SUCCESS AND FAILURE IN INDUSTRIALIZED PREFABRICATED HOUSING IN NORTH AMERICA

MICHAEL J. OBRIEN

[1]*Department of Architecture, Texas A&M University, College Station, Texas, U.S.A.*

Prefabrication and modular production of housing is one of the oldest "new topics" in architectural discourse. Prefabrication in North America has been underway continuously since the 17th century. It flourishes in economic booms in remote locations, and as an interim solution to disaster relief, but unlike the giants of the automotive industry, innovators in residential prefabrication seldom succeed, or endure. This research is about using the historical record to understand the characteristics of failed and successful residential prefabrication systems. A literature search was undertaken to identify the key professional publications and governmental programs impacting the topic. Professional Journals, Federal reports, and books published by prefabrication advocates were examined for the answer to "what happened to housing prefabrication as a mode of residential construction innovation? I discovered that proprietary package systems or kits employing non-wood-based materials and connectors required sophisticated industrial tooling, management and production/ shipping methods that cannot be successfully amortized in the competitive residential construction market. Perhaps the most important discovery was that compatibility and extensibility within the residential building culture are the key indicators of longevity/success in the marketplace.

Keywords: Prefabrication, Housing, Paneilization, Modular Construction, Industrialized Housing.

1 INTRODUCTION

Prefabrication in North America began as early as 1633, driven by the rush for the fur trade, the need for rapidly-constructed shelter, and the need for shelter robust enough to withstand harsh winters as well as small-arms and arrows drove William Holmes to load his ship with lumber "ready cut and fitted" (Nelson 1975) and sail it upriver of the Dutch fort at Hartford. Holmes understood the risks brought by both the countryside, and its current occupants and used prefabrication as a key strategy to establish a foothold in the lucrative fur-trading market. Holmes choice of planks and mortise and tenon framing members was not particularly innovative. The first houses at the Plymouth colony built in 1620 were very similar. Holmes's innovation was loading the parts on a ship to rapidly deploy shelter once the crew landed at present day Windsor CT.

Rapid modes of construction have ever thus defined the historic "boomtown" beginnings of settlements across North America. Boomtown construction methods often included other industrialized forms of prefabrication for early shelter (Kelly 1951) i.e. panelized (sectional), modularized and "mobile" solutions in over the precut approach to rapid construction. As the boomtown economy matured, these more "shipping intensive" forms of construction were often deemed more costly than the use of locally produced lumber and masonry.[1]

Today, housing in the rapidly expanding oil-field towns in the Baaken Shale areas in North Dakota, the Permian Basin, and the Eagle Ford areas in Texas are dominated by the mobile and manufactured housing prefabrication strategies introduced in the interwar years 1919-1938 and postwar years 1945-1964 that are characterized by even less in-field assembly than the precut, and sectional strategies that dominated the 18th and 19th century prefabrication options. This period of time was considered the golden era of prefabrication by the Alfred Bemis Foundation.

Burnham Kelly reported for the Bemis Foundation in 1951 that there had never been more options in prefabrication or more firms offering prefabricated systems than at any other time in history. The interwar and postwar years were rich with industrial capacity being redirected from national defense towards housing, there was a huge demand for housing, particularly affordable housing for returning veterans, and an ample supply of entrepreneurs filled with a "can-do" spirit who were focused on solving the housing problem in America.

2 PREFABRICATION TYPES

The producers of prefabricated housing generally use one of the following strategies:

1. Precutting, a method using common wood materials (studs, joists, rafters) prepared for assembly by cutting, drilling, etc, and labeled for installation in the proposer location. 1624 to present.[2]

2. Systems or "Package" homes, a proprietary method using parts and connectors designed for multiple roles (walls, partitions, floors, etc.) with the express purpose of allowing a high degree of flexibility, in form and

[1] Kelly, B. (1951). The prefabrication of houses. The Prefabrication of Houses. New York, New York, The Alfred Farwell Bemis Foundation. Pp 8-11.

[2] Schweitzer, Robert and Davis, M. America's Favorite Homes: Mail-Order Catalogues as a Guide to Popular Early 20th-Century Houses, Wayne State University Press 1990. Pp. 37. References Edward Winslow's "Great House" at Cape Ann, Massachusetts, and subsequent precut frames shipped with colonists moving from the Plymouth Colony to Connecticut in 1630.

layout to achieve a diverse set of outcomes tailored to individual needs. 1920 to 1960's.

3. Panelized or sectionalized, larger preassembled components (walls, partitions, floors, roofs) which are designed to be assembled in a predetermined way, to make a specific design for a house. Panels may be open, allowing field installation of insulation, systems and finishes, or closed panels, complete with finishes and systems. 1820s to present, SIP variants, 1930's to present.

4. Modular, TVA secional and demountable, large, structurally independent assemblies of floors, walls, and roof, often with interior finishes preinstalled, transported on, and subsequently removed from road going trailers at the installed site. This system is also called a modular system, which today is fully International Residential Code (IRC) compliant construction. 1930's to present.

5. Mobile, developed in parallel with the sectional/demountables and distinguished from same by the mobile units dependence on an integral roadworthy steel chassis, to which wheels were attached. Following the passage of the National Manufactured Housing Construction Safety Standards (also known as the HUD code) in 1974. 1920's to present.

These strategies are the primary approaches to prefabrication and are significantly represented in the historical record (Raskin 1936) (Bruce 1945) (Kelly 1951). They continue to be represented in the contemporary North American housing market (MHI 2014). What has changed over time is the degree of interoperability in materials and production methods between the prefabricated systems and the site built and do-it-yourself market.

2.1 Looking back at a diversity of systems and materials

In 1936, Eugene Raskin published an article describing and illustrating 48, systems of prefabrication (Raskin 1936). The systems illustrated represented the best thinking in precut and panelized systems at the time. No modular/mobile solutions were illustrated there even though the Tennessee Valley Authority had built hundreds of mobile sectional houses for its worker communities at the Norris Dam. In this same issue of American Architect and Architecture the editorial by Kenneth K. Stowell derided the mobile delivery of housing, proposing it as a threat to the system of land investment and mortgage banking, as well as to the economic and political stability of every town and city in America. Effectively, Stowell was equating the mobile/modular approach to prefabrication to a threat to America and the American way of life and thus omitted it.

Raskin's article featured prefabrication systems were mostly produced by materials manufacturers (80%) and few by architects, engineers, inventors or government agencies. Burchard, in his introduction to the Alfred Bemis Foundation survey on American Prefabrication, (Kelly 1951) noted that manufacturers were very serious about prefabrication as a strategy to boost sales of their products/equipment in a stagnated post-depression housing economy. Reviewing the manufacturer-developed systems, it was as if each manufacturer said "perhaps if we used (fill in any material name here) i.e. asbestos for everything the consumer would prefer and purchase the house because it was sole-sourced for materials and production."[3]

Given this "package" approach, almost all the prefabricated systems illustrated in the architectural press during the 1930's through the postwar years can be considered "closed" systems, that is, a system that is not extensible outside of its proprietary set of components. Of all the 48 systems in Raskin's survey, and the 80 systems included in Kelly's survey for the Bemis Foundation, fewer than 20% might be considered extensible by a homeowner working with materials and components readily available in the market.

Operation breakthrough was the next postwar push for innovation in housing design and production in the United States using an aerospace model (and subcontractors) of procurement and management 2,800 units were constructed on 9 sites across the country. (Jazairy 2011) Operation Breakthrough's participants were primarily focused on mobile and or modular / mini-modulars (prefab kitchen/bath) construction practices in steel, wood, concrete, and honeycomb plastic panels. The 1970's program was an effort to leverage similar procurement, management and technological partnerships that had made the lunar landing successful in 1969. Key participants in Operation Breakthrough later noted that the solving the problems of urban systems were much more difficult than going to the moon. A 1976 assessment of the program by the Government Administration Office (GAO) noted that the program had succeeded in raising awareness of the need for more unified building codes (leading to the Federal Manufactured Home Construction and Safety Standards, the HUD code) to facilitate the use of new materials and selling the prefab systems in more market areas, but overall the program failed to "create the large continuous markets necessary for efficient industrialized housing construction" [4]

2.2 Failures and Successes in Prefabrication

[3] Burchard writes "the manufacturer of conventional building materials wonders whether he may not sell more of these by making them into some sort of package: …a president of a national corporation faced with depression may look to it as a new industry to lead (their organization) from the morass…" Kelly, B. (1951). The prefabrication of houses. The Prefabrication of Houses. New York, New York, The Alfred Farwell Bemis Foundation. Pp. viii.

[4] GAO report on Operation Breakthrough, 1976, p. 16.

Of the 48 *proprietary* systems of prefabrication described in the Raskin 1936 survey, the subsequent 80 studied by the Albert Bemis Foundation in 1951 and the 22 funded through Operation Breakthrough, none are in production today under the corporate banners that initially promoted them. This is likely due to a combination of technical, environmental and financial concerns as the initial investment in space, tooling, labor, design and materials is typically higher with prefabrication systems than the cost of a magnetic sign for a pickup truck, articles of incorporation, and hand tools needed to begin a site-constructed home.

Material innovation is well represented in this group of proprietary systems, houses made with asbestos, asbestos-cement, magnesite, gypsum, steel, concrete, fiberglass, aluminum, phenolic resins, and wood abound. The material innovation aspect is perhaps the least successful of all aspects of prefabrication. The Ambler Asbestos house, of course, is not in production today due to the health and environmental costs of its primary material, but steel and concrete pose no such risk, why did they not succeed in the prefabrication of houses as they have in commercial construction? One significant reason is the focus on the single family detached type of prefabricated house. Concrete, whether cast on site as Thomas Edison proposed, or precast as Grosvenor Atterbury, Moshe Safde and numerous others proposed will always require sophisticated (expensive) equipment to produce it, will mostly suffer from high thermal conductivity, (which can be compensated for with mass), and will not be easily adaptable/modifiable by the do-it-yourself homeowner. Concrete remains a strong contender in the mid to low-rise multifamily housing markets in the U.S. The production equipment, its difficulty in modification, and high weight to surface ratio will continue to be a challenge for prefabrication.

Steel, which takes the most significant investment in tooling to stamp, shape, and coat offers the advantage of low weight for many of the housing system components. When coated with porcelain-enamel, provides a lifetime finish. Steel prefabrication systems struggled with condensation control since their inception. The only semi-successful prefabrication system using porcelain-enamel steel was the Lustron home, which completed over 2,400 units of housing across the U.S. The Lustron wall panels were equipped with a mineral-fiber batt that helped keep the condensation and thus corrosion within the wall to a minimum. The Lustron system is a closed kit of parts. No adaptation or modification is designed into the system. Expansion or growth is only possible through the sale of one model and the owner moving into a larger model. It is estimated that 2,000 or so Lustron homes survive today, primarily as historic properties but still habitable.

Many of the *strategies* employed in this historical set of prefabrication systems are, in fact, in use today. The Forest Products Laboratory developed the most important prefabrication system in the 1936 publication. It employed stressed-skin wall panels, large enough to make residential spans, but small and light enough to installed by 3-4 people. These load bearing wood panels were the forerunner of todays Structural

Insulated Panels (SIPS) that today offer the builder the speed of installing one component that can replace dozens, and offer the homeowner a highly insulated structural enclosing shell that can still be modified and added to with simple tools.

Perhaps the next most consequential strategy would be the panelized approach to both walls and roofs. So called "sectionalized" buildings dating back to Lyman Bridges prefabricated home and school presented in Paris at the Exposition Universelle in 1867 and the popular Hodgson portable houses (Darnall 1972) are the forbearers of todays panelization strategy. Wood panelization as we know it today requires a modest investment in capital for layout and production, ships relatively simply compared to larger component approaches, and speeds the erection of the enclosing shell of the house, while employing materials and connections that are compatible with and extensible through the do-it-yourself residential building culture. This was successfully demonstrated in the Missouri-Farms project of the later 1930's where unemployed and relatively unskilled farm labor produced a set of building components, walls, trusses, privies using industrialized prefabrication methods in an outdoor factory, and then to pick the appropriate wall, door, or window panels and roof trusses for field assembly by a similarly unskilled crew.

The final successful strategy would be the modular/mobile home, particularly when designed to blend in to the neighborhood rather than stand out as the flat roofed modules used by Paul Rudolph in the Masonic Gardens project or Safde's Habitat 67 project. Aesthetics that meet the market allow for the quality and performance-enhanced modular to rise in value without challenging the aesthetic expectations of potential buyers.

3 Conclusions

However misguided, however its origins and ideals have been mangled through unrelenting suburban sprawl, ownership of the detached single-family home structure remains a central component of the American Dream. As our contemporary building culture considers industrialized and prefabricated single-family housing, they might do well to:

1. Use materials and connectors that can be modified/extended by the owner. Thirty-year mortgages mean multiple families with varying needs for space over time will inhabit the house. A "do-it-yourself" friendly system is the key.
2. Avoid proprietary materials and methods, the house, as an investment tool and primary wealth-building process for many middle and lower-income families needs to be as similar as possible to the market to retain its ability to be rapidly resold.
3. Avoid experimental aesthetics. Distinction of design in the marketplace is frequently an impediment to rapid resale. Safde, Rudolph, Gropius, Byrne, each associated an modernist aesthetic with their system and introduced the system into markets that remain resistant to non-traditional aesthetics to this day.

Appendix A.1 Prefabricated Systems in 1936

The wood, metal, or plastic frame and panel systems presented by Raskin include:

1. Ambler Asbestos Building
2. Enterlocking House
3. Bossert House
4. Forest Products Laboratories House
5. Superior Home
6. General Houses
7. Copper Houses, Inc.
8. American Houses, Inc.
9. Berloy Houses
10. Corkansteel House
11. Crowe House Construction
12. Ferrocon Corporation House
13. Phemaloid Compound Lumber House
14. Insul Steel Corporation
15. Novelle System of Construction
16. Rostone House
17. Steel House, Inc.
18. Stran-Steel House
19. Structo House
20. Van Ness Steel Houses
21. Buell House
22. Gropius House
23. Winter House
24. Luri House
25. Palmer House
26. Porcelain Steel House
27. Neutra Diatom
28. "E" Frame House
29. Swan House
30. Unit Panel Construction Systems House

The concrete systems included:

31. Connecticut Precast House
32. Dextone Self-Centering Wall System
33. Earley System
34. Hahn Concrete Lumber System
35. Lockwood System
36. Rockwood Gypsum House
37. Rackle System
38. Underdown System of Reinforced Concrete Structures
39. Byrne House
40. V.D.L. House

And the frameless houses included:

41. Frameless Steel House
42. Lindsey House
43. Steelox House
44. Lindberg House
45. Wheeling House
46. Universal House
47. Wudnhous
48. Stockade House

(A.2)

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