefits | % of Builders | OK1 | OK2 | OK3 | TX1 | TX2 | TX3 | N 1 | N 2 | N 3 | N 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time Savings | 100% | X | X | X | X | X | X | X | X | X | X |
| Labor Savings | 30% | | X | X | | | | | | | X |
| Material Savings | 40% | | X | X | | | X | | | | X |
| Consistency | 70% | X | X | X | | X | | X | X | X | |
| Less Waste | 60% | | X | | X | X | X | | X | | X |
| Warranty | 20% | | | | | X | | X | | | |

*N = National. OK = Oklahoma. TX = Texas.*

*Source: Authors' calculations based on interviews conducted for this study*

With no current use of panelization in Oklahoma City and one of the regional builders in Dallas-Fort Worth recently abandoning it, the challenges or drawbacks to this building method are important to consider. Interviews revealed more than 100 challenges to panelization adoption. From those, five themes emerged, with 12 specific challenges. The builders most frequently reported issues relating to labor, cost, and complexity. Exhibit 4 displays the results.

**Exhibit 4**

Challenges to Panelization

| Theme | Drawbacks | % of Builders | OK1 | OK2 | OK3 | TX4 | TX5 | TX6 | N1 | N2 | N3 | N4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Labor | Framers dislike | 30% | | X | X | | X | | | | | |
| | Labor shortage | 70% | X | X | X | | | | X | X | X | X |
| | Lack of education | 40% | X | X | | | X | | X | | | |
| Cost | Upfront cost | 20% | | X | | | | | | | | X |
| | Construction cost | 80% | X | X | X | X | | X | X | | X | X |
| Availability/ Complexity | Lack of production capability | 20% | | X | | | | | | X | | |
| | Lack of manufacturing facilities | 70% | X | X | X | | X | | X | | X | X |
| | Complexity of projects | 70% | X | | X | X | X | X | X | | | X |
| | Customer ability to change | 40% | X | | | | X | X | | | | X |
| Logistics | Tight lots | 40% | | X | X | | X | | | X | | |
| | Transport/ deliveries | 30% | X | | | | X | | | X | | |
| Perceptions | Customer perceptions | 20% | | | | | X | | X | | | |

*N = National. OK = Oklahoma. TX = Texas.*

*Source: Authors' calculations based on interviews conducted for this study*

Finding the labor force with the proper skill set is essential to implement panelization. Eight of the 10 builders reported some type of labor challenge, whether it was framers who disliked the panels because of size or their lack of experience and knowledge working with panelized components. One builder indicated, "Generally speaking, trades do not have much interest in working with prefabricated components due to their weight and dimension." Roof trusses are a good example of this challenge, as the prefabricated trusses can be very large and, as a result, heavy. They may even require the use of a crane to lift them into place. Labor's preferences and lack of willingness to work with panelization are major challenges to greater adoption of the method.

Beyond preference, labor cost associated with panelization was reported as a challenge by 8 of the 10 builders—a contradiction to the reported benefit of panelization in reducing costs. Framing contractors generally base their price on the square footage of a home, and they want the same price whether they are using panels and trusses or stick framing. As a result, labor costs are not always reduced by panelization, which suggests that framers do not take into consideration the reduction in labor hours when using panelized components. Those challenges with labor are magnified given the current labor situation, in which trades can pick and choose the jobs they take.

In addition to labor costs, material costs were reported as a challenge. Despite past research and results from this study indicating that panelized homes cost less, the material cost of panelization was a challenge reported by 9 of the 10 builders. Some builders were turned off by the higher cost of panelized components compared with the raw lumber used for stick framing. For one builder, it was more than double the price, so they did not consider panelization competitive; however, these builders did not account for the savings realized through reduced waste and quicker framing time, which may explain why cost emerges as both a benefit and challenge of panelization.

Beyond the cost of materials and labor, availability and complexity were challenges reported by the builders. Panelization is difficult to implement when components are not readily available. One builder in Oklahoma did not believe the local truss and panel supplier could keep up with their demand. As a result, they would have to source products from Wichita, Kansas, or Dallas, Texas, to implement panelization. Having production facilities in Texas did not seem to place the builders in Dallas-Fort Worth at an advantage, however; all builders operating in Texas indicated a shortage in the supply of panelized components.

Sourcing the materials was not the only logistic challenge. A few builders noted the challenges with transportation and issues with receipt and staging of the materials. Production homebuilding has long been a means to providing affordable housing, but rising land prices have led to smaller lot sizes. The smaller lots do not allow adequate staging areas for panelized components before installation. One builder put it this way: "Lot sizes are smaller, and there's just not much room on the lots to put deliveries, and most cities don't want you to deliver them in the streets." In some cases, the lot simply does not have enough room on which to deliver panel or truss packages.

Beyond those logistical challenges, the complexity of design was also an issue in the supply chain. Seven of the 10 builders reported that panelization could not meet the demand of home designs as related to the shape or slope of the roof. Further, four builders pointed out the inability of panelization to allow for or adjust to customer changes.

The final challenge to panelization reported by builders was customer perceptions. Although only two builders reported this challenge, its implications are substantial. The homebuilding business is driven by homebuyers, so customer perceptions can have a dramatic impact on what builders do. One regional and one national builder reported that customers equate the panelized components to a lower quality product. Those perceptions are further exacerbated in the sales and marketing process. One builder reported that their competitor's sales personnel were equating panelized products to manufactured homes—as a tactic to sway buyers—which almost certainly results in the loss of sales for the builder using panelization and is thus a barrier to its further implementation.

## Conclusions

The interviews conducted were targeted to identify the extent of the use of panelization and the challenges that prevent its widescale adoption. Innovation in construction is often met with resistance, and panelization is no different. Resistance was seen in the challenges reported. Although the builders interviewed reported more challenges than benefits, that does not mean panelization should be abandoned. In fact, despite the challenges reported, nearly all homebuilders

interviewed believed that the quality of panelized products is superior compared with traditional stick-built construction. Further, the national homebuilders who are using panelization are trying to increase its use within their companies. For the regional builders not using panelization, the decision seemed based as much on preference as on any specific set of challenges identified.

Direct costs (labor and materials) were cited as a challenge to adoption, but many builders did not seem to consider the other cost variables that panelization affects. A reduction in build time would reduce the direct overhead cost of supervision and, potentially, the carrying costs related to financing a home under construction for a longer period. In addition, lack of education by the trades about panelization is a challenge that should be addressed to increase adoption. Panelization should make construction faster and allow for a smaller crew, both of which should drive down the labor costs of panelization and positively affect the skilled labor shortage. If trades are not trained and educated about the process, however, those savings are never realized, and, paradoxically, costs of panelization become reported as both challenges and benefits.

Whereas all the builders faced some challenges, other challenges seem to be unique. For example, only the regional homebuilders reported that framers disliked panelized construction. The challenge of the labor shortage, on the other hand, was reported by all national builders but only one-half of regional builders. Perhaps the biggest difference between regional and national builders was their overall attitude toward panelization. The national builders not only use panelization to some extent but are pushing for greater levels of adoption. Regional builders, on the other hand, are moving away from it. That difference seems to be resource based, as national builders are more likely to employ individuals dedicated to managing supply chain issues and improvements, whereas regional builders generally do not have those positions. Although they are all production homebuilders, differences in perspectives and priorities between regional and national builders affect panelization adoption.

The authors recommend future study on this issue in other regions and markets in the United States to determine if the results here are unique to Oklahoma and Texas or are consistent on a broader scale. In addition, further study should be undertaken to explore the differences discovered here regarding regional and national builders.

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