

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 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.

Challenges to Offsite Construction Due to Jurisdictional Regulations

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Abstract

The adoption of offsite construction techniques offers significant benefits over traditional onsite methods, yet its use remains low in the United States compared with other developed countries. Although previous research has identified various barriers, the effect of regulations and local building codes has been underexplored. This article examines these regulatory challenges in Oklahoma through interviews with building inspectors and contractors involved in offsite construction. Findings reveal that regulatory barriers, practices of authorities having jurisdiction (AHJs), and mindset issues among different stakeholders hinder adoption. Recommendations include leveraging third-party inspectors, standardizing regulations, educating AHJs, fostering collaboration among stakeholders, and studying successful international practices. Addressing the challenges can streamline the code adoption process, ensure safety and quality, and increase offsite construction adoption. This article contributes to a more streamlined regulatory framework for offsite construction practices.

Introduction

Offsite construction involves the planning, design, manufacturing, and assembly of building components at a location other than the final installation site, enabling rapid and efficient construction of permanent structures (NIBS, 2024). This approach can include producing entire building units, such as modular structures, or individual components, such as panels, which are then transported and assembled at the construction sites. When effectively managed, offsite construction offers numerous advantages for both residential and commercial projects, including reduced waste, faster onsite construction, fewer labor hours during assembly, and enhanced quality, safety, and sustainability (de Laubier et al., 2021; Fannie Mae, 2020; Jin et al., 2018; Loizou et al., 2021). Expanding the use of offsite construction in the United States could help address the current housing shortage. The Federal Home Loan Mortgage Corporation, or Freddie Mac, estimates that the United States needs 3.8 to 5.5 million housing units to address the current deficit (Fannie Mae, 2020). Given this need for greater housing stock, traditional construction practices have not been able to keep up with the demand, making it necessary to adopt innovative methods—such as offsite construction—to tackle these problems (NIBS, 2024). The construction industry has historically struggled to adopt and adapt to innovations. If the housing industry is to thrive and the current deficit of housing stock is to be reduced, innovation such as offsite construction practices will be necessary (de Laubier et al., 2021).

For this research, offsite construction encompasses prefabricated components, including modular elements used for single-family and multifamily residential units. These components can be either volumetric or panelized. *Volumetric* construction is a form of offsite construction that involves assembling buildings by connecting large, prebuilt sections, whereas *panelized* construction refers to prefabricated sections of walls, floors, or roofs that are assembled on site. The overall construction processes for offsite and traditional construction differ in that offsite construction involves manufacturing some components offsite, transporting them to the site, and assembling them with onsite construction processes in compliance with local building codes. Despite those differences in the process, the final product of offsite construction is similar to that of traditional construction in terms of appearance, quality, durability, and safety. For this article, manufactured houses are not considered a part of offsite construction because they are regulated by the uniform and performance-based construction standards of the U.S. Department of Housing and Urban Development (HUD) and are subject to HUD standards, whereas offsite construction without the standardized code is subject to local, state, or regional building codes (MHI, 2023; Vukelich, 2022), which brings about a fragmented regulatory landscape and hinders widespread adoption of offsite construction.

Code Compliance and Regulation

Offsite construction offers promising benefits for the U.S. construction industry, including increased efficiency, improved quality, and reduced environmental impact. However, its widespread adoption is hindered by several challenges. Studies by Kazem-Zadeh and Issa (2020) and Lim et al. (2022) highlight regulatory hurdles as challenges that impede the wider acceptance of offsite construction. They point to the complex web of state and local regulations, different building codes across jurisdictions, and limitations on third-party inspections as major challenges. Thirty-nine states in

the United States require a governmental or third-party agency to complete factory inspections to ensure compliance with state codes governing offsite construction (Abu-Khalaf, 2019; Ryder, 2023). In Oklahoma, the process of obtaining building permits includes submitting detailed plans for the project, applying for permits, awaiting review and approval, and arranging for inspectors (The City of Oklahoma City, 2024). In addition to obtaining a building permit ahead of construction, builders are typically required to pass a series of inspections. Most inspections are conducted at the factory, although some occur on site. Out-of-state factories use third-party inspections. Although the intent of multiple inspections is to ensure compliance with local jurisdictional building code requirements, they add a layer of complexity to the approval and inspection processes (Abu-Khalaf, 2019). These cumbersome processes increase delays and negate some of the gains that might be realized from offsite construction's time-related cost savings.

Lack of Clarity in Adopted Codes and Standards

The lack of standardized codes and quality assessment tools has been identified as a significant barrier to the adoption of offsite construction (Mao et al., 2015; Rahman, 2014). The development of building codes in the United States has been a long and evolving process. Early codes were developed by regional organizations and focused on fire safety. Over time, the need to unify codes and increase flexibility led to the development of performance codes. In 1994, the International Code Council (ICC) was formed, and both the International Residential Code and the International Building Code, published in 2000, became the de facto national code (Mathewson, 2023). However, the federal government had limited direct authority over building codes because local jurisdictions have the final say on whether to adopt the ICC codes, reject specific provisions, or introduce more stringent versions of their own.

In the United States, standards to facilitate the wider adoption of offsite construction methods are lacking (Rahman, 2014). In a study on China, Mao et al. (2015) highlighted the role of a robust regulatory framework, complete with efficient enforcement mechanisms, to address these challenges. In countries such as Singapore and China, government policies, regulations, and initiatives have been supportive in promoting offsite construction (Razkenari et al., 2020). By contrast, the United States faces a fragmented and complex building code landscape, where requirements vary significantly between jurisdictions and states (Colker et al., 2022). The lack of clear and consistent codes and standards hinders the adoption of offsite construction because the potential economic and time-saving benefits could be compromised without efficient compliance mechanisms. Furthermore, the inconsistency in code interpretation and enforcement complicates the collaboration among stakeholders, which is essential for effective coordination between offsite manufacturers and onsite construction workers (Gan et al., 2018).

Authorities having jurisdiction (AHJs), which can be either governmental or nongovernmental entities, enforce regulations such as building and fire codes in specific areas. Although those regulations ensure the structural safety and integrity of the buildings, Kennerley (2019) and Darlow, Rotimi, and Shahzad (2021) suggest that building codes and policies be amended to provide a simplified and faster process of approval and inspection for offsite construction. Razkenari et al. (2020) supported that recommendation, emphasizing the importance of streamlining the approval process to promote local offsite fabrication.

This article highlights challenges to the adoption of offsite construction in the state of Oklahoma by examining how regulatory frameworks can be a bottleneck. Through engaging subject matter experts, the authors explored the current state of the offsite construction permitting and inspection process in Oklahoma, revealing barriers that have emerged because of the existing regulatory framework.

Background and Objectives

Offsite construction has been recognized as a solution to several problems associated with traditional onsite construction methods by moving a large proportion of the work from an uncontrolled setting with limited working hours into a safe, controlled environment with more efficiency and productivity measures in place (de Laubier et al., 2021). Components are built in a factory and then transported to the construction site and assembled or installed into their final position (Colker et al., 2022). Despite the numerous benefits associated with offsite construction, its current level of adoption in the United States is still limited, especially compared with countries such as Sweden, Singapore, China, and Japan (Ajayi et al., 2019; Gan et al., 2018; de Laubier et al., 2021; Razkenari et al., 2020).

Several studies have explored the barriers to the adoption of offsite construction (Lim et al., 2022; Razkenari et al., 2020). Those studies examined the barriers from various perspectives, including the high capital costs of production facilities (Shahzad et al., 2023), the uncertainties associated with offsite construction projects (Lee et al., 2023; Yang et al., 2021), and the image problem of offsite components being of low quality and lower durability (de Laubier et al., 2021; Rahman, 2014). The regulatory framework of construction has evolved in response to and in support of onsite construction, thereby creating conditions that often are incompatible with offsite construction (HUD, 2023). However, very few studies have attempted to investigate the role played by regulations that hinder the adoption of offsite construction.

This study examined how regulatory frameworks can be a bottleneck in the adoption of offsite construction. It uncovered the extent and significance of the roadblocks AHJs pose to the adoption of offsite construction by identifying the challenges in securing building permits and inspections for structures using offsite construction, specifically in the state of Oklahoma. The authors chose Oklahoma as the focus for this study because it is one of the 15 states in the United States that does not have its own enclosed or modular requirement process for subassemblies and offsite components (HUD, 2023). The lack of specific requirements adds another layer to the jurisdictional complexity associated with offsite construction because it creates an environment for potential conflicts between local authorities and state agencies overseeing specific regulations.

The research questions addressed in this study are—

1. What are the specific mechanisms by which AHJs pose roadblocks for offsite construction, and how do those barriers vary across different jurisdictions and project types?
2. To what extent do local AHJs' interpretations of the ICC codes hinder or facilitate the adoption of innovative building products and systems in offsite construction projects?

3. What strategies or reforms can address AHJs' roadblocks and promote the adoption of offsite construction practices that ensure safety, quality, adherence to building codes, and easy replication across different jurisdictions?

Addressing those questions is crucial to creating a supportive environment that fosters the adoption of offsite construction in the United States and unlocking its full potential.

Methodology

The study adopted a qualitative approach in which insights were gathered from key stakeholders through semi-structured interviews. The interviews covered the processes by which AHJs adopt and update their codes, their familiarity with offsite construction techniques, and the overall process from code adoption to enforcement. The questions were designed to capture a broad range of perspectives and did not specifically differentiate between single-family and multifamily units, based on the assumption that the approval and permitting processes are similar for both types. The questions were mostly open-ended and aimed to produce comprehensive results, enhancing the reliability of the responses.

Selection of Interviewees

To objectively answer the research questions, the authors used purposive sampling combined with a snowball technique to recruit participants from the cities of Broken Arrow, Edmond, Moore, Norman, and Oklahoma City—six of the seven largest cities in Oklahoma. Nine participants were interviewed for this study, including city inspectors and contractor project managers, who were critical to providing a comprehensive perspective. Exhibit 1 provides the designation of the interviewees with their years of experience. The interviewees had a combined total of 155 years of experience, averaging more than 17 years each.

Exhibit 1

Interviewees' Background Information		
Interview ID	Current Position	Industry Tenure
Interviewee 1	Chief Building Inspector	24 years
Interviewee 2	Plumbing and Building Inspector	10 years
Interviewee 3	Development Services Manager	17 years
Interviewee 4	Residential and Commercial Building Inspector	17 years
Interviewee 5	Director of Building and Fire Code Services	17 years
Interviewee 6	Senior Project Manager (contractor)	27 years
Interviewee 7	Project Manager (contractor)	8 years
Interviewee 8	Operations Manager (contractor)	25 years
Interviewee 9	Senior Project Manager (contractor)	10 years

Source: Authors' interviews

Data Analysis

The following steps were taken to analyze the interview transcripts:

- First round of coding (initial): The first round of coding involved analyzing the transcripts to highlight key terms in response to specific questions and tabulating those terms in an Excel spreadsheet. Furthermore, phrases in the transcripts were highlighted and typically represented with fewer words, which stood as the codes.
- Second round of coding: This round involved grouping codes into sets or summaries to identify patterns. The aim at this stage was to try to merge codes that fundamentally meant the same thing or had similar meanings. This step was repeated across all the transcripts, and the initial codes were revised—a crucial step in identifying themes, which was the next step.
- Identifying themes: This activity was carried out alongside the second round of coding. By combining codes that had similarities, the authors created the themes for the study, keeping the research objectives in mind.

Findings

This section presents the themes identified through the analysis and discusses them as they relate to the questions outlined in the study.

Question 1: What are the specific mechanisms by which AHJs pose roadblocks for offsite construction, and how do those barriers vary across different jurisdictions and project types?

The findings from the conducted interviews revealed that a lack of systemic mechanisms makes getting approvals for offsite construction more difficult. City inspectors generally agreed that cities lack the autonomy to create their codes and primarily rely on state directives. However, cities can adopt amendments specific to their jurisdiction in addition to state-prescribed codes, which can sometimes limit offsite construction if the amendments are strict or prohibitive.

Inspectors and contractors agree that the construction documents should meet or exceed the code, with code application that is consistent for both offsite and traditionally built structures. However, unlike traditionally built structures, offsite structures often undergo multiple layers of inspections, which are not typically required for traditional construction. Thus, obtaining permits for offsite construction can be complex because of the need for rigorous certification and inspection at the fabrication plant. Two contractors noted that permit approval can be challenging due to the numerous inspections required for quality assurance and quality control. The prefabrication of multiple components often necessitates more stringent reviews and a series of inspections to ensure safety and verify material quality.

To mitigate those challenges, two contractors mentioned that they used front-end planning with AHJs before beginning fabrication, which led to fewer issues later in the process. This proactive approach involves clarifying at the project's outset whether inspections should occur at the job site or at the fabrication plant. Those early discussions helped achieve mutual understanding

and agreement on the inspection process, preventing potential issues such as delays due to failed inspections or noncompliance with local regulations.

What's extremely important is, you know, we work in different cities, different states, we have always sat down with the inspectors, with the city officials at the beginning of the job, and when they are talking about proposing prefab/offsite, it's always a discussion. It's like, do you wanna [sic] inspect it when it hits the job site? Or do you want to inspect it at the fabrication plants?

—Interviewee 8

Question 2: To what extent do local AHJs' interpretations of the ICC codes hinder or facilitate the adoption of innovative building products and systems in offsite construction projects?

The three building inspectors interviewed expressed limited experience with offsite construction in their jurisdictions and unfamiliarity with the code adoption process. The lack of building inspectors' direct involvement in the process of building code adoption can hinder their ability to inspect and approve such projects effectively. Having to depend on directives the inspectors receive from their superiors without direct involvement in the code adoption process limits their ability to handle the nuances and complexities of offsite construction. Their limited practical experience with offsite projects can make it challenging for AHJs to understand and adapt to the unique requirements of these methods.

Despite those limitations, all the inspectors stated they had no bias—positive or negative—toward offsite construction methods, which is crucial because it indicates that the inspectors can objectively review plans for offsite construction without prejudice. That objectivity provides an opportunity to bridge the knowledge gap and facilitate smoother adoption of offsite construction projects through proper training and clear communication between inspectors and contractors.

The interviews also highlighted several factors that could enhance the adoption of offsite construction techniques, including the standardization of requirements. All interviewees mentioned that permitting procedures for both traditional and offsite construction involve submitting engineered plans and specifications. However, offsite construction requires additional documentation, such as third-party certifications, to demonstrate compliance with the jurisdiction's codes. Standardizing requirements is important because it streamlines the approval process, enabling inspectors to easily assess how offsite construction meets code requirements. The presence of standardized codes across different jurisdictions—at least within the state—could create common ground, making approval of offsite construction projects in various locations easier and reducing uncertainty and delays for contractors.

Question 3: What strategies or reforms can address AHJs' roadblocks and promote the adoption of offsite construction practices that ensure safety, quality, adherence to building codes, and easy replication across different jurisdictions?

The acceptance of third-party certified inspectors for the certification of offsite components is necessary for the increased adoption of offsite construction. Certified inspectors can help inspect offsite components built in controlled factory environments. Accepting documented inspections from third-party certified inspectors can streamline the permitting process for offsite construction

components if the inspectors provide clear documentation that the components meet all code requirements essential for AHJ approval. This process alleviates the burden on AHJs, as the following excerpt mentions.

I think they play a huge role. We couldn't accept modular construction unless they existed, and I will tell you the state of Oklahoma has gone so far as to create a chart in their special inspections section. —Interviewee 5

The benefit of third-party inspectors is that they validate compliance with the codes accepted by the specific AHJ, thus facilitating their acceptance, expediting the permitting process, and enhancing the adoption of offsite construction methods. However, the interviews revealed that the acceptance of third-party inspectors is contingent on their being Oklahoma-certified. Although that inspection criterion ensures quality and compliance, it could also limit availability, flexibility, and cost effectiveness.

A common belief among contractors and offsite manufacturers is that standardizing requirements can help increase the adoption of offsite construction. Currently, contractors are not required to submit any additional drawings for offsite construction beyond what is normally required for traditionally built structures. However, two senior project managers interviewed believe that having clear requirements from AHJs and uniformity across jurisdictions can reduce complexities, especially as contractors move subassemblies or offsite components across state lines.

Although local AHJs' interpretation of code requirements might not directly hinder the adoption of offsite construction techniques, two interviewees representing general contractors noted that resistance to change is a significant barrier. A conservative culture that discourages new ideas can stifle innovation and impede the adoption of offsite construction. Contractors comfortable with traditional practices may resist innovative construction practices because of a preference for familiar approaches and apprehensions about the unfamiliar. To remedy that problem, participants recommend using open communication to address concerns about the potential risks of using untested technologies, showcasing successful project examples, and highlighting benefits such as time savings and efficiency. This approach can build trust and overcome client and contractor concerns.

Offsite construction thrives on efficiency and repeatability. Simplified designs with standardized components and repeatable sequences are more conducive to offsite construction, whereas complex or intricate designs may pose transportation, assembly, and quality control challenges. Considerations such as transportation logistics, site access, and space constraints are crucial in determining the feasibility and effectiveness of offsite construction for a given project. Therefore, although offsite construction offers numerous benefits, the buildability of the structure can influence the effectiveness of these methods.

Another recurring theme from the interviews was the importance of communication between contractors and inspectors and collaboration between contractors to—at a minimum—share best practices and facilitate consistent requirements for the adoption of offsite construction. However, inspectors and contractors believe that communication and collaboration go beyond sharing best

practices. Contractors explained how thorough preplanning or front-end planning led to strategies such as leaving specific component sections exposed for easier inspection during fabrication and exploring pre-inspections at fabrication facilities to reduce onsite inspector workload. Those efforts aim to mitigate time constraints and ensure efficient inspections.

Conclusions

This study identified the challenges to adopting offsite construction in Oklahoma by examining how regulatory frameworks create barriers. Through interviews with inspectors and contractors, the authors gained research that highlighted issues in permitting and inspection processes that hinder offsite construction in the state.

The interviews highlighted the complexity of obtaining permits for offsite construction because of state and local regulations, varying building codes, and limitations on third-party inspections. Although the state of Oklahoma prescribes a uniform code to be adopted statewide, jurisdictional considerations allow local AHJs to enforce stricter controls, which are detrimental to the adoption of offsite construction. Although safety is paramount, offsite construction can improve quality control because the components and modules are fabricated in controlled environments. Quality checks in such environments are more reliable compared with inspections of traditional onsite construction (de Laubier et al., 2021; Loizou et al., 2021). This finding presents an opportunity for AHJs to review the processes they undertake, placing more emphasis on quality control of offsite components.

The study also revealed that unfamiliarity with the code adoption process limits inspectors' ability to effectively assess plans for projects involving offsite construction, highlighting the need for continuous education and training for AHJs on the code creation and adoption processes. In addition, the resurgence of offsite construction has created a demand for developing consistent standards, a sentiment echoed by more than one contractor interviewee. As more companies adopt offsite construction techniques, a need will arise for active changes to reduce errors, improve safety, and regulate market entry.

Variations in requirements across different jurisdictions add a layer of complexity. The interviewees advocated for streamlining permitting requirements across jurisdictions to eliminate unnecessary logistical hurdles and delays. They also suggested that proactive engagement with AHJs and front-end planning are crucial to mitigating complexities in the permitting process for offsite construction. Early discussions with city officials and inspectors can clarify the inspection process, whether at the job site or at fabrication plants, fostering a mutual understanding. This proactive approach can help avoid delays and streamline permit approvals for offsite construction.

The findings from this study offer valuable insights into promoting offsite construction while addressing AHJ concerns and ensuring safety, quality, and code compliance across jurisdictions. To promote the adoption of offsite construction, stakeholders should focus on standardizing regulatory frameworks across jurisdictions, ensuring consistency in permitting and inspection processes. Developing unified guidelines can reduce the complexity and variability currently experienced among different jurisdictions within states and across different states in the nation.

Also, HUD can consider investing in training and continuous education programs for AHJs to enhance their understanding of offsite construction and its unique code requirements. Promoting the shift toward performance-based codes would also allow for more flexibility and innovation in offsite construction practices. Finally, HUD can play an instrumental role in fostering collaboration among jurisdictions to streamline permitting processes, thereby reducing delays and logistical challenges that currently hinder the adoption of offsite construction. These efforts can increase the adoption of offsite construction while maintaining safety, quality, and code compliance across different jurisdictions.

Future research should explore the effect of standardized building codes on the adoption of offsite construction, focusing on how uniform regulations could streamline processes and reduce barriers. Investigating the role of AHJ training in enhancing code compliance and enforcement would provide insights into how education can improve the permitting and inspection processes. Furthermore, studies should assess the economic benefits of streamlined permitting processes, including cost savings, the facilitation of broader adoption of offsite construction, and their overall effect on the housing market.

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