ETHIC

Enabling Technologies for Housing Innovation Center

Housing Production in Texas: Mapping the Value Chain and Evaluating the Role of Industrialized Construction

The Enabling Technologies for Housing Innovation Center (ETHIC)
A HUD Hispanic Serving Institution Center of Excellence

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Executive Summary

In Texas, housing affordability has become an increasingly critical issue. There is high immigration and a severe supply mismatch between housing that is available and housing that is affordable, leading to what is currently a shortage of nearly 1 million housing units in the state. Industrialized Construction (IC) has the potential to address this shortage by increasing efficiencies in housing production and offering greater certainty over construction costs.

Despite its proven advantages, IC adoption remains slow across all housing typologies. The most prominent home typology in Texas is single-family detached homes (IRC-code), which constitute around 65% of new housing permits and are not yet produced at scale using IC. Approx. 25% of Texas housing is multifamily developments, well suited for IC due to its unit density and repeatability, but also lags in IC market adoption. The balance of housing is HUD-manufactured homes (9%) and is the one segment that widely uses IC technology, known as volumetric and/or modular construction.

Texas has infrastructure in place that can increase housing supply and affordability. This includes federal tax credits, a state-wide Industrialized Housing and Buildings Program, and an active trade corridor with Mexico. Significantly, several hubs in and around the 'Texas Triangle' are also investing in raw material production. Additionally, Texas has one of the largest construction labor markets in the country, with nearly 900,000 people employed as of 2024.[1]

Manufacturers producing IRC-modular homes (such as StudioBuilt by Amherst and Cherry Communities by Instabuilt) and HUD-manufactured homes (such as Clayton Homes and Champion Homes, who have hundreds of retailers across Texas) are expanding their manufacturing capacity in the state. Key innovators in computational design, automation, process optimization, and other functions are either headquartered in Texas or seeking to gain adoption at scale in the state, creating promising outcomes as industry stakeholders unite.

To successfully nurture an IC ecosystem, the Texas construction industry must first adopt a product-driven mindset, and work to aggregate demand around IC-based products, which will then drive expansion/investment in IC production capacity alongside IC workforce training. While Texas aggregates key ingredients that can enable the state to develop a robust and thriving IC ecosystem, obstacles remain. This white paper seeks to present a landscape view of housing production while discussing regulatory, educational, financial, and technological considerations to nurture a thriving IC ecosystem in the state. Furthermore, it will shed light on the complex web of stakeholders in IC housing production.

[1] All Employees: Construction in Texas, FRED

Introduction

Affordability in Housing as a Major Issue for Texans

Housing affordability is a pressing issue across Texas, affecting most of the state's population as home prices and rents continue to rise faster than wages, fueled further as the state experiences one of the top three fastest-growing populations and is home to more than 50% of the fastest growing cities in 2023, underscoring an increasing demand for housing.[2] The housing affordability landscape in Texas is a microcosm of the broader Nation's crisis: "Between 2021 and 2023, the U.S. experienced its fastest-ever deterioration in housing affordability, due to the surge in home prices and rapidly rising interest rates".[3] The Department of Housing and Urban Development (HUD) defines affordable housing as housing costs that do not exceed 30% of a household's gross income. The housing market in Texas, once considered relatively affordable, has become increasingly out of reach for many families, where currently almost half of Texas residents are spending above the 30% limit.[4] Urban areas such as Houston and Dallas are found in the top 10 lists of the least affordable places for low-income renters.[5] In Texas, "Individuals and families with low income" means individuals and families earning not more than 80% of the area mean income (AMI) or applicable federal poverty line.[6]

According to the Texas Affiliation of Affordable Housing Providers (TAAHP), there is a shortage of close to one million affordable and available units for households living at or below 50% AMI. The state is the sixth least effective nationwide in supplying affordable rental housing for extremely low-income renters (earning up to 30% of AMI).[7] Between 2019 and 2024, the shortage of affordable and available homes for renters below 50% AMI worsened by over 22%.[8] While the affordability crisis impacts all Texans, it disproportionately affects minority populations, who already face economic disparities. Texas is home to over 19 million Hispanic and 4 million Black residents, who experience poverty at rates almost twice that of their white counterparts.[9] This makes housing affordability even more elusive.

Several factors have contributed to increasing home prices in the state over the last decade, including population and economic growth, supply constraints, and construction costs. The state has experienced net positive in-migration for most of its history, with the rate of domestic in-

[2] Census Data: Population boom in Texas catalyzes housing development gains, Dallas Morning News
[3] The Housing Affordability Challenge, Texas Comptroller of Public Accounts
[4] Texas Housing Facts, Texas Affiliation of Affordable Housing Providers
[5] The Gap Report March 2024, National Low Income Housing Coalition
[6] Chapter 2036 Texas Department of Housing and Community Affairs
[7] Gap Report: Texas ranks the 6th worst state in the nation for affordable housing
[8] The Gap Report March 2019, National Low Income Housing Coalition
[9] 2022 ACS 1-Year Estimates - Poverty and Income in Texas, Every Texan

migration[10] accelerating since 2019. This has led to a larger pool of residents competing for units within a limited housing stock. In 2024 alone, the shortage of housing units was 320,000 units, a 31% increase since 2017.[11] Construction costs have meanwhile surged by over 30%[12] within the last five years for many builders, leading to overall increases in home prices. Median home prices in Texas have surged by approximately 36% since 2021, reaching $337,000 as of September 2024, according to Texas A&M's Real Estate Research Center.[13]

Understanding the Housing Production Ecosystem as Key to Reducing Costs

As Texas continues to experience rapid economic and population growth (routinely ranking in the top 3 states with the highest population growth year over year[14]), the demand for new housing is outpacing the state's current production capacity. Developers are increasingly drawn to the Texas market, yet face rising costs for construction materials, labor shortages, and lengthy approval processes. According to the National Association of Home Builders,[15] approximately 61% of the average sales price of a new home can be attributed to construction costs (hard costs), while the remaining 39% is accounted for by non-construction costs (soft costs) such as land acquisition, financing, regulation, professional fees, and profits.

Reducing housing production costs requires a comprehensive understanding of how the process operates across the state, especially considering the greater demand for construction materials, a trained construction workforce, and transportation capabilities to keep up with the growing demand for housing. The housing production value chain involves multiple stakeholders, including but not limited to material suppliers, component manufacturers, builders, developers, and local governments. Each of these actors plays a critical role in determining the final cost of a home, and inefficiencies at any point in the chain can lead to delays and prohibitive increases in expenses.

To establish ecosystems that enable faster and more effective deployment of housing across the state, it is important to first understand the actors that participate in the housing production value chain, the workflows and limitations that define how they collaborate, and the bottlenecks that constrain the overall ecosystem.

Approach to Mapping Housing Production

This paper provides insights into the current state of housing production in Texas, investigating how IC can play a role in enabling more housing supply. Key terminology is defined below.

[10] Migration to Texas Fills Critical Gaps in Workforce, Human Capital

[11] Texas has a housing affordability crisis

[12] Rising above inflation: Texas experts pave the way for construction success and innovation

[13] Texas Housing Insight September 2024, Texas Real Estate Research Center

[14] Texas gained more people than any other state in the last year, William Melhado

[15] Cost of Constructing a Home, Carmel Ford

Table 1: Key Terminology Considered in this Paper

Key Term	Definition
Industrialized Construction	Construction utilizing workflows that leverage optimized manufacturing, assembly, and installation of standardized components. Often enabled by digitalization, automation, supply chain integration, and lean processes in order to increase productivity, quality, efficiency, and lifecycle value through advanced manufacturing techniques and interdisciplinary collaboration.
Offsite Construction	The practice of prefabricating buildings in a manufacturing environment and transporting them to the construction site to be assembled.
Onsite Construction	The practice of building structures entirely on the final site, linearly from foundation to finish. Also referred to as 'conventional' or 'stick-built.'
Modular	An Offsite Construction strategy that involves dividing a building into smaller, standardized units called modules, which are manufactured offsite and then assembled onsite to form a complete structure. Modular construction usually involves a combination of volumetric, panelized, and pods. Modular construction is designed to meet the International Building Code (IBC) and the International Residential Code (IRC).
Volumetric	A type of modular construction which involves manufacturing fully enclosed modules on all six sides (one floor, four walls, and one ceiling) and transporting the 'box' to the construction site.
Pods	A component of modular construction in which smaller volumetric subassemblies are manufactured as 'pods' and either incorporated into a volumetric module at the factory or transported as a standalone pod to the construction site. Pods are mostly used for mechanical/electrical/plumbing (MEP) rooms, bathrooms, and kitchens.
Panelized	A type of modular construction in which building elements like floor/ceiling, cassettes, and walls are manufactured as panels and then flat-pack transported to the construction site.
Manufactured Housing	Houses built according to the U.S. Department of Housing and Urban Development (HUD) Code.[16] These houses are manufactured in a factory, transported on a permanent chassis, and set at the final location.
Industrialized Housing and Building (IHB) Manufacturer *(Texas-specific)*	A manufacturer certified by the Texas Department of Licensing and Regulation (TDLR) who is both registered and approved to construct modules or modular components for Texas.[17]
Industrialized Builder *(Texas-specific)*	A person registered with TDLR who is engaged in the assembly, connection, and on-site construction/erection of modular components at the building site or is engaged in the purchase of industrialized housing or modular components for sale or lease to the public.[18]

Various datasets were examined from the following sources: Texas Department of Housing and Community Affairs (TDHCA), the U.S. Department of Housing and Urban Development (HUD), the United States Census Bureau, and Texas A&M's Real Estate Research Center, among others. Additionally, this white paper is informed by conducting one-on-one structured discussions with

[16] Manufactured Housing and Standards FAQ, HUD

[17] Industrialized Housing and Buildings Certified Manufacturers, TDLR

[18] Industrialized Builder, TDLR

stakeholders who are actively engaged in housing production in Texas and therefore influence distinct parts of the value chain. The table below summarizes the types of stakeholders engaged.

Table 2: Stakeholder Engagement in this Paper

Stakeholder Type	Primary Sources (interviews)	Secondary Sources (desktop)
Finance and Insurance	2	13
Developer	3	13
Manufacturer	7	18
Supplier	3	13
Government / Authority Having Jurisdiction	3	7
Housing Non-Profit or Industry Group	3	8
AEC (General Contractor, Architect, Engineer)	3	28
Tech / Construction Innovation	5	14
Code / Policy Organization	2	6

II. State of Affairs for Housing Affordability

National Housing Context

Housing affordability challenges are far from unique to Texas. The nation is facing a severe shortage of affordable housing, with the National Low Income Housing Coalition estimating a shortage of up to 7.3 million rental homes that are both affordable and available to extremely low-income renters.[19] Housing affordability has worsened over the past two decades, affecting both urban and rural areas, and has been exacerbated by factors such as high interest rates, low inventory, and demographic shifts.[20] For example, the percentage of households earning between $50k - $75k per year that experience rent burden (meaning they spend over 30% of monthly income on rent) increased from approximately 17% in 2010 to approximately 40% in 2022. Affordable and available housing (which extends the definition to units that are affordable and either vacant or not occupied by higher-income households) increases in supply as income increases, resulting in extremely low-income families having the most difficult time securing

[19] The Gap 2024, National Low Income Housing Coalition

[20] Hitting Home: Housing Affordability in the U.S. - Karan Bhasin, Prakash Loungani and Aziz Sunderji

housing that they can afford. Despite various federal programs[21] and initiatives aimed at increasing the supply of affordable housing, demand continues to outpace supply, making housing affordability a pressing national issue. The National Association of Home Builders estimates that 77% of households in the US cannot afford a median-priced new home in 2024.[22]

Affordable housing shortage disproportionately affects Black, Latino, and Native households, who are twice as likely to be extremely low-income renters[23] due to historical drivers of inequality. For these groups, the percentage of households able to afford the median home payment dropped by almost 40% over the past year.[24] In Texas, immigrant households comprise approximately 21% of total households, making up a racially and economically diverse share of the housing market in a state that may not be prepared to meet the demand coming from this population.

Housing Affordability in Texas

Texas is a high net-inflow state in terms of its population, with the highest number of residents migrating inwards[25], resulting in over 473,452 people[26] moving to the state in the year 2023 (an all-time high). Most of these residents are attracted to Texas's lower cost of living than in the major metro areas from which they are migrating (e.g., California and New York). The relatively high affluence of a portion of the incoming population has triggered interest from developers in building new mid- to high-end housing (generally producing higher profit margins), creating a situation where there is an oversupply of mid- to high-end housing and an undersupply of affordable housing. To create and maintain long-term housing affordability that addresses the critical root socio-economic causes, the costs of construction and development need to be drastically reduced across the board - industrialized construction can drive broad construction industry savings through efficiencies gained from shifting from a predominantly (+85%) onsite activity (higher labor cost, longer build times, higher weather-related risk) to a healthier mix of onsite (~50%) and offsite construction (~50%).

Affordable housing developments face unique financial challenges that make them more sensitive to rising construction costs compared to market-rate or luxury projects. Several key factors contribute to this disparity:

- **Lower Revenue Potential:** Affordable housing projects typically generate less rental income due to rent caps tied to tenants' income levels.[27] This limitation reduces the

[21] The Affordable Housing Crisis Grows While Efforts to Increase Supply Fall Short
[22] Nearly 77% of U.S. Households Cannot Afford a Median-Priced New Home, NAHB
[23] The Gap Report March 2023, National Low Income Housing Coalition
[24] The State of the Nation's Housing 2023, Joint Center for Housing Studies of Harvard University
[25] State to State Migration Flows, US Census Bureau
[26] Texas Population 1900-2023
[27] Technical Appendix to The Cost of Affordable Housing: Does It Pencil Out?

potential net operating income (NOI), making it more difficult to cover construction and operational expenses. Consequently, developers may be deterred from pursuing such projects due to the lower return on investment.

- **Complex Financing Structures:** Affordable housing developments often rely on a mix of funding sources, including government subsidies, tax credits, and grants. Assembling these funds can be time-consuming and may involve higher administrative costs, adding complexity to the development process.[28]
- **Regulatory and Compliance Costs:** Developers of affordable housing must navigate various regulations and compliance requirements, such as prevailing wage laws and specific building standards. These mandates can increase construction costs compared to market-rate projects.[29]
- **Community Process and Zoning Restrictions:** Affordable housing developments may face challenges such as community opposition and restrictive zoning laws, including minimum lot or unit sizes. These obstacles can lead to delays and increased costs in obtaining necessary approvals, making smaller 'starter homes' less feasible.[30]
- **Higher Per-Unit Costs:** Due to economies of scale, smaller affordable housing projects may have higher per-unit costs compared to larger market-rate developments.[31] This is because fixed costs are spread over fewer units, making each unit more expensive to build.

Permits in Texas have increased yearly, with Dallas and Houston dominating the growth of private housing for the past three decades, with each city currently approving approximately 5,000 building permits for private housing per month.[32] In regions experiencing growing needs for housing (single and multi-family), industrialized construction can provide an important solution by leveraging efficient manufacturing, transportation, and lower labor costs. However, making the case for IC is not black and white. For example, one developer who was interviewed for this white paper described an ongoing multifamily project with site-built costs of roughly $\$120/ft^2$, while just the volumetric modules for the same project would cost $\$130/ft^2$ (doesn't include onsite prep and modular onsite finishing cost). This simplistic "developer comparison" does not account for IC speed of construction savings (or other potential savings related to jobsite safety and construction quality). As industrialized construction gains greater adoption (thus fostering competition) and as factories and developers can reach manufacturing economies of scale, IC costs will see a significant drop, eventually becoming the obvious developer construction methodology choice for IC-relevant housing (high repeatability, high configurability).

[28] The Complexity of Financing Low-Income Housing Tax Credit Housing in the United States, Terner Center

[29] Low-Income Housing Tax Credit Construction Costs: An Analysis of Prevailing Wages, Terner Center

[30] How Zoning Regulations Affect Affordable Housing | NAHB

[31] Low-Income Housing Tax Credit: Fast Facts

[32] Housing Units Authorized by Building Permits, FRED

Fragmented building codes add complexity to housing production in the state, often resulting in approval delays. In Texas, the adoption code follows the 'home rule' system,[33] according to which a non-mandated building code establishes baseline standards through state statutes, but regulation is adopted and enforced according to local jurisdiction. Conventional onsite construction is regulated by local jurisdictions, and industrialized housing and buildings are regulated at the state level by the Texas Department of Licensing and Regulation (TDLR). As discussed in the Codes section of this white paper, this can help increase housing affordability by creating pathways to streamline housing production and increase the supply of affordable housing.

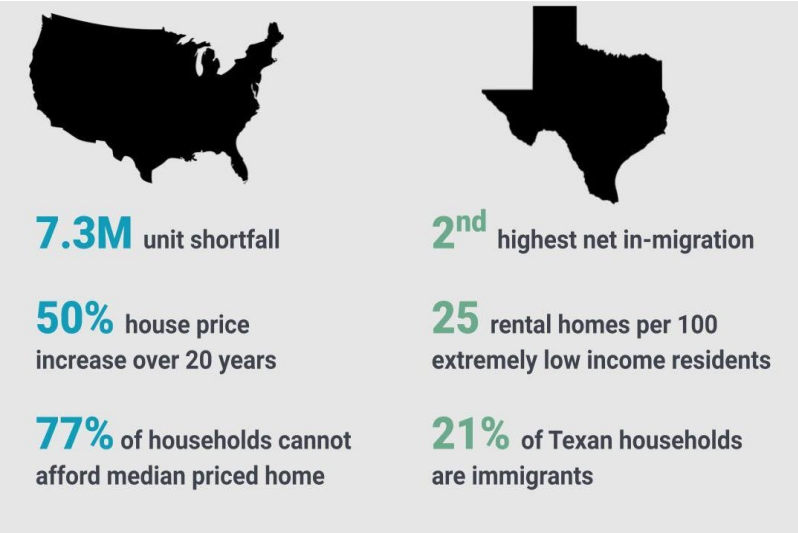

Fig. 1. Key nationwide and statewide housing statistics

Incentives and Challenges

The most significant financial incentive for developers to address the affordable housing shortage is the Low-Income Housing Tax Credit (LIHTC). The LIHTC is the primary driver of affordable rental housing in the U.S., responsible for funding about 2,996 properties (~267,000 low-income units) in Texas since 1987.[34] Through this program, federal funds are allocated to the Texas Department of Housing and Community Affairs (TDHCA), which distributes tax credits to qualifying developers.[35] Texas receives approximately $95 million annually in LIHTC funds, ranking second in the nation for tax credit allocation. This underscores the program's importance to the state's affordable housing supply.

LIHTC operates through a 4% credit (non-competitive), typically used for the acquisition of existing buildings and rehabilitation projects, and a 9% tax credit (allocated through a competitive process), generally used for new construction and substantial rehabilitation projects without

[33] Texas Building Codes, ICC

[34] Low-Income Housing Tax Credit: Property Level Data, HUD

[35] Competitive Housing Tax Credits, TDHCA

federal subsidies. Since 9% of LIHTC projects have a "placed-in-service" deadline,[36] which enforces a time-bound expectation for project delivery and occupancy, IC can help projects ensure federal funding remains intact by compressing schedules up to 50% as compared to onsite construction. The Texas Qualified Allocation Plan (QAP), managed by TDHCA, outlines the criteria for awarding LIHTC credits each year.[37] Projects are evaluated based on factors such as unit size and quality, green building features, energy efficiency, and affordability. The Texas QAP does not currently include construction methods as a criterion, suggesting limited support for IC. However, the QAP can be influenced by public advocacy to incentivize the use of improved construction techniques.[38]

In addition to tax credits (focus on financing development), Land Banks (focus on land acquisition/site control) and Community Land Trusts (focus on permanent community affordability and stewardship) are complementary pathways to creating long-term affordable housing. Through land banks, government entities can buy an underused, abandoned, or foreclosed property, maintain it, and then sell it at a lower cost to approved developers. Community Land Trusts move land out of the speculative real estate market and place it under community control, thus creating affordable homeownership and rental housing for current and future generations.[39] Cities across Texas have land banks, and nonprofits across the state have set up community land trusts, with entities like the Texas State Affordable Housing Corporation (TSAHC)[40] offering land trust services to support the development of long-term affordable housing.

While tax credits and low-interest programs are important for making many affordable housing projects feasible, long-term sustainability is doubtful. In the next decade, LIHTC contracts for an estimated 21,000 units in Texas will expire,[41] removing the guarantee that these units will remain affordable. Since affordable housing cannot solely rely on LIHTC, it is time to rethink how to directly incentivize IC to further enable the supply of affordable housing across the state. Two examples include; 1) providing direct funding to clusters of regional municipalities to develop standardized, pre-approved, configurable, and interoperable "IC-based kit of parts" solutions that can be used by affordable housing developers (i.e., municipalities designing and pre-approving ADUs) and 2) establishing a similar program to the Canadian Rapid Housing initiative[42] (3 successful rounds which outperformed expectations[43]) which required 50% of the funding be used on IC-based (primarily modular technology was used. Both of these solutions expedite the

[36] IRS Form 8609

[37] 2024 Governor Approved Qualified Allocation Plan

[38] For example, the Virginia QAP was revised to award credits for projects using innovative construction methods that meet the International Residential Code (IRC), with an expert committee evaluating qualifying technologies.

[39] Community Land Trusts, The Uprooted Project at UT Austin

[40] Texas State Affordable Housing Corporation, Land Trust and Joint Ventures

[41] AP News "As Affordable Housing Disappears, States Scramble to Shore up the Losses"

[42] Canadian Rapid Housing Initiative update, Canadian Housing and Mortgage Corporation

[43] The Rapid Rise of Affordable Modular Housing in Canada, MBI

deployment of high-quality IC-based housing while the "kit of parts" model also lowers design costs to affordable housing developers.

III. Considerations for Housing Production in Texas

Codes

As mentioned in the glossary, it is important to distinguish between *modular houses*, which must comply with TDLR's IHB program and be built to meet IBC and IRC standards, and *manufactured houses* which must comply with the federal HUD code.

As of 2024, Texas has adopted the 2015 International Building Code (IBC) and the 2018 International Residential Code (IRC) for conventional construction, although individual jurisdictions may adopt different editions on different timelines, while other jurisdictions, particularly unincorporated areas of counties do not enforce any building codes.[23] For example, Austin and Houston use 2021 IBC, while smaller and more rural, cities like Garland, Leander, Port Arthur, are still using all of or part of the 2015 code. Liberty County, north of Houston, has seen rapid, unregulated growth with little or no code enforcement. This provides numerous challenges for designers and builders, especially in terms of the efficiency and replicability of housing solutions. However, as of July 2024, industrialized housing and buildings, modules, and modular components need to be compliant with the 2021 IBC and the 2021 IRC across the state irrespective of local code requirements.[44] With this recent adoption of the 2021 codes for industrialized buildings, developers and builders who build offsite have a defined set of requirements to meet. This better clarity supports the wider adoption of IC.

Texas has an Industrialized Housing and Buildings (IHB) program that is managed by the Texas Department of Licensing and Regulation (TDLR).[45] State-approved third-party inspectors are responsible for manufacturer certification, plan review, and module inspection, leaving onsite inspection to municipalities. All approved modules are stamped with a label at the factory, which certifies to onsite inspectors that the unit is compliant. Modules manufactured in a controlled environment and certified by third-party inspectors promote consistency and give confidence to regulators and developers that they are dealing with a low-risk product.

Material Production

The availability of construction materials sourced locally or regionally can be an enabler for manufacturing. Eastern Texas, particularly the northeast region,[46] is a hub for raw material

[44] Mandatory Building Codes, TDLR

[45] Industrialized Housing and Buildings, TDLR

[46] National Association of Manufacturers

suppliers and manufacturers,[47] employing around 900,000 people across 20,000 manufacturing companies. This region also aligns with the demand for housing in the "Texas Triangle", home to major metro areas Austin, Dallas, and Houston. In these cities, significant investments in advanced manufacturing by companies such as Samsung, Toyota, and Texas Instruments highlight Texas's appeal as a general production center featuring building industry leaders including Knauf Insulation and Corrigan OSB that have invested heavily (more than $200M each) in their Texas facilities.[48]

Cement and mineral processing facilities are concentrated in central and eastern Texas, particularly around Houston, Austin, and Dallas.[49] The presence of concrete batch plants and aggregate facilities creates potential for IC methods with precast concrete and 3D printing with concrete.

Forest product mills, primarily located near Houston and Dallas, play a critical role in housing production by supplying materials such as dimensional lumber and plywood. Although Texas has only around 100 lumber production facilities, the high demand for locally sourced lumber indicates an opportunity for expanded capacity to meet the needs of residential construction.[50] Evidence supporting this unmet demand for lumber is Georgia-Pacific's 2022 expansion of its sawmill in Pineland, TX, which has increased its capacity to support up to 30,000 homes per year and introduced cross-laminated timber (CLT) as a sustainable material option for Texas builders.[51]

Steel production is another important part of Texas's construction supply chain, and although the state's production capacity is still inferior to that of states like Indiana and Ohio, Texas's steel industry continues to grow. Companies like Nucor and Steel Dynamics operate in the eastern region, and Steel Dynamics' new facility near Corpus Christi, built with a $2 billion investment, is expected to bolster the local supply chain and support both conventional construction and IC.[52] Interviewed stakeholders identified steel as a key material, second only to lumber, and with growing popularity in manufacturing environments for industrialized buildings. This underscores the importance of a robust local supply chain for both types of materials.

Glass production is also well established, with over 350 manufacturers in the state. Dallas-based Oldcastle Building Envelopes leads the market with $1.8 billion in revenue. Vitro Architectural Glass, one of the largest glass producers in North America, constructed a new $55M jumbo magnetron glass coater in 2017.[53] Glazing produced in these facilities is high-performing, precision manufactured, and extremely energy efficient.

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[47] Off-Site Heat Map, Housing Innovation Alliance

[48] Made in Texas, SiteSelection

[49] Texas Aggregate Production Operations and Adjacent Industries Map

[50] Primary Forest Products Mill Map

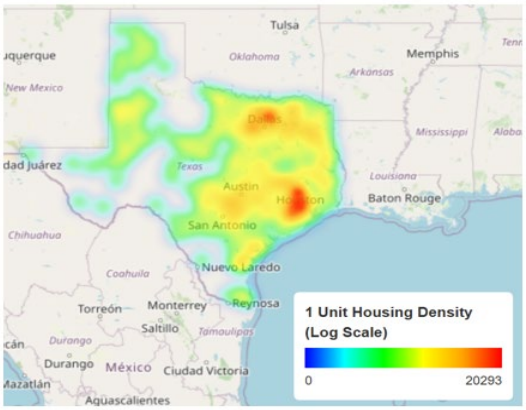
[51] Georgia-Pacific Invests $120 Million into New Technology at Pineland Lumber

[52] Steel Dynamics Announces Planned New Flat Roll Steel Mill Site Selection

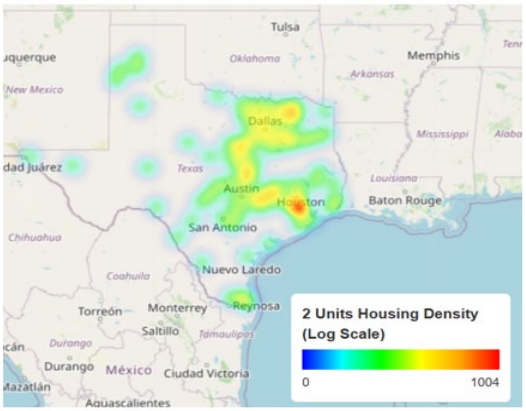
[53] Vitro Breaks Ground on Jumbo MSVD Coater at Wichita Falls Facility

Housing Typologies

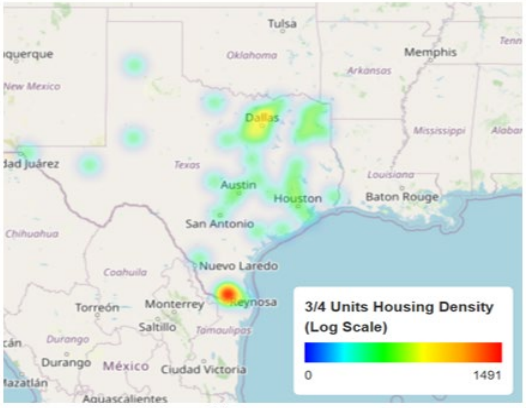
There are two prominent types of housing in the U.S. that are broadly categorized as single-family and multi-family homes. Accessory dwelling units (ADUs) are becoming a popular third type. Understanding these prominent typologies, where and how they are built, and the populations they serve helps assess the IC's potential to build them. Statewide, close to 65% of new housing units being permitted are developed as single-family homes, and approximately 35% of new units come from multifamily buildings.[54] The bulk of residential construction is taking place in the eastern half of the state, dominated by the construction of single-family homes. Meanwhile, multifamily buildings containing five or more units have greater prevalence in the Austin region relative to other metro areas.



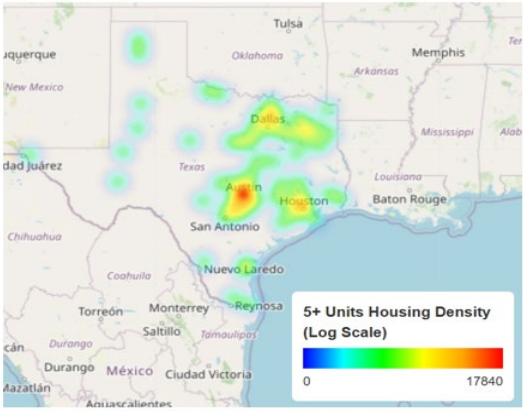
1 Unit Building Permits across Texas



2 Units Building Permits across Texas



3 or 4 Units Building Permits across Texas



5+ Units Building Permits across Texas

Fig. 2. Heat map showing distribution of building permits across Texas by number of units constituting the building.

Single-Family Homes

Detached single-family homes are the most common type of housing in Texas with approximately 7.5 million units statewide. While the median home price in Texas is $330,000 (lower than the

[54] US Census Bureau

national average of $419,000), high prices in metro areas such as Austin ($515,000) highlight affordability challenges that are not equally distributed across the state.[55] In addition to standard homeownership, Texas is a leader in Built-to-Rent (BTR) housing, with all four major markets (Dallas, Houston, Austin, and San Antonio) being among the top 20 markets nationwide for total BTR inventory.[56] Build-to-rent housing is usually entire communities (50+ properties) owned by a single entity, often in the form of Real Estate Investment Trusts (REITs). BTR portfolios are therefore an ideal candidate for the replicability and standardization realized by IC. In 2023, only around 1% of new homes in the South[57]—one of the largest US housing markets, with Texas a major contributor—were built using modular methods (including volumetric and panelized systems). This suggests that there is still a significant regional gap before IC becomes a default option for developers.[58]

Large offsite builders such as Champion Homes and Clayton Homes are well established in Texas's single-family market, offering both modular and HUD-code manufactured homes at lower price points than conventional builds. HUD-code manufactured homes makeup around 6.4% of the current housing stock in Texas.[45] Between 1994 and 2000 manufactured homes peaked in production with over 350,000 units shipped annually but dropped to less than 50,000 per year by 2009.[59] Today, manufactured homes are experiencing a resurgence as the median housing costs have skyrocketed (33%[60]), and aided by the 2018 emergence of CrossMod[61] homes (built to HUD code but with fewer restrictions on where they can be placed) which has made manufactured homes more appealing in the market. Modular single-family homes are also on the rise (1% total market share increase) as new factories open across the state (For example, The Amherst Group, LLC opened a new factory in Cuero, TX in 2023 for their StudioBuilt brand.[62]). Home buyers seeking affordable housing often find that homebuilders in their area forego smaller builds in pursuit of higher dollar-value projects. This has opened a space in which modular construction is steadily gaining traction.

Modular homes tend to offer higher resale values compared to HUD-code manufactured homes, and HUD-code manufactured homes often face zoning restrictions. Both types of factory-built housing are well suited for single-family homes, and especially for starter homes, which greatly

[55] Austin, TX Housing Market; Zillow

[56] Build-to-Rent Residential Market Overview

[57] "South" Region includes: Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia (US Census Bureau, Survey of Construction Definitions)

[58] Characteristics of New Housing, US Census Bureau

[59] The Role of Manufactured Housing in Increasing the Supply of Affordable Housing, Housing Finance Policy Center

[60] FRED Economic Data, St. Louis Federal Reserve

[61] Factory Built Housing Types, NextStep US

[62] Amherst Announces Grand Opening of StudioBuilt Factory in Cuero, Texas, The Amherst Group

benefit from the reduced costs and faster builds. Modular homes generally are built to the more stringent IRC code which varies by jurisdiction but wind, fire, egress, and energy, tend to be stricter. Additionally, IRC-code-built modular homes typically qualify for standard mortgages which offer lower interest rates, tax advantages, and longer terms than chattel loans used by many HUD-code homes. While housing built to either code can appreciate in value, HUD-code manufactured homes' resale potential can be hindered by market perception, non-permanent foundations, and higher-interest loans[63].

Multi-Family Homes

Multi-family housing, such as duplexes and apartment buildings, uses land efficiently to house more people in a smaller footprint and serves diverse groups, including seniors, professionals, and students. With an increasing demand for affordable units, multi-family structures are an ideal fit for IC, as they can benefit from standardized, repeatable designs that lead to building out more housing units per project. According to the U.S. Census Building Permit Survey, only 1.43% of new building permits are for multifamily buildings containing five or more units, yet these permits are responsible for adding close to 31.91% of all new housing units in the state.

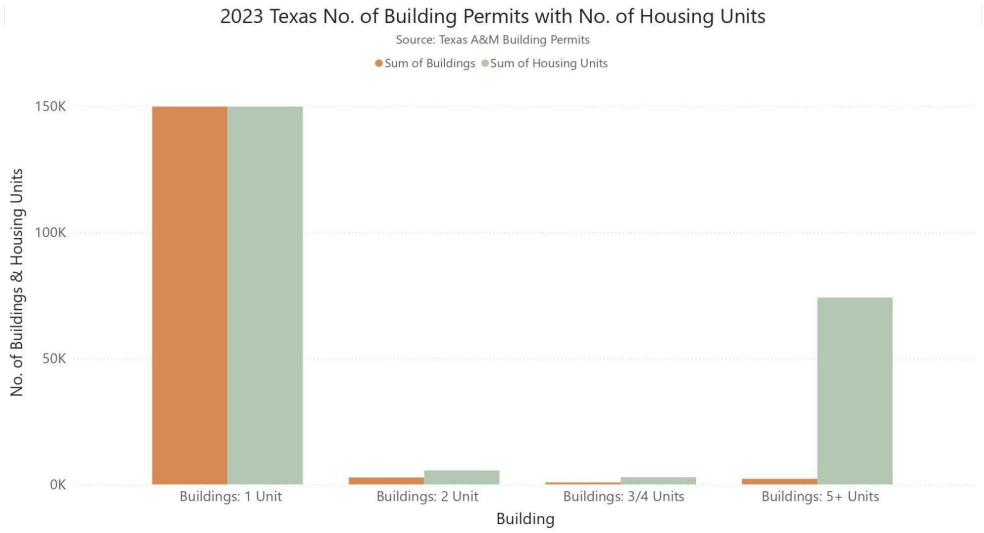


Fig. 3. In orange, the sum of building permits for a given typology. In green, the corresponding number of units offered by that typology. Data shown is based on building permit data for Texas in the year 2023.

Texas has seen successful modular multi-family projects ranging from tens to hundreds of units demonstrating the scalability of this approach for multi-family housing (As reference, a few example projects are listed in the Appendix). Still, in 2023, less than 0.5% of new builds were built using modular and only 1% of new builds with panelized methods.[49]

[63] Myth Busted: Modular Homes Appreciate in Value, MBI

Real estate analysts suggest that Texas may have overbuilt its market-rate and luxury multi-family housing pipelines in response to the pandemic-era demand boom, as evidenced by occupancy levels decreasing below 90% in cities such as Austin and San Antonio.[64] Although there might be a perceived oversupply of housing, many of the available units do not fit the budgets of the state's prospective residents. They are built (and priced) for higher-end accommodations and located in metro areas, which are home to the state's highest median monthly rents.[65] Forward-looking developers have predicted that as demand and supply rebalance, and. as the next cycle of development frenzy starts, IC could become a differentiator for beating the competition.

Accessory Dwelling Units (ADUs)

ADUs are small, independent units on the same parcel lot as a primary residence, often used for rental income or housing family members. Given their compact size, ADUs are well-suited for modular construction, as they enable a single volumetric module structure to be adapted to a variety of interior layouts. This in turn allows for efficient production and placement as well as for the testing of standardized and automated construction processes. Due to their growing popularity, cities such as Austin have rolled up ADU designation into the single-family home category. Other cities such as Houston are providing pre-approved architectural plans for ADUs,[66] which simplifies permitting, and further enhances compatibility with IC methods.

As is true across the U.S., over the past 5-7 years, Texas cities (San Antonio[67], Austin[68], Houston[69]) have begun to loosen regulation (but there remains some regulation barriers) to make it easier for homeowners to build ADUs. ADUs can offer a lower-cost alternative for prospective homebuyers, especially in high-priced urban areas. While overall costs are normally lower for ADUs than for primary single-family homes, ADUs tend to be more expensive on a per-square-foot basis because expensive features such as HVAC, bathrooms, and kitchen are amortized over a smaller area.

Construction Methodologies

Streamlined manufacturing processes are shown to reduce project timelines by up to 50% and construction costs by up to 20%.[70] Nonetheless, the use of IC across the industry is still low. A common experience shared by developers using modular construction in Texas is that when freight

[64] Multifamily goes from darling to distress in Texas
[65] Texas Housing Prices on the Rise, Texas Comptroller
[66] "Granny Flats" Could Remake the Housing Market. Why Are They So Contentious?
[67] Why more people want to build casitas in San Antonio, Axios
[68] HOME Amendments, AustinTexas.Gov
[69] ADU's explained: Building an ADU in Houston, Maxable
[70] Off-Site Construction: Delivering Better Buildings, National Institute of Building Sciences

and set costs are factored into the total price, site-built and IC turn out to be cost-comparable. Estimates of adoption rates of modular for residential construction range from 3% (as per National Association of Realtors[71]), to 6% (as per Modular Building Institute[72]). Though state-specific data is not widely available, single-family homes in the South mirrored the national trend in 2023, with IC accounting for 1% of new housing. For multi-family however, 5% of new builds nationwide were built using IC whereas around 1% of new builds in the South were built using IC, suggesting that there is a regional gap in support for IC among developers—depending on project typology.[49]

IC can offer potential savings in both hard and soft costs. In a factory setting, material usage is optimized, reducing waste and enabling labor to be more efficient, while also minimizing overages and delays that result from weather and other site-based issues. Hurricanes and tropical storms often extend as deep as central Texas, and tornadoes are not uncommon. The ability to avoid having a structure exposed to the risk of weather conditions can be transformative for sites across the state, and especially in vulnerable regions. Full volumetric provides the lowest exposure to weather-related damage, but so do other IC technologies such as prefab pods and panels (with their many variations) because they all effectively reduce weather exposure time.

Table 3: Cost/Schedule Comparison between "Stick-built" and Industrialized Construction

Cost Type	Conventional "Stick-Built" Construction	Industrialized Construction
Hard Costs	Higher variability in material and labor costs	Reduced waste, more predictable costs
Soft Costs	Higher due to custom designs, variable timelines	Lower due to standardized designs, pre-approved plans
Time Efficiency	Delays common due to onsite dependencies	Reduced project timeline by up to 50%

With greater predictability in timelines and costs as well as systems to capture continuous improvement, properly implemented IC reduces financial risk and can make projects more attractive to financiers. Moreover, Authorities Having Jurisdiction (AHJs) can benefit from standardization and repeatability to simplify permitting and reduce design fees while enabling pre-approved plans.

Time savings for one-off IC projects are well documented (up to 50%), however, to realize the full benefits of IC, developers/investors must consider broader portfolio needs that an IC product can solve, versus the conventional one-off project approach. For example, in conversations with modular manufacturers, when they repeatably produce the same product many times (ideally their own product), be it single or multi-family structures, they can generate significant economies of

[71] Modular Stacks Up to Stick-built, National Association of Realtors

[72] 2024 Permanent Modular Construction Report, MBI

scale that drive costs down. Additional cost savings are generated with larger orders, such that factories can more confidently forecast their production needs (an essential difference in manufacturing vs. on-site construction), which results in material supply chain savings and lower sales costs. The HUD manufacturing sector is proof of these points. All the major HUD manufacturers (Clayton, Skyline-Champion, Cavco) have dozens of factories that largely manufacture their own standardized product catalog, whereas non-HUD manufacturers, who often only have 1-2 factories, produce bespoke products based on customers' specific needs. Although there will always be a need for custom manufacturing, true savings come from scaling manufacturing across many facilities like the HUD and open-wall panel sector have been successfully done for decades.

Labor and Workforce

Texas is home to one of the strongest construction labor markets in the country. Since 2011, there has been a steady increase in the post-recession construction workforce, with about 861,000 people employed in the whole sector in Texas as of 2024.[73] Construction site labor in Texas has the highest employment level of any state, with Houston and Dallas having the 2nd and 3rd highest construction labor employment levels out of any urban area in the country, respectively.[74]

Hispanics comprise 61% of the construction workforce in the state, nearly twice that of the national average. Federal immigration policy changes could have significant impacts on the construction labor market.[75] According to The Center for Construction Research and Training, Hispanic construction workers are younger on average than the rest of the workforce, and much more likely to stay in the trades for a longer time.[76] Factors such as language barriers, legal status, and educational attainment remain paramount to upskilling workers and creating viable career pathways in IC in the state of Texas.

Unlike conventional onsite construction, offsite construction offers consistency in work location and a better work environment in which workers are not exposed to extreme weather conditions (particularly significant in the context of rising temperatures in the region), and where they experience better ergonomics. For these reasons, offsite construction is often associated with higher retention rates among trades personnel. This is also more welcoming to women and workers with different levels of physical capabilities in the construction workforce.

Compensation for workers in modular factories varies depending on various factors. For example, some factories pay workers on an hourly basis only, while others implement a base pay plus

[73] All Employees: Construction in Texas, FRED

[74] Occupational Employment and Wage Statistics, Construction Laborers, US Bureau of Labor Statistics

[75] Hispanics Comprise 61% of the Construction Workforce in Texas, NAHB

[76] Hispanic Employment in Construction, ELCOSH

incentive based on production. Experienced, cross-trained workers usually earn more, and maintenance people tend to be the highest paid. Compensation requirements are also influenced by whether a factory is unionized or not, with non-union plants generally having soft costs account for approximately 30% of operating costs, while in union plants soft costs are closer to or above 40% of operating costs. Prevailing wage requirements also influence compensation and cost of labor for offsite construction. While prevailing wage requirements have historically not applied to modular factories, a re-interpretation of the Davis-Bacon Act by the U.S. Department of Labor in 2022 has brought new interest to this topic. Modular Building Institute (MBI) has led efforts to educate industry and policy stakeholders on the effects that applying prevailing wage requirements to modular factories would have on increasing the cost of housing production.[77]

IC requires a labor force skilled in manufacturing and assembly, so a transition from educating students on conventional building tools to coding and robotics is important. The Texas Association of Homebuilders suggests educating young people at least as early as the eighth grade[78] on professional career opportunities that exist in the industry, and the National Association of Homebuilders (NAHB) has 27 local chapters[79] throughout Texas. The NAHB member base has the potential to both provide educational opportunities on IC and entice the next generation of construction workers.

Bottlenecks for Faster Widespread Adoption of Industrialized Construction

Despite the advantages of IC, its faster adoption in Texas is prevented by several significant hurdles, from regulatory barriers and market perceptions to financing challenges.

Fragmented Codes, Zoning Laws and Regulatory Hurdles: A common barrier used to IC adoption is the fragmented nature of building codes and regulations in Texas.[23] While building codes are often cited as a barrier to industrialized construction adoption in Texas, the core issue lies not in the codes themselves but in their implementation at the local level. Most industrialized construction methods—including modular, panelized systems, and mass timber—can be accommodated under the International Residential and Building Codes. However, inconsistent interpretation, unfamiliarity among permitting and inspection staff, and fragmented enforcement practices across jurisdictions create costly delays and uncertainty for builders. This is a classic example of a policy implementation challenge: even when regulations allow for innovation in theory, inconsistent application in practice can function as a de facto barrier. Addressing this requires not just code reform, but targeted investments in training, model permitting frameworks, and clearer state-level guidance.

[77] Modular Building Institute, How Does Davis Bacon Affect Modular Construction?

[78] Workforce Development, Texas Association of Homebuilders

[79] National Association of Homebuilders chapters

Resistance to Technology Adoption and Perceived Design Constraints: The construction industry is known for its conventional practices, and stakeholders often hesitate to adopt new methods despite potential benefits. IC introduces different workflows that require coordinating multiple trades under one roof, a shift that can seem risky and unfamiliar.[80] Architects and designers sometimes also resist IC due to perceived constraints on creativity—designing within standardized systems can require new approaches to incorporating variation while maintaining efficiency. Designers familiar with modular construction agree on the importance of advocacy for IC within the design community, especially to understand the important benefits it can bring to their own practices and profits (for example recurring revenue from licensing standardized designs).

Market Perception and Education Gaps: Public perception and a lack of education about IC and modular housing also limit its adoption. Many stakeholders, including developers, homeowners, and community members, conflate modular homes with manufactured or "mobile" homes, which they associate with lower quality. This misconception obscures the fact that modular homes are built to the same IRC codes as onsite construction rather than federal HUD codes used for manufactured housing. Additionally, developers often seek proof of success from existing IC projects before committing to this approach. Tailored education across stakeholder groups—from owners and developers to contractors and end-users and building code officials—will be essential to shifting perceptions and highlighting IC's benefits.

Financing Challenges and Capital Requirements: IC projects often require higher upfront capital, which can deter financiers who typically release funds based on visible, onsite progress (adds value to the collateralized land). IC can shift up to 70% of construction offsite, creating a need for alternative financing models that accommodate different timelines and capital structures. Additionally, financiers require strong collateral from IC manufacturers, with concerns about what will happen to partially complete projects if a factory fails (bankruptcy or product delivery). Establishing reliable collateral and developing financing structures specific to IC (both for developers and for factories) will be crucial to easing these financial bottlenecks, as well as to addressing the risks and opportunities that arise over a project's life cycle.

Efforts to establish industry-wide standards for interoperability of IC products between components (panels, pods, mods) themselves and interoperability between different manufacturers (or same or different components), such as the effort being led by The Center for Offsite Construction at New York Institute of Technology, could prove helpful in increasing lenders' confidence with financing offsite construction projects.

IV. Housing Production Process Mapping

We illustrate a preliminary process map in Figure 4 below. This was built based on our many stakeholder interviews and our existing domain expertise in industrialized construction. Many

[80] Finding Solutions to Modular Construction's Challenges, Rommel Sulit

stakeholders are involved in the housing production process, creating a complex web of interconnected stakeholders from the idea/design stage all the way through to construction, occupancy, and post-occupancy. Certain stakeholders play a greater role in determining the feasibility of the overall project, like the developer and their team of architects, engineers, and consultants. In general, the developer holds a outweighed power over other stakeholders to endorse or veto the use of alternative methods of construction such as IC.

Value Created Along the IC Housing Production Process

For the purposes of this report, one of the approaches we took was to categorize stakeholders based on how directly they add value to the actual construction process. For this purpose, we differentiate between the following three types of stakeholders, recognizing that categorization for certain actors may change depending on the circumstances of a specific project or development:

- **Primary Value-Creation Stakeholders:** These stakeholders create value for the project directly by engaging in the physical creation and improvement of the building and providing expertise that contributes to the building's quality, function, and end-user appeal.
- **Enabling/Supporting Stakeholders:** These stakeholders provide essential resources and/or approvals while often not directly affecting the physical building process. They make project execution feasible through financial, logistical, and organizational support, often working behind the scenes while playing a critical role to project viability.
- **Ecosystem Stakeholders:** These stakeholders influence the conditions and requirements that a project must follow (for safety, quality, durability, health, and access), but are not considered to be Primary Value-Creation Stakeholders or Enabling-Support Stakeholders. These stakeholders play a critical role at the ecosystem level and sometimes (but not necessarily) at the project level.

Figure 4 illustrates a generalized IC housing production flow for a building's life cycle, starting with design and ending with demolition and disassembly. Primary Value-Creation Stakeholders define the central flow sequence of housing production, and checkmarks depict where in the sequence the other two types of stakeholders play influential roles. It is important to note that the production process is not necessarily linear or sequential and that not all stakeholders included in the figure are involved in every individual component of a project.

In many instances (more common for modular homes than for manufactured homes), subassembly fabricators and distributors do not play a role, given that their scopes are integrated into those of manufacturers. Similarly, general contractors often perform the onsite installation themselves, removing the need for installers/setter.

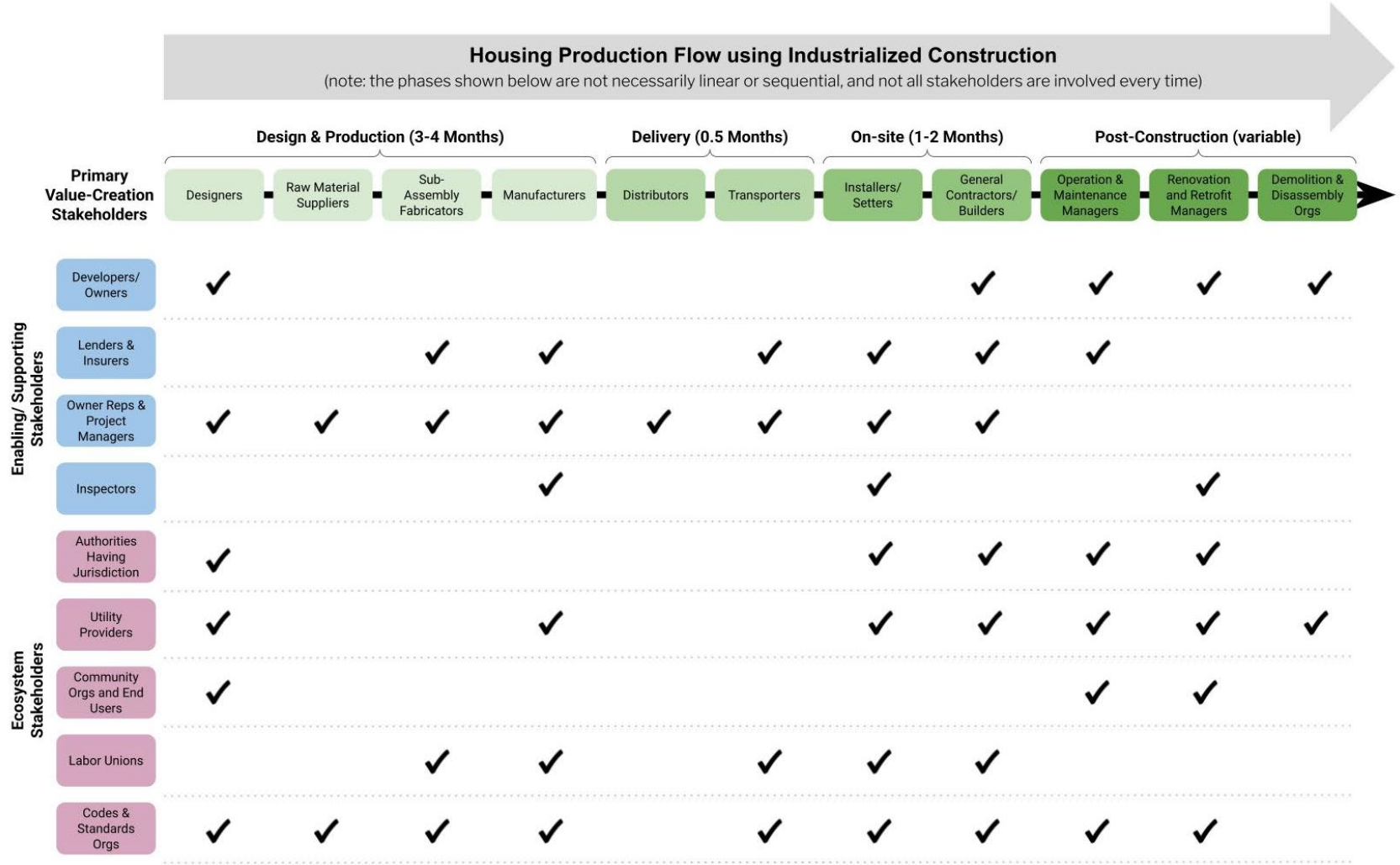


Fig. 4. Generalized IC housing production flow depicting value-creating stakeholders (green) and influencing stakeholders (blue and purple). Check marks indicate where influencing stakeholders exert direct influence on the value-creating stakeholders.

Understanding Complexities of the IC Housing Ecosystem

When shifting from conventional construction towards IC, new important relationships emerge within the housing production process. As part of our research, we interacted with many different stakeholders, as described below. As expected, we validated there are distinct differences between the onsite conventional and IC ecosystems. To illustrate this, Figure 5 provides a simplified schematic of how key groups of stakeholders interact with each other. It should be noted, that we did not do a deep dive into the degree of interaction between specific stakeholders to explore the level, frequency and intensity of engagement; however, we will investigate further and share our findings at a later date.

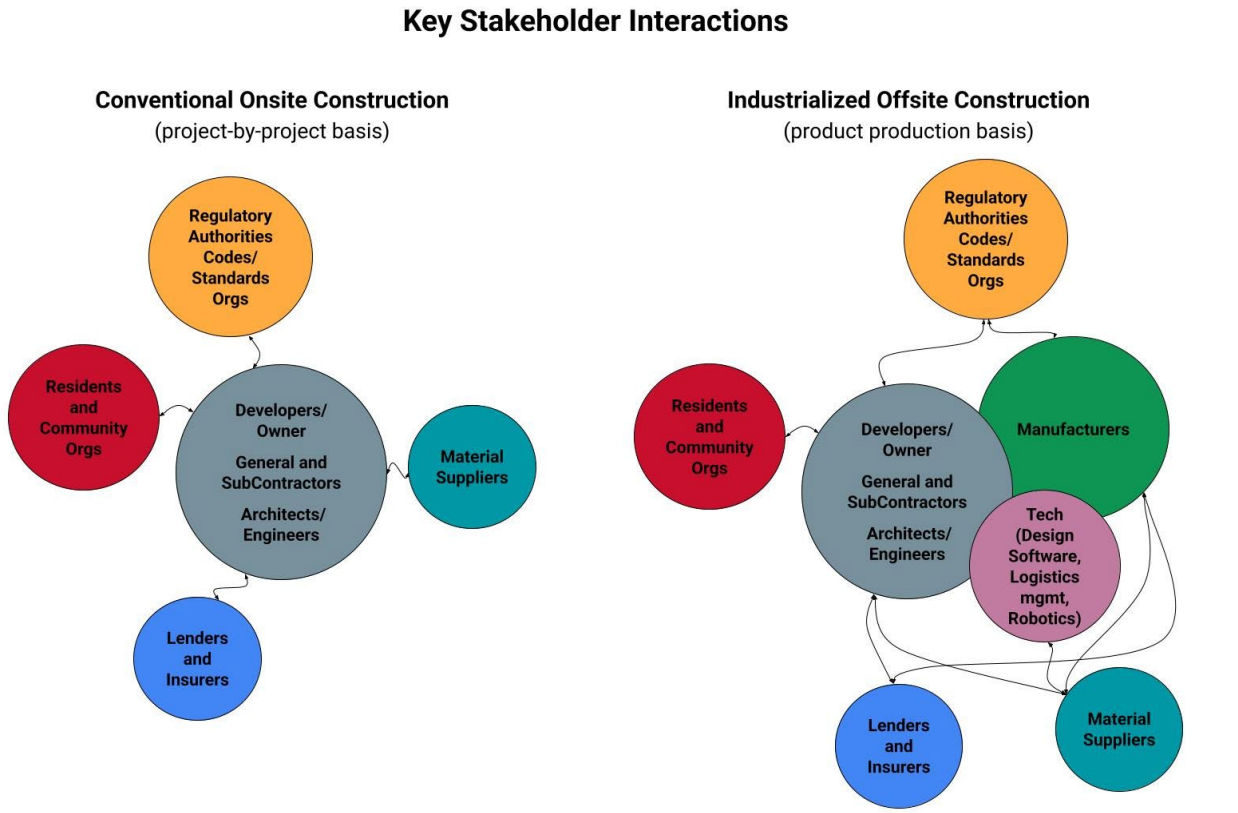


Fig. 5. Key stakeholder interactions for both conventional construction and IC. The larger the circle, the greater the scope influenced by the stakeholder category.

The level of collaboration (degrees of interaction) required for industrialized construction is important because it can influence, among other things, speed of adoption/implementation, buy-in and trust, quality of outcomes, and power dynamics (between developers, GCs, AEs, and manufacturers). Starting at the beginning, effective implementation of IC demands that greater effort is dedicated upfront for product design and planning across a portfolio of projects. The AEC team and the manufacturers need to work closely to develop designs with as-built-level fidelity before starting fabrication. This greater complexity in upfront activities for the first few projects

can be considered a "ramp-up cost", which can yield sizeable dividends with every subsequent project that is able to leverage those standardized designs and processes. These ramp-up costs depend on product and system standardization and the IC technology leveraged, but generally speaking, the design and engineering fees in a typical one-off residential building is about 5-10% of the total project cost. Industry experts have observed that the design and engineering costs for industrialized construction (IC) are typically much higher than those for traditional one-off residential projects (based on conversations, we estimate it to be roughly 1.5 to 3 times higher). This aligns with the fact that the construction industry spends <1% of revenues on R&D, compared to a conservative average of ~5% for all industries[81,82].

As depicted in Figure 4, Developers, AEC Team, and Manufacturers play a central role in IC. Supply chain partners play a bigger role than they do in conventional construction given that efficient logistics and timely delivery of materials and modules both to the factory and to the site are critical for achieving the schedule compression benefits of IC. Based on conversations with stakeholders and practical experience from industry engagement, the following key relationships emerge as particularly important in IC:

- **Architects/Engineers ←→ Manufacturers:** In IC, architects and engineers need to inform their designs based on what is feasible to manufacture at the factory (e.g., Design for Manufacture and Assembly, or DfMA). If the designs require work beyond the manufacturer's capabilities, this will result in additional costs that will not allow the project to reap the full benefits of IC. Coordination between design teams and manufacturers is paramount and can help motivate manufacturers that are slow to adopt new technologies. In other industries, systems engineers often perform this integration between design and manufacturing.
- **Manufacturers ←→ Suppliers**: Keeping a factory in operation and optimized through lean manufacturing principles is not trivial, since factories rely on consistent throughput. Receiving the right materials in the right condition and at the right time is crucial for a factory. Managing this relationship typically falls to plant engineers and managers.
- **Developers ←→ Finance & Insurance:** Unlike conventional construction loans which disburse money to the developer in "draws" as the project progresses, IC requires most of the loan upfront in order to enable manufacturing to begin offsite. Securing a financier who understands the nuances of IC is important. Similar to other types of construction, it is prudent for developers to educate lenders who may misperceive greater risk in IC.
- **Inspectors ←→ Manufacturers:** Since many modular building products arrive at the construction site with a high level of completion, the inspection and approvals process must be conducted in the factory. In Texas, this is done by state-approved third-party inspectors. Approved factories (as well as plans and drawings) are evaluated regularly by the third-

[81] National Center for Science and Engineering Statistics, National Science Foundation

[82] R&D Intensity Ratios, Schonfeld & Associates, Inc.

party inspector for compliance with the quality assurance plan, which has been approved by the state, and components are inspected at various stages in the manufacturing process.

- **Developers & AEC Team ←→ Technology Providers:** To capture the cost reduction and timeline compression benefits offered by IC, Developers & AEC teams rely on technology providers to bolster design, optimize scheduling and logistics, and transmit information to manufacturers and supply chain partners. Selecting the right technologies is critical in enabling ecosystem continuous improvement, which is one of the key benefits of adopting IC. It is important to note that Technology Providers interface with more than developers/AEC/manufacturing stakeholders in meaningful ways, but this relationship is highlighted because developers and their teams tend to have outsized influence on the adoption (or lack thereof) of technologies. Technology providers also collaborate with different AEC teams and manufacturers, creating an important channel for knowledge sharing across the industry. Technology providers may also be internal to AEC teams rather than independent.
- **Finance & Insurance ←→ Manufacturers:** Factories are susceptible to increases and decreases in demand and must balance production rates and throughput. Often, they rely on banks and financial partners to scale, purchase raw materials, invest in equipment, and provide working capital to bridge the peaks and troughs in demand.
- **Developers ←→ Regulators:** This relationship is very important in both conventional construction and IC. Developers comply with regulators and work with local jurisdictions to get their projects approved. With IC, this means that developers and local regulators need to collaborate closely to navigate nuances that do not show up with conventional construction, and bridge coordination and understanding with state regulators who oversee modular building codes. Education and marketing is key—successful IC developers and builders often speak about their experience to state code associations, local offices, and the International Code Council (ICC).

IC is still not commonplace across the U.S., and the relationships between stakeholders in many ways differ from those in conventional construction (see section IV). Figure 5 is a distillation of information gathered from stakeholder interviews and provides a closer look at the stakeholders involved within each of these categories with an emphasis on the production of industrialized housing. While not exhaustive of all the potential stakeholders nor all potential relationships involved in the IC housing production process, the depicted web reveals the high level of complexity that characterizes the IC ecosystem. This complexity often presents challenges when trying to align the interests of different stakeholders.

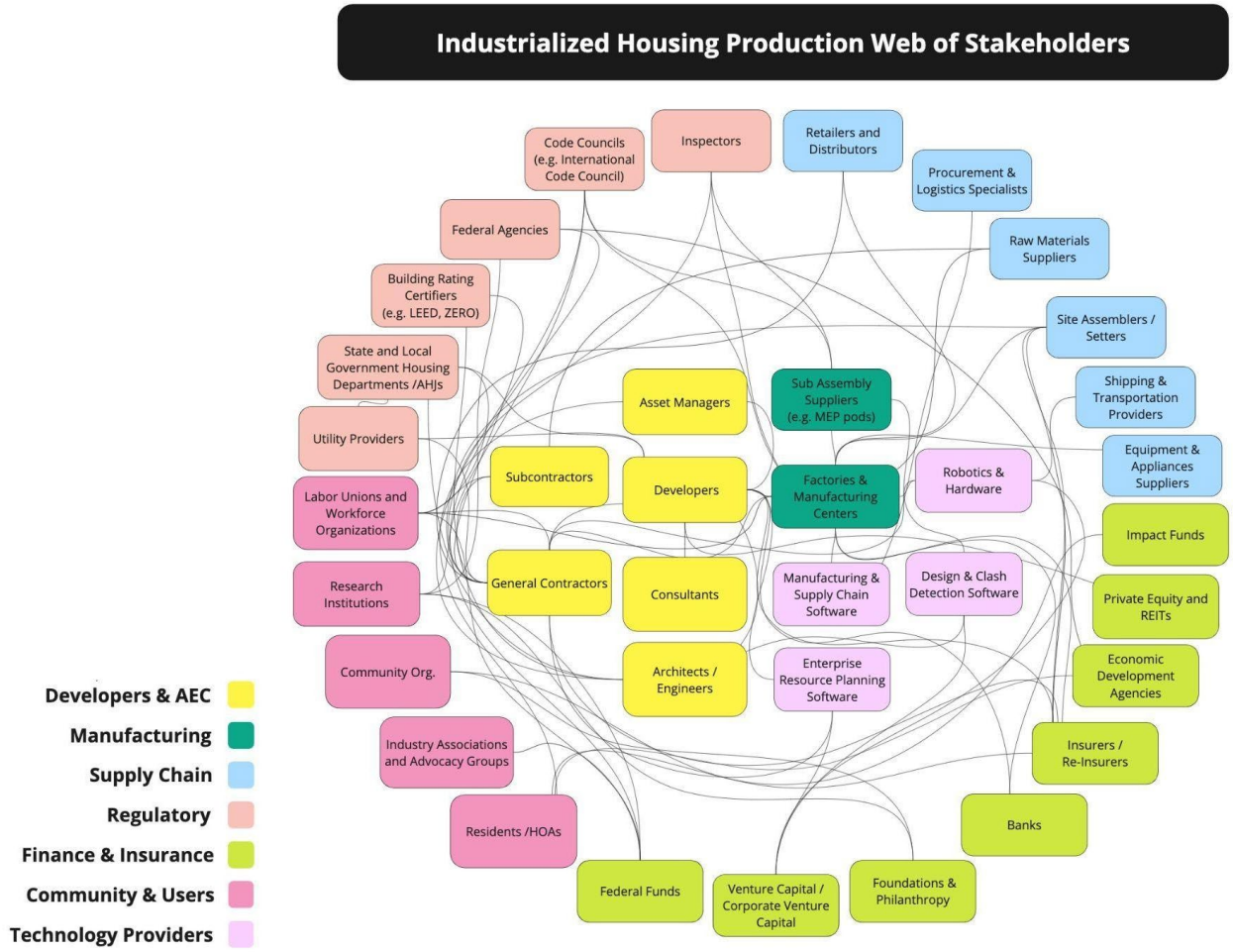


Fig. 6. An interpretation of the deeply complex web of stakeholders involved in industrialized housing production, color coded by stakeholder group. *As depicted, the ecosystem can be complex.*

Each of these nodes can create obstacles for proper implementation of IC for housing production: This reinforces the idea that *the biggest challenge in achieving widespread adoption of IC is a systems integration problem*. By working to more deeply understand how to interact across disciplines, we can better identify where bottlenecks occur and recommend how to restructure relationships and incorporate specific expertise to continue removing barriers to the adoption. Figure 6 emphasizes IC's need for a systems integrator whose skills include coordinating across the value chain (and whose position does not fall into any existing or traditional role of the AEC industry).

V. Industrialized Construction – Current Needs and Capabilities in Texas

To establish a thriving IC ecosystem, three core pillars are required: 1) a transition from a bespoke project-driven mindset to a product-centric mindset, 2) aggregated demand for factory-built structures to achieve economies of scale, and 3) increased capacity to manufacture, transport, and assemble structures. Also imperative for the realizing benefits of IC are a strong manufacturing base equipped with appropriate technologies, efficient logistics networks for transportation, and reliable supply chains.

Texas's geography and transportation networks create a unique opportunity for IC. The "Texas Triangle" (Austin, Houston, Dallas) is highly urbanized and connected to Mexico via the Monterrey-Texas trade corridor (Federal Highway 85 to I-35).[83] Laredo, a major port along this route, ranks as the top U.S. trade port by value, facilitating extensive import/export operations and enabling direct access of foreign goods and talent to Texas. Texas's 28 border crossings handle 68% of U.S. international trade, making it a prime location for the transport of building materials and modular components.[84] In addition to trade corridors over land, Texas is home to over 10 major seaports through which the state imports steel, construction machinery, forestry products, and other housing inputs.[85]

Understanding the importance of these trade routes, the Texas-Mexico Border Transportation Master Plan seeks to facilitate the movement of talent and materials across the border, providing the right ingredients for industries that revolve around manufacturing.[86] Manufacturing and logistics associations, such as the F50 Nexus, are leveraging this trade corridor to augment manufacturing capacity in the U.S. Partnering with such associations to support manufacturing-based construction could be crucial for establishing an IC ecosystem in the state. This focus on trade and manufacturing, combined with the state's growing need for housing, positions Texas as a potential leader in IC logistics and manufacturing.

[83] Monterrey: A Look Inside Mexico's NAFTA Capital
[84] International Trade and Border Planning, TX DOT
[85] AAPA Member Ports Map
[86] Texas-Mexico Border Transportation Master Plan, TxDOT

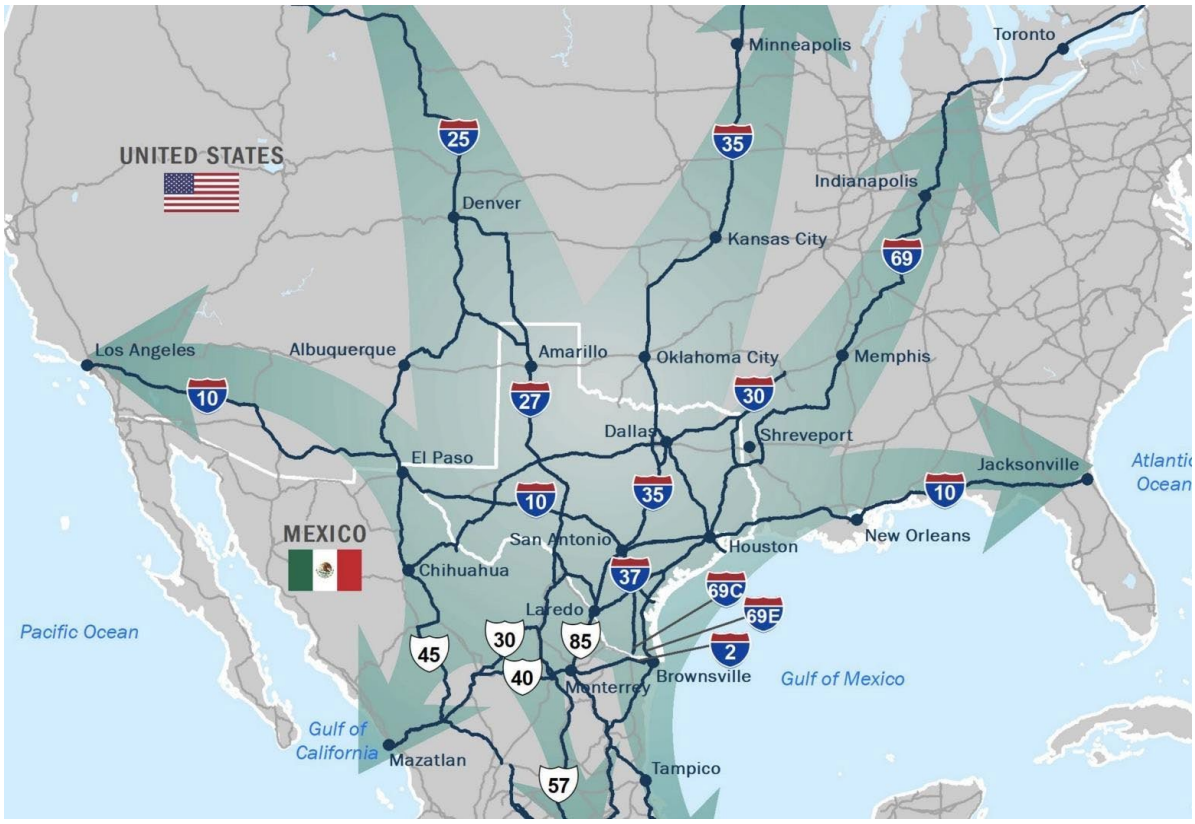


Fig. 7. Trade flow (via road) from Mexico through the US which show great potential for utilization by IC supply chains.

The presence of existing housing manufacturers and fabricators headquartered or with a significant presence in Texas further strengthens the state's potential as an IC hub (sharing resources, sharing suppliers). For example, Oak Creek Homes, which has a significant presence throughout the South, has been in business for over 50 years and has 100 different housing product offerings.[87] Pratt Homes has been building modularly for over 20 years and owns over 10 different building facilities throughout the state.[88] Clayton Homes[89] and Champion Homes[90] are the two largest manufacturers in the U.S. and both have significant operations in Texas—Clayton Homes owns eight factories and works with around 100 retailers throughout the state, while Champion Homes owns five factories and works with hundreds of retailers throughout the state. Almost all of these factories, however, produce manufactured homes (built to HUD code) and manufacturers that offer modular homes built to IBC/IRC code are harder to come by—or, according to one stakeholder we interviewed, "almost impossible." This has resulted in most modular developers currently sourcing

[87] Oak Creek Homes
[88] Pratt Homes
[89] Clayton Homes
[90] Champion Homes

their modules from out of state, bringing them in from places such as Oklahoma, Alabama and Kansas. To date, TDLR has certified 71 manufacturers[57] to produce modules and modular components across the state and has identified over 389 firms[58] in Texas categorized as "Industrialized Builders," which includes both HUD-code homebuilders and modular homebuilders who build to IBC/IRC code.

More recently, a large international firm (Admares)[91] has been looking to invest and build a 2 million square foot IRC-based modular factory in Texas, largely based on the long-term market and population growth in Texas. This follows a previous large investment by StudioBuilt by Amherst (The Amherst Group[92]) who converted a 300,000+ square foot facility to manufacture IRC-based build-to-rent housing. As more of these investments are made in the state, there will be further strengthening of the region's IC-based material suppliers, vendors, and general market awareness and adoption which continues to unlock economies of scale as conventional onsite construction transitions further into the industrialized construction space.

Texas's favorable business climate is drawing major companies and venture capital investment, setting the stage for growth in construction innovation. Large technology enterprises such as Oracle, Tesla, and HP Enterprise have relocated their headquarters to Texas, joining AECOM and CBRE, both of which moved from California to Dallas. Lower taxes, more business incentives, and greater flexibility in land use regulations make Texas attractive for industry growth. The state's investment ecosystem is increasingly aligned with construction innovation. Austin-based Ironspring Ventures, for example, recently launched a $100 million fund focused on construction tech, aiming to address key industry challenges such as material procurement, labor shortages, and operational inefficiencies.[93]

Industrialized Construction Technologies Overview

Following the categorization framework proposed by the Enabling Technologies for Housing Innovation Center in a separate published literature review, below we explore each of the IC technology categories and how the current Texas landscape applies to them. Texas. As shown in the figure below, it is key for IC stakeholders to know where certain technology interventions can play a critical role in the housing production flow.

In the proceeding section, we provide a high-level overview of different IC technologies. Although we outline each IC technology separately, it is important to note that a framework integrating many (or all) of these disparate products will be most effective in uniting stakeholders, thereby making the construction process more efficient.

[91] ADMARES Homes

[92] StudioBuilt by Amherst

[93] Contech backer launches second, $100M fund, Construction Dive

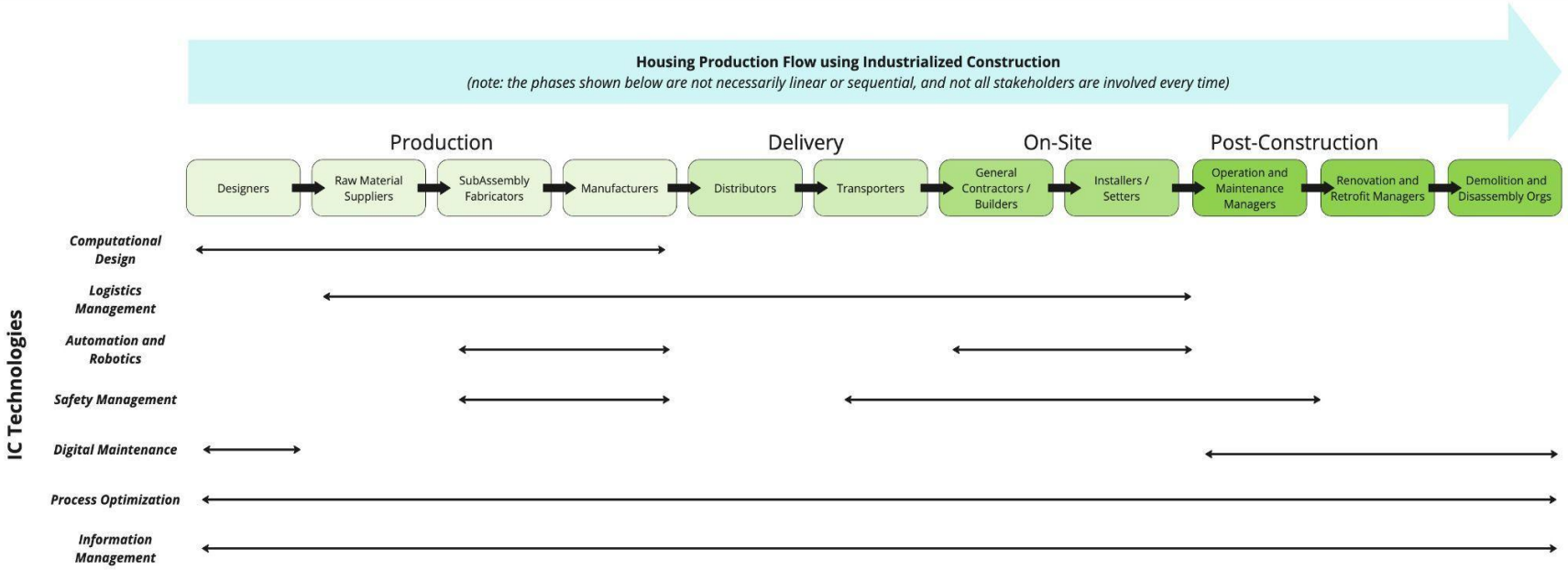


Fig. 8. Housing production flows using Industrialized Construction. The arrows indicate housing production stages where each technology category can likely make the most impact.

Computational Design

Computational design technologies empower architects and designers to create cost-effective, performance-optimized structures by utilizing digital tools and advanced algorithms. These technologies, which include parametric and generative design, enable designers to explore a wide range of options based on specific performance criteria. Parametric design refines choices within defined parameters, while generative design generates new solutions based on constraints. The tools allow project teams to balance complex requirements more efficiently than with conventional approaches, as well as optimize manufacturability and constructability from the onset of design.

Computational design can be a powerful enabler for IC, where precision and efficiency are critical. Properly implementing this design approach can help streamline production and make IC more viable by minimizing costly rework and accelerating project timelines. Companies such as Dallas-based Testfit simplify early-stage project feasibility by evaluating different project alternatives for a given site and assessing preliminary financial viability.[94] Another example is the City of Austin, which is using computational design to streamline plan reviews through its partnership with Archistar.[95] Given the complexity of Austin's land development codes, reviewing and approving building plans is a significant bottleneck, so Archistar acts as a digital "autocorrect" for the city's Development Services Department, speeding up approvals, facilitating design iteration, and ultimately supporting faster project delivery. The most high-impact computational design tools do not just provide architectural and engineering plans; they also help integrate stakeholders by creating manufacturing plans and digital files for construction, operations and maintenance.

Logistics Management

Efficient logistics management is essential for streamlining the complex network of stakeholders, material flows, and data that influence project timelines in IC. Advanced logistics solutions, such as real-time data analytics, optimization algorithms, and digital and virtual planning tools, enhance the housing production process. Improved logistics help with inventory control, manufacturing coordination, and delivery planning, which are critical when there is a factory that depends on consistent throughput.

Companies such as Austin-based StructShare are driving innovations in logistics management which can be leveraged for IC.[96] The platform integrates procurement, inventory tracking, and cost management, reducing material waste and improving cost accuracy across projects. Additionally, the data leveraged from this platform can be useful for the whole value chain, allowing key stakeholders such as developers and builders to make quantitatively informed decisions.

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[94] Testfit

[95] Archistar

[96] Structshare

Automation and Robotics

Automated manufacturing, robotic assembly at the factory, and robotic installation at the jobsite all enable efficient, high-precision production with decreasing levels of human intervention. Robotic systems can assist with lifting, positioning, and joining elements, as well as ensuring quality and reducing errors. These technologies can also enhance productivity, lower labor costs, and lead to safer, more accessible job sites. This makes them highly desirable for IC, where consistency and scalability are so essential. By standardizing processes, advanced manufacturing — including 3D printing — minimizes variability in the building product and accelerates project timelines.

Companies such as ICON, CyBe Construction, and Hive3D are advancing IC through 3D printing. ICON uses locally sourced materials to 3D print homes with reduced embodied and operational carbon.[97] In partnership with Texas A&M, CyBe Construction trains local workers to operate 3D printers,[98] expanding the skilled workforce. Houston-based Hive3D employs a carbon-neutral cement mix for diverse residential and commercial projects, including single-family homes, "tiny" homes, and commercial properties.[99]

Some solution providers are developing humanoid-type robots intended to perform a wide variety of tasks, while others are developing highly specialized robots intended to perform a limited number of tasks very well. Houston-based Rugged Robotics builds field robots that help address common challenges in construction layout and installation.[100] Their robotic systems replace manual taping and chalking, swiftly marking out the jobsite with part numbers, outlines, and labels for on-site crews. This innovation saves time and labor, supporting IC by streamlining onsite workflows, enabling higher levels of precision at the jobsite, and helping to identify errors before prefabricated components arrive at the site. Future applications for onsite robots and automation will likely include automated cranes that can assemble volumetric modules.

Safety Management

Safety is essential across all phases of IC production flows, from manufacturing to transport and onsite assembly. Technologies designed to improve safety allow teams to proactively anticipate hazards and implement mitigation plans, protecting both workers and end users. Workflow simulations and ergonomic risk assessments using reality capture and machine learning can help identify where personal protective equipment or task automation can prevent injuries. Furthermore, altering the sequencing of assembly or designing components that enable easier installation can prevent ergonomically unsound activities altogether.

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[97] ICON

[98] CyBe Construction

[99] Hive3D

[100] Rugged Robotics

Meritage Homes, for example, is an active builder in Texas that has partnered with Safesite to digitize OSHA compliance using real-time data sharing and transparent safety reporting to streamline safety protocols.[101] Kewazo, with its U.S. headquarters in Houston, uses robotics to improve safety in material handling, reducing worker exposure to high-risk tasks and enhancing efficiency on construction sites.[102]

Digital Maintenance

Digital maintenance leverages sensors, models, and data analytics to monitor the structural health of buildings, allowing renovation and retrofit managers to address maintenance needs proactively. By minimizing unexpected repairs, equipment downtime, and safety risks, digital maintenance benefits both occupants and property managers and is complementary to an IC paradigm where standardized building designs allow for manufactured components to be replaced and repaired over the lifetime of a building. Generalizable methodologies tailored to different building types and materials enhance the efficiency and lifespan of structures.

Companies such as Hexagon[103] and research institutions such as Texas A&M's MAESTRO Lab[104] are advancing digital maintenance technologies. Hexagon's digital reality capture solutions create detailed digital twins, enabling remote access to building information down to the component level, and reducing the need for on-site inspections. MAESTRO Lab is pioneering real-time structural health monitoring by embedding magnetic-sensing particles into metallic components to detect crack propagation, paving the way for future innovations in building maintenance and solutions that can be factory-installed when buildings are manufactured.

Process Optimization and Information Management

Process optimization technologies improve efficiency and reduce costs by streamlining the design, manufacturing, and construction phases of a project, while information management technologies support the timely sharing and retrieval of information. By employing data analytics, workflow automation, advanced planning tools, and centralized project data, these technologies help teams manage resources more effectively, predict project timelines, and minimize waste. Optimization software integrates with IC workflows to enhance coordination and allows manufacturers and contractors to reduce delays and make real-time adjustments based on project data.

In Texas, companies such as Richardson-based Projectmates provide cloud-based construction management solutions that automate workflows, schedules, and reporting.[105] Other common

[101] Safesite
[102] Kewazo
[103] Hexagon
[104] MAESTRO Lab
[105] Projectmates

industry solutions used by projects incorporating different degrees of offsite construction in Texas include Procore,[106] Autodesk Construction Cloud,[107] and Manufacton.[108]

VI. Conclusion

Analyzing Texas's housing production landscape reveals both the challenges and opportunities in addressing the state's critical housing affordability issues. Texas's strong demand for housing, driven by economic and population growth, is outpacing the existing production capacity, making IC a viable and effective approach to meet demand more efficiently and affordably. Although IC is still underutilized in Texas, the state's strengths in manufacturing, international trade, robust logistics networks, and favorable business climate offer a solid foundation for developing a thriving IC ecosystem.

Currently, IC adoption faces hurdles, including fragmented building codes, a shortage of IC-specific financing options, and industry resistance to technology adoption. However, growing interest in construction technology and increased spending in factories in the state together signal a readiness to modernize the homebuilding sector. Texas-based companies and institutions are already making strides in IC technologies, from robotics and 3D printing to logistics optimization, showcasing the state's potential to become a national leader in IC.

To fully realize this potential, Texas must invest in an integrated IC ecosystem that better aligns policy, financing, and education initiatives with the needs of IC stakeholders. Streamlining regulatory processes, increasing public awareness, and aligning financing incentives are critical next steps to address barriers to adoption. In terms of education and awareness, it is paramount that stakeholders across the housing production supply chain are aware of misconceptions and complexities of the IC ecosystem as proof of success is established and learnings are tailored to each stakeholder group.

The Enabling Technologies for Housing Innovation Center (ETHIC) at The University of Texas at Austin is uniquely positioned to lead this effort. Established as a U.S. Department of Housing and Urban Development (HUD) Hispanic Serving Institutions (HSI) Center of Excellence, ETHIC serves as a technological engine for shaping innovative products, policies, and people that provide affordable housing solutions. ETHIC's mission encompasses researching digital twin technology, developing an industrialized construction ecosystem for more affordable housing, reshoring American jobs, and creating new capabilities centered around a circular economy and supply chain resilience.

[106] Procore
[107] Autodesk Construction Cloud
[108] Manufacton

Through its multidisciplinary expertise and strong industry-academic partnerships, ETHIC is committed to aggregating, translating, and disseminating IC research into usable knowledge for practitioners, policymakers, and the broader public. By serving as a central hub for education, training, and technical assistance, ETHIC will help accelerate awareness and build the capacity necessary to scale IC across Texas and beyond.

Appendix - Example Modular Multifamily Projects

Robbins Place Modular Infill[109] - Designed by KRDB, Robbins Place is a missing-middle project currently in development in Central Austin.

Community First! Village[110] - In collaboration with Mobile Loaves and Fishes, ICON 3D printed a six-home community for people experiencing chronic homelessness in Austin, each 400 sq ft.

Cheatham Street Flats[111] - Completed in 2020, Cheatham Street Flats is a mixed-use housing building constructed using steel-framed volumetric modular. Z Modular out of Killeen manufactured the modules.

West Campus Lofts[112] - Clayton Building Solutions and Hayes Modular Group constructed this student housing project for Baylor University with strategies that complemented the site's adjacent historical building.

Tunnel to Towers Comfort Home[113] - Safe and Green Holdings along with Peak Modular constructed this home for homeless veterans in only 33 days using only one type of module.

[109] Robbins Place Modular Infill
[110] Community First! Village
[111] Cheatham Street Flats
[112] West Campus Lofts
[113] Tunnel to Towers Comfort Homes