Industrialized Construction for Affordable, Low-rise Housing using Cross Laminated Timber with Modular Bathrooms and Kitchens.

Part Two: Market Analysis and Product Selection

In the second installment reviewing our Industrialized kit-of-parts for market rate and affordable housing in Northwest Arkansas, we discuss the role of strategy and product selection in the set up of the Industrialized Construction program.

Market Context

Industrialized Construction (IC) programs tend to do best when they align with a broader structural change in an existing market. This should be seen in contrast to cyclical market changes, which are more short term and less fundamental. The structural change provides the IC program a longer payback duration and a well defined business rationale for the investment. The markets can vary widely, as defined by the individual IC customer, but the common thread in all cases is a fundamental change, requiring reconfiguring or acquiring built assets, at some scale and over an extended period time.

Some possible examples:

- A large multinational company, already an employer in a small but growing local economy, moves its headquarters to that area, mandating the relocation of staff within six months. The local region, already shifting from rural to suburban housing patterns, must now urbanize faster to meet surging demand. The ensuing change in the real estate market is catalytic.
- A retailer with a national footprint of existing stores plans to announce a major new business unit which will require new space attached to its locations. A multi-year coordinated rollout will be required. Store operations must not be disrupted.
- An owner/ operator organization of complex facilities has identified new, high growth geographic markets for its strategic expansion. ‘Speed-to-market’ is a critical metric of its execution plan. An internal real estate function, already extant within the enterprise, is tasked with site acquisition.
- A manager of a large portfolio of real estate assets requires upgrades and renovation due to aging and obsolescent systems. The modernization effort will standardize the most repetitive and expensive portions of the reinvestment in order to better manage unit economics.

Sometimes, the IC program *can* be localized to a single, sufficiently large or complex project. These cases are unique in that all of the demands made of the potential program will arise out that sole projects requirements and can be justified on that basis. Most often, the project team selected should have capability and experience with IC. This type of IC deployment should be carefully evaluated, with rigorous cost and quality assurance measures identified during planning phases.

In the case of the Northwest Arkansas Industrialized Construction Program, the scenario most closely resembles the first of the four examples above. The Northwest Arkansas (NWA) region is the 15th fastest metro region in the country, cracking the list of 100 largest regions in 2023. It has not one, but at least three major employers driving regional growth and, through numerous public and private initiatives, identified housing supply and quality as a top priority for managing growth.[1]

Alignment and Strategy

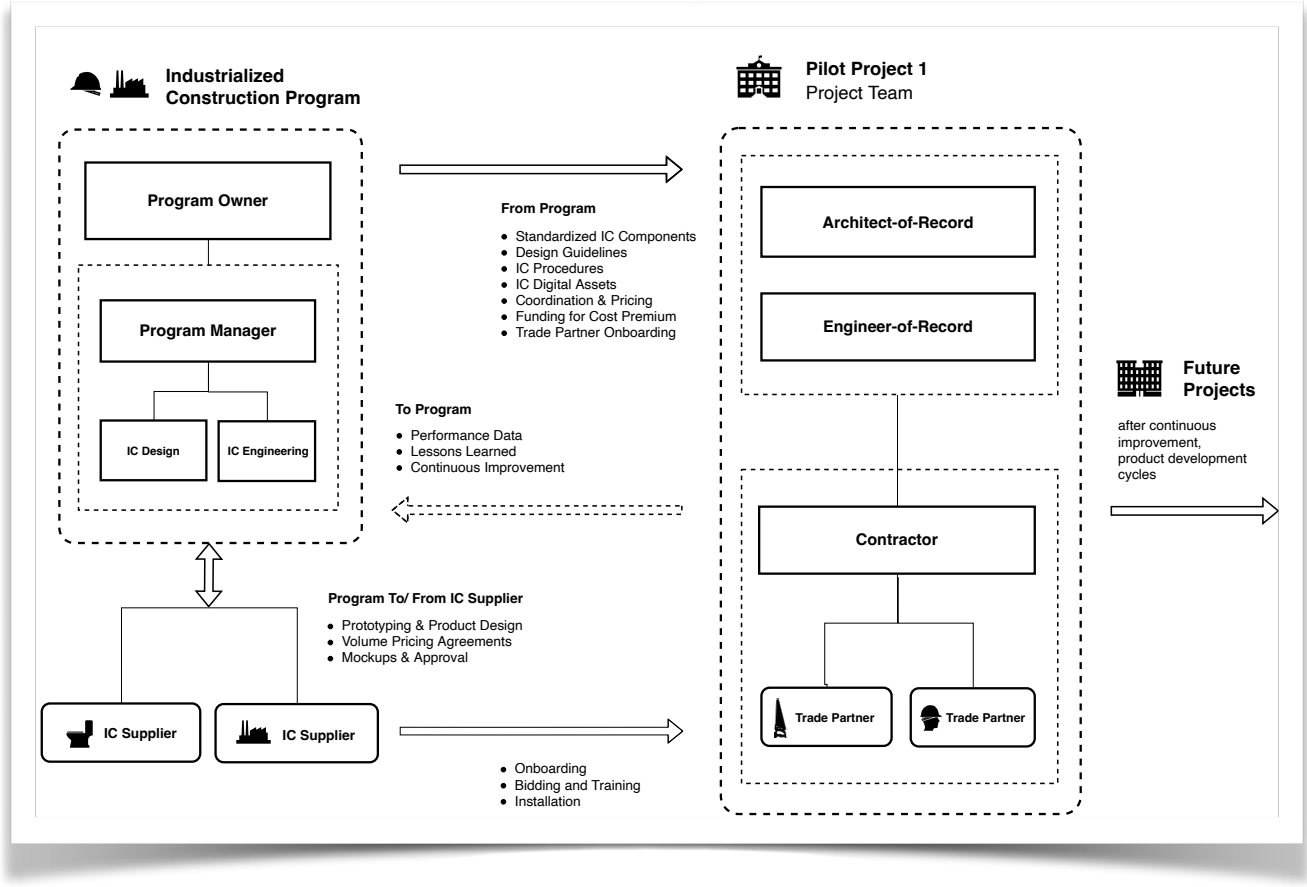
The expense and time involved in setting up an IC program will usually require a review process to ensure alignment. Typically, this is in the form of a report that can be presented to leadership for approval.

The report should contain:

- **Market Analysis:** Total addressable market for the IC products should be identified. The market can be internally or externally oriented with respect to the client organization. Analysis should include likely growth in demand and shortfalls in supply that necessitate the need for IC. Expected cost escalation and historical price volatility can provide important context.
- **Owner Criteria:** The IC program must reflect the goals of the owner organization. IC Products should be tailored to the customers specific functional needs and experience. Secondary goals such as sustainability, efficiency and design quality will help define the program and need to be well understood by the IC team.
- **Program Structure:** An organizational structure showing approval, reporting and responsibility for the program functions should be developed. Responsibility for standards and IC product development should be clear. *Program* vs. *project* scopes of work must be differentiated (see below).
- **Go-to-Market Roadmap:** A phased approach for implementing IC should be outlined. Likely IC product vendors should be identified where possible. The cost and risks of building a new plant may be part of the roadmap, with clear target production volumes that can be compared to the market analysis included. Early phase milestones such as mock-ups, product design iterations and pilot projects will be important markers along the way. Performance thresholds and off-ramps for owners and stakeholders should also be considered. Minimum production and pain thresholds will be important indicators.i
- **Proposed Product Mix:** The diversity and type of Industrialized Construction product envisioned should be presented. There should be a clear rationale behind the type of product selected and its suitability for the given application. The level of standardization and amount of variation needed for each product selected should be identified (see below). An estimate of total IC content as a percentage of the whole can be a helpful benchmark.

Program and Project

The diagram below, based on the Northwest Arkansas IC program, illustrates a potential relationship between the IC program and the building project. In this case, the IC program resides within the owner/ operator/ developers organization.



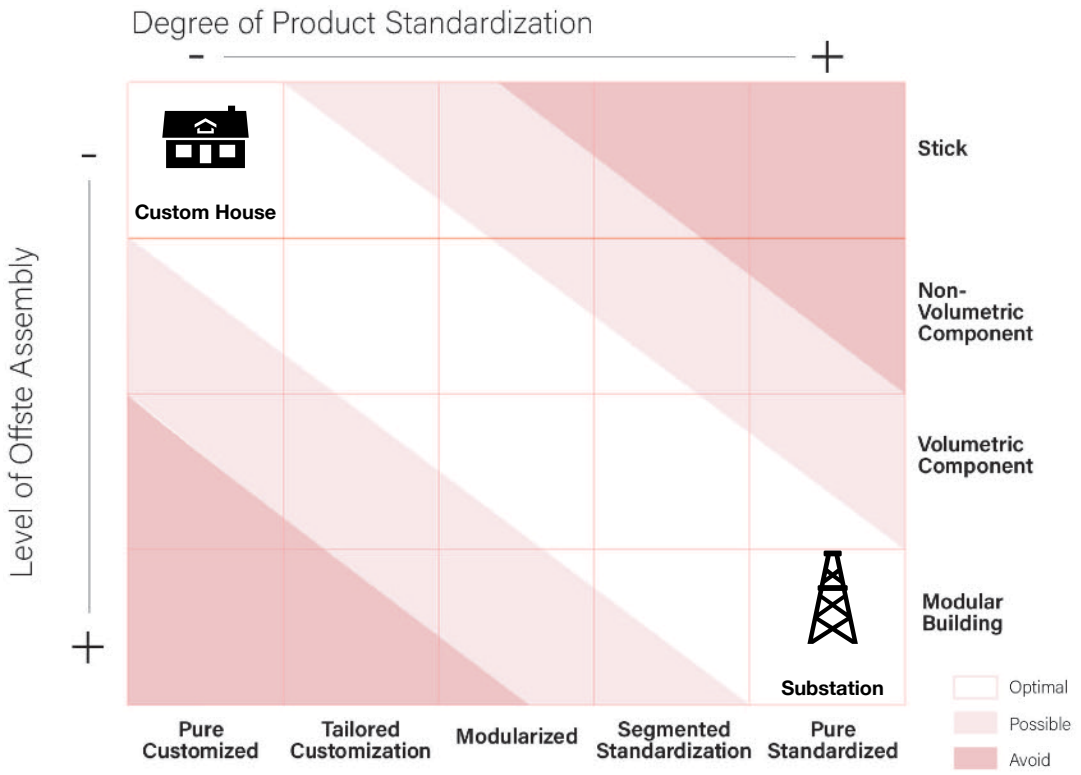
The program is responsible for the overall IC strategy, execution and supply chain. Design and prototyping functions for IC products are run from within the program, independent of project activity. This allows the owner the flexibility to contract with any number of AEC firms across multiple projects, while deriving benefits from an ongoing continuous improvement program. IC component vendors, like bathroom and panel fabricators, contract directly with the program, enabling it to negotiate agreements and develop standards prior to any work beginning on a project.

Standardized designs and content are developed within the program and then packaged for use be the project design team. Standard operating procedures, trade partner onboarding and best practices are developed by the program for use by the contractor and installation teams. Performance data, lessons learned and product improvement ideas are collected from the project and centralized by the program for use in future project and product development cycles.

Product Selection

A helpful framework for thinking about an IC investment is to visualize it as a set of products sitting somewhere on a spectrum, spanning fully customized on one end, and completely standardized on the other.

See the diagram below:



This framework is derived from a series of papers by Henric Jonsson and Professor Martin Rudberg of the Department of Science and Technology at Linköping University in Sweden. [2]

Any potential IC 'product' has an optimal level of standardization determined by how much design flexibility is required. The horizontal axis represents the amount of standardization needed to meet market expectations. On the extreme left would be bespoke products like a custom luxury home and on the opposite side of the axis would be a highly standardized structure, such as an electrical substation.

The level of product standardization is best paired with one of four possible products types, shown on the vertical axis. A modularized structure, such as found in a substation, would be most ideal if it was highly standardized with very little design flexibility from site to site. A one-off premium custom home, with a lot of unique and site specific elements, should in most cases be delivered with the lowest degree of offsite assembly. The matrix also works for ‘sub-products’ such as panels and bathrooms.

Customer Criteria

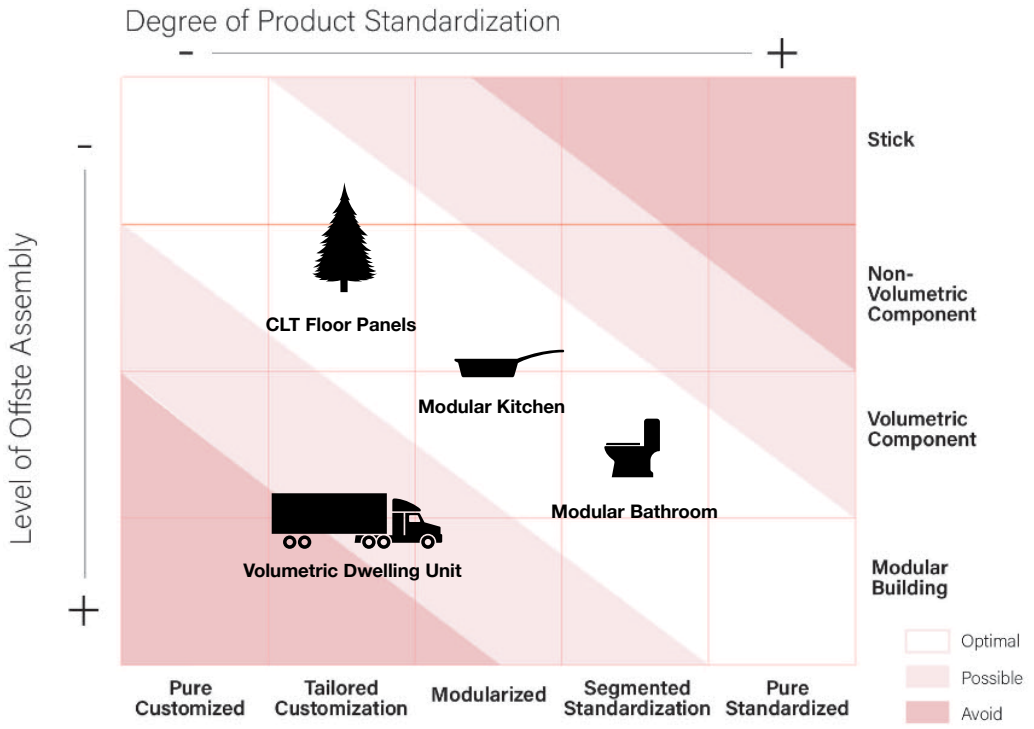
The IC customer will require a level of flexibility in the design of the IC products, based on their value proposition. Some will require the ability to offer a wide array of unit layouts, but are comfortable limiting bathroom designs. There may be an emphasis on finish, or durability or other attributes depending on the market. The customer will have a number of these objectives to consider.

In Northwest Arkansas this included:

- **Use of Mass Timber and SYP:** An interest in using Mass Timber, especially southern yellow pine, due to the importance of forestry industries in the regional and state economy. Local sourcing would also reduce the carbon footprint of the development
- **Emphasis on Design Quality and Variety:** Customers brand is oriented to affordability, sustainability and a higher level of design quality for their properties. The developer worked with a number of different architectural firms. Multifamily projects in their portfolio were highly site specific and varied in scale and type.
- **Capacity Constraints:** The local construction market is highly supply constrained. A large backlog of units is needed to support the regions growth.
- **Priority on Sustainability:** The developer prioritizes sustainable design and development. Any solution proposed had to contribute to the overall sustainability of any project.

Product Mix

The diagram below represents the results of our analysis for the IC program in NWA, with notes following:



- **Volumetric Dwelling Units:** This refers to a complete enclosure for a section of the building, delivered by truck and stacked vertically. Using this type of module would have overly constrained the design freedom for Blue Cranes architectural teams and limited the IC program to developments that could support the minimum production runs required. Few potential suppliers within delivery range.
- **CLT Floor Panels:** CLT Floor Panels were found to be economical if standardized to a few sizes and manufactured at high volumes. The standard sizes, while imposing *some* constraints on the design team, would be flexible enough to accommodate a wide variety of unit configurations and sizes. Sourcing a southern yellow pine panel also satisfied an owners criteria.
- **Modular Kitchens:** Modular Kitchens afford a high level of design flexibility for the customer. Suppliers, options and styles are widely available.
- **Modular Bathrooms:** A few standardized designs and options could service a wide variety of unit plans. Potential for strategic sourcing of fixtures and finishes. Well established supplier network within delivery radius.

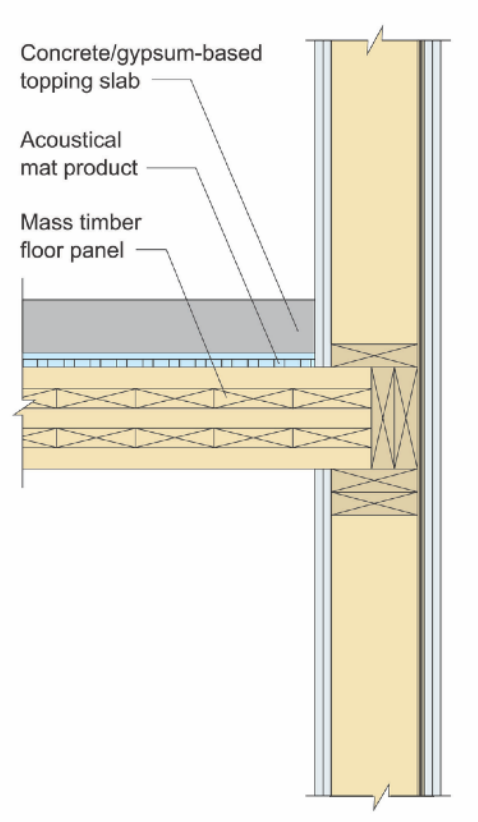
Hybrid System

The mix of IC products selected also reflects use of a **hybrid structural system** which a combines CLT floor system in the horizontal axis, with a load bearing stick framed wall system in the vertical axis. [3]

These elements are selected for their economy, simplicity and speed. When used in the right combination, the advantages each component type offers are amplified while disadvantages are managed or eliminated through the use of complimentary systems. In this case, the utility and availability of stick framed walls is paired with the large formats, sustainability and visual quality of the CLT floor deck.

Panelized or light gauge wall systems can also be used in lieu of wood stick frame. These alternative were unavailable in the NWA market. The program will continue to investigate panelized wall systems for this application.

The use of a topping slab on this system also pairs well with modular bathrooms, since the topping can be used to level against the modular bathroom floor. Leave-outs and penetrations can be pre drilled into the CLT panel at the plant, reducing on-site installation durations.



Top: Typical Section, Hybrid CLT Structure (Woodworks)

Next: Vendor Selection and Component Design

[1] Sparkman, Worth. “Northwest Arkansas' stunning — yet sometimes painful — reinvention.” Axios, https://www.axios.com/2023/09/12/nwa-northwest-arkansas-population-growth-moving-austin. Accessed 13 March, 2024

[2] Jonsson, H. and Rudberg, M. (2015), “Production system classification matrix: matching product standardization and production-system design”, Journal of Construction Engineering and Management, Vol. 141 No. 6., DOI: https://doi-org.e.bibl.liu.se/10.1061/(ASCE)CO.1943-7862.0000965

See also,

Henric Jonsson & Martin Rudberg (2014) Classification of production systems for industrialized building: a production strategy perspective, Construction Management and Economics, 32:1-2, 53-69, DOI: https://doi.org/10.1080/01446193.2013.812226

And

Jonsson, H. and Rudberg, M. (2017), "KPIs for measuring performance of production systems for residential building: A production strategy perspective", Construction Innovation, Vol. 17 No. 3, pp. 381-403. https://doi-org.e.bibl.liu.se/10.1108/CI-06-2016-0034

[3] For more please see:

“Hybrid Design: Mass Timber Floor and Roof Panels Over Light-Frame Wood Walls.” Woodworks, https://www.woodworks.org/resources/hybrid-design-mass-timber-floor-and-roof-panels-over-light-frame-wood-walls/. Accessed 13 March, 2024