Research into Modular Construction

Spring 1972

Richard L. Tash

University of Central Florida

Find similar works at: https://stars.library.ucf.edu/rtd

University of Central Florida Libraries http://library.ucf.edu

Part of the Engineering Commons, and the Environmental Sciences Commons

STARS Citation

Tash, Richard L., "Research into Modular Construction" (1972). Retrospective Theses and Dissertations. 35.
https://stars.library.ucf.edu/rtd/35

This Masters Thesis (Open Access) is brought to you for free and open access by STARS. It has been accepted for inclusion in Retrospective Theses and Dissertations by an authorized administrator of STARS. For more information, please contact lee.dotson@ucf.edu.
RESEARCH INTO MODULAR CONSTRUCTION

BY

RICHARD L. TASH

A Research Report Presented in Partial Fulfillment of the Requirements for the Degree
Master of Science in Environmental Systems Management

FLORIDA TECHNOLOGICAL UNIVERSITY

June 1972
# TABLE OF CONTENTS

I. INTRODUCTION .......................................................... 1
   Purpose and Scope .................................................. 1
   Definitions .......................................................... 1
   History ............................................................... 2

II. PRESENT DAY MODULAR CONSTRUCTION .............................. 6
   Wooden Construction ................................................ 9
      General ............................................................. 9
      Availability ..................................................... 10
      Size .............................................................. 11
      Economics ......................................................... 11
   Concrete Construction ............................................. 12
      General ............................................................. 12
      Availability ..................................................... 15
      Size .............................................................. 15
      Economics ......................................................... 18
   Metallic Construction .............................................. 19
      General ............................................................. 19
      Availability ..................................................... 20
      Size .............................................................. 20
      Economics ......................................................... 24
   Plastic Construction ............................................... 26

III. ADVANTAGES OF MODULAR CONSTRUCTION ........................ 27
   Availability ........................................................ 27
   Economics .......................................................... 28
   Utility ............................................................... 32

IV. FACTORS CONSTRaining THE EXPANSION OF MODULAR
    CONSTRUCTION ....................................................... 35
   Technical ............................................................ 35
   Economic ............................................................ 36
   Social/Political .................................................... 37
   Marketing ........................................................... 38
V. FACTORS TO BE CHANGED TO ENCOURAGE MODULAR CONSTRUCTION

Technical ............................................. 39
Economic ............................................. 39
Social/Political ...................................... 40
Marketing ............................................ 44

VI. EAST CENTRAL FLORIDA ............................................. 49

VII. CONCLUSIONS ............................................. 53

SELECTED BIBLIOGRAPHY ............................................. 55
### LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Projected Difference Between Nations Housing Requirements and Conventional Construction Rates</td>
<td>7</td>
</tr>
<tr>
<td>2.</td>
<td>Relationship Between Number of Wood Module Dwelling Produced and Cost per Square Foot</td>
<td>13</td>
</tr>
<tr>
<td>3.</td>
<td>Relationship Between Number of Metal Module Dwelling Units Produced and Cost Per Square Foot</td>
<td>25</td>
</tr>
<tr>
<td>4.</td>
<td>Yearly Hourly Wage Increase of Construction Industry and All Other Industries</td>
<td>30</td>
</tr>
<tr>
<td>5.</td>
<td>Additional Number of Dwelling Units and Hotel/Motel Rooms Required in East Central Florida vs. Year</td>
<td>52</td>
</tr>
</tbody>
</table>
I. INTRODUCTION

Purpose and Scope

The purpose of this report is to examine the present-day concepts of modular housing design and construction, and to identify technical, political, and social factors which stimulate or retard the uses of modular housing in the United States.

The scope of this report is restricted to consideration of permanent and semi-permanent dwelling structures of single or multiple unit design based upon materials and construction techniques currently in use. The scope of this report excludes mobile dwellings and also excludes materials and techniques which have not yet achieved general acceptance in the construction industry.

Definitions

1. Building Code: Technical requirements usually specified by state or local governments applying to buildings and building service systems to ensure safety throughout the life of the structure.

2. Single Dwelling: A unit constructed primarily for occupancy by a single family and generally isolated in structure on a certain parcel of land.

3. Multiple Dwelling: A unit constructed primarily for occupancy by a single family with units generally grouped to share certain service systems and building components.
4. Mobile Home: A manufactured dwelling unit characterized by being constructed on a trailer chassis and therefore being capable of being towed from place to place. The mobile home is generally not capable of meeting building code requirements for permanent or semi-permanent structures.

5. Modular Construction: Structures built or erected from one or more three-dimensional cubical or box-shaped units which frequently are completely factory finished. This broad definition is inclusive of single and multifamily dwelling units as well as hotel and motel units. It is limited to structures which are designed and fabricated to meet local building codes and other pertinent regulations for permanent installation.


History of Modular Construction

The covered wagon used in the Nineteenth Century western migration represents one of the earliest successful types of preconstructed dwellings in America. Mobile home production is the most organized and developed segment of the factory-built housing industry in America. Production of mobile homes has risen from a 1,300 unit output in 1930 to a 413,000 unit output in 1969. Mobile home manufacturers have gained a clear lead over modular housing developers in

---

establishing markets, defining product lines, and employing production line techniques to manufacturing operations. The factory built permanent dwelling field has not experienced the expansion and maturity that has been achieved in the mobile home area.

The origin of the factory built modular home is rooted in both the mobile home field and the field of conventionally constructed housing. Many mobile home manufacturers have produced and are producing a variant of their mobile homes for permanent or semi-permanent installation on a fixed site.

Conventionally constructed housing has set the marketing pattern for what the American home-buyer demands in a dwelling. Conventional construction using predominantly on-site processes allows extensive variation in owner options and the American buyer has come to expect diversity in options in housing purchase. Conventional construction has also, especially since World War II, made use of progressively more off-site manufactured components with cost savings which suggest that even more economies can be realized if complete dwelling units can be factory constructed.

A form of construction generally referred to as pre-fabricated housing has further demonstrated economies in home construction. It is fair to classify pre-fabrication as the immediate predecessor to modular construction. This type of building is characterized by materials and sub-assemblies arriving at the construction site in "kit" or disassembled (flat) form with assembly to be done on-site. Pre-fabrication should not be confused with modular construction since the
latter, as defined in this paper, is characterized by a three-dimensional factory built structure.

Pre-fabrication was the predominate type of industrial and commercial construction in Europe following World War II. The need for inexpensive construction capable of rapid completion eliminated the possibility of conventional construction and allowed many production techniques to be developed, especially regarding pre-cast concrete applications.

The trend has aimed for some time toward modular construction. In America, a significant impetus has been given to modular housing by the United States Department of Housing and Urban Development in their program Operation BREAKTHROUGH. Operation BREAKTHROUGH is a broad residential development program designed to resolve a multitude of problems in order to make available quality housing in large quantities. It aims to do this by utilizing modern design and technology, and through contemporary approaches to financing, marketing, land use, and management. Creating substantial local, regional, and perhaps national markets, BREAKTHROUGH is intended to demonstrate the extent of the potential demand and how it can be brought together with those capable of, and interested in, producing both housing and sites for housing. This program, begun in May, 1969, may be the pivot point around which the modular housing concept can be organized, developed, and given direction.

The modular housing industry in the United States has not yet developed general-case answers to certain key questions, such as:
1) Which processes should be in-factory and which should be on-site?

2) What type of purchaser options should be available?

3) How will costs of factory tooling be apportioned?

The lack of definite solutions to basic problems such as the above underscores the fact that the modular housing industry has yet to mature.

Under the guidance of Operation BREAKTHROUGH, design, site preparation, and construction of some 2,800 modular homes in nine locations is being undertaken. The experience gained through this project will add a great deal to the body of knowledge on modular construction and should provide industry with the impetus to progress in the most profitable direction.
II. PRESENT DAY MODULAR CONSTRUCTION

The Department of Housing and Urban Development in 1968 placed the nation's housing requirements at 2.6 million units annually for the next ten years. During the last several years, our annual production rate has ranged between 1.4 and 1.6 million dwelling units.²

The demand is obvious. Figure 1 is a predictive plot of the difference between the nation's housing requirements and conventional construction rates. Many manufacturers are entering the field of modular housing production. Anyone can build modulars, but not everyone can build modulars and make a profit. If the fatality rate of prior years is applied, only about 75 percent of the three or four hundred companies now in the modular field, most of them relatively new, will still be in business at the end of the next twenty-four months. Far more planning and risk of error goes into modular manufacturing than most people realize.

The newcomer will learn that he has all the problems of a manufacturing business plus those of a new industry striving for volume production and public acceptance. Also, he must learn that the mechanics of modular design and manufacture are far more intricate than those of conventional structures. Tolerances are finer, errors are more costly and planning is less forgiving.

²Ibid., p. 89.
Fig. 1—Projected Difference Between Nation's Housing Requirements and Conventional Construction Rates
At the start, a sizeable capital investment is required. It can easily be misspent. A thorough market study must first determine the type of product and size of the market. Next comes establishment of an organization and the engineering of a plant capable of maximum efficiency and economical flow and production. Flexibility in these areas is a must, so that the entire organization can rapidly adapt itself to changes in the market. The manufacturer will soon discover that costs can soar and profits plummet when a departure is made from basic production line units, in an effort to customize individual orders. But there are many ways to stylize the exteriors as well as interiors of modulars to present a wide choice of designs. Roof design and roof lines, windows, colors and finish materials can easily be changed without sacrificing the advantages of basic components and subassemblies, thus maintaining standardization on the production line.

It must be kept in mind that a basic modular unit is not a factory produced custom-built structure, but a unit conceived and designed from the very start to be mass produced on an assembly line. The modular is not the result of building from an architectural plan, but is instead engineered specifically for factory production.

The truth of the matter is that the only real and significant newness of the industrialized process today is the fact that it is more advanced and is at last being recognized as an extremely good method for producing quality housing units in large volume. It is therefore not being recommended nor accepted as a matter of choice, but instead is receiving its past due recognition out of sheer necessity: dictated
by high labor costs, the scarcity of construction labor, and the pent-up demand for housing units.

There are really no great technological advances being made in the field of factory housing as we start the 70's. New manufacturing facilities are being planned and built almost daily in answer to the housing dilemma, but it is most significant to note that the great majority of these production lines are being designed to provide nothing more than conventional wood framed housing units. These coupled with concrete modules and an increasing use of metal framed housing units make up the modular housing industry as we know it today.

Wooden Construction

General

At present, the most prevalent type of modular construction is the single unit dwelling of wooden construction. The walls are factory finished drywall or prefinished plywood paneling, while ceilings are usually drywall. The floor finish material most common seems to be split rather evenly between vinyl tiles and carpet. Kitchen cabinets and other fixtures are factory installed, including formica counters, sinks, tubs, showers and the like. Exterior windows and doors, asphalt roof shingles, and a variety of siding materials are typically factory installed over fully insulated walls. In some instances, the exterior siding material may be eliminated at the factory to permit brick veneer application at the job site. Major appliances, including range, oven and refrigerator, may be included. The heating system is
either hot air or electric baseboard and, along with all plumbing and wiring, is usually factory installed.

Wooden construction methods allow the greatest degree of buyer options of style, etc., within the constraints of factory production. Further, tooling costs are relatively low. These produce a unit marketable in an attractive price range even for relatively low production volume.

Availability

Wooden Construction is generally limited to single family or small one or two story multiple dwellings.

In 1960 there were perhaps a dozen producers of wood frame modular housing. Today this number probably exceeds 300, and the list of new manufacturing facilities grows daily. The attitude of code and other regulatory groups has changed from rejection to general acceptance, while better shipping laws and several forms of federal support also lend approval to modular systems. This housing form is quantitatively real, and a significant trend has been established across the nation.

The wooden modular housing unit currently being produced is not significantly different from its counterpart in conventional construction. Wall stud's spacing, floor joists, partitions, trussed rafter roof systems and other wood framing techniques employed closely approximate traditional framing methods. With the possible exception of its low profile roof line, the shape and size of this modular house resembles the ranch or rambler style of suburban America.
Modular housing of wooden construction comprised approximately 36 percent of the modular housing proposed in Operation BREAKTHROUGH.

Today, a single unit can be delivered and installed ready for home-owner occupancy within three weeks of ordering.

Size

The average modular house is a unit 24 feet wide and 42 to 44 feet in length, divided into two modules for transportability and, providing about 1050 square feet of floor space. This wood framed, two piece sectional house would contain three bedrooms, living room, dining room, bath, kitchen and utility room. After leaving the factory, the unit is transported over the highway up to a distance of 200 to 250 miles, and is erected on a previously prepared foundation by either a locally rented crane, by special tracks or roller systems.

Low rise multiple unit wooden construction has experienced limited acceptance, although many proposals submitted for consideration in Operation BREAKTHROUGH dealt with low-rise multiple units of factory assembled wooden construction.

High-rise multiple units are generally not adaptable to wooden construction. In addition to structural loading factors which usually exclude wood as a satisfactory material, building codes for multiple dwellings often exclude or minimize the use of wood for the sake of fire prevention.

Economics

A general survey of the modular housing manufacturers revealed that during 1969 the factory price of wooden modular homes ranged from
a low of $7 per square foot to a high of $13. Figure 2 relates the number of wooden module dwelling units produced to the cost per square foot. The average price was $8.78 per square foot, exclusive of taxes, transportation and erection. For the typical modular home, the median factory price was $9629.\(^3\) When the homes are transported by truck within a 300 mile radius of the plant, moving costs will average less than three percent of the finished cost of the dwelling, excluding land cost.\(^4\) The common on-site costs vary from $1.25 to $1.50 per square foot for single family dwellings. Economies can be realized in multi-family site preparation. These costs are based upon site preparation in a reasonably accessible location and relatively flat, firm ground. Additional features such as pile supported bases, basements, or extremely sloped terrain raise the cost.

Set up charges, on-site, vary from $0.25 to $0.50 per square foot for single family dwellings assuming either drive through or truck to foundation transfer. Crane costs, if required, would be approximately $1.00 per hour of ton capacity for a 25 to 50 ton crane. Multi family dwelling erection in projects of over 10 dwelling units can be accomplished for $0.10 to $0.30 per square foot.

**Concrete Construction**

**General**

Concrete modules, precast with lightweight aggregate are used most often in multiple dwelling modulars where its fireproofness is

\(^3\)Ibid., p. 75.  \(^4\)Ibid., p. 127.
Fig. 2.--Relationship Between Number of Wood Module Dwelling Units Produced and Cost per Square Foot.
a distinct advantage. Also, modules can be designed with sufficient structural strength to allow stacking, without auxiliary support, to twenty or twenty-five stories.

The basic steps of concrete module construction begin with the casting of the modules in a yard or plant, followed by a varied degree of finishing, ranging from the installation of basic fittings to complete furnishings. Modules are then transported to the site, erected by a crane in the desired arrangement, and joined. Finally, finishing is completed and utilities are connected.

The use of concrete modules in residential construction originated in Europe, Russia and Israel. The first housing in North America to be constructed with this method was Habitat, at the Montreal World's Fair of 1967. Habitat was a very expensive but dramatic exhibit of a combination of concrete module techniques and architectural concepts appropriate to a high density urban environment. Another center of activity was San Antonio, where the H.B. Zachry Company used concrete modules to build: first the Padre Island motel in 1967; next, the Hilton Hotel in the Spring of 1968; and, the Richard Allen Villa garden apartment complex. Zachry has achieved very rapid construction times and has greatly reduced costs from the Habitat level.

Single family concrete modular construction has been initiated by the H.B. Zachry Company, though this use today is impractical except in large developments.
Availability

Large investment in casting yards, expensive heavy handling and shipping equipment coupled with the weight of modules which constrains shipping have limited concrete module production to a few heavy volume projects.


Size

The concrete module size is limited by the weight of the module as well as transportable dimensions. Typical of the major concrete modules are the type used by Zachry in construction of the Hilton Hotel in San Antonio, Texas. The hotel's units were completed, down to the carpet and wallpaper, at the plant. They came in two sizes--32 ft. 8 in. long or 29 ft. 8 in. long (by 13 ft. wide and 9 ft. high)--which were stacked alternately to produce the in-and-out facade. Weight is approximately thirty-five tons per module. In producing the Allen Villa apartment project in San Antonio: Three different module sizes were produced at the Zachry plant. A main unit consisting of a living room, dinette, kitchen and bathroom

measures 33 ft. long, 13 ft. wide and 9.1 ft. high. A two-bedroom attachment is 24.8 ft. long, 13 ft. wide and 9.1 ft. high, while the one-bedroom attachment is 14.8 ft. long, 13 ft. wide and 9.1 ft. high. Floors and walls are 5 in. thick, ceilings 4.6 in. thick.

The concrete modules were cast in 16 giant steel forms, resembling uncoupled freight cars, set up on two lines of eight forms each. Four-legged gantry cranes moving on fixed rail tracks straddled each production line.

All door and window openings and conduit were cast into the boxes. Unlike the Hilton Hotel units which are open at one end to accommodate solid glass, the Allen Villa modules have closure panels.

Shelley Systems utilizes modules approximately the size of Zachry's hotel modules. Additional created space between concrete modules stacked in checkerboard fashion, is the hallmark of this system. Unlike some concrete modular systems, there is no duplication of walls or floors. The area of every module is matched with an equal area of adjacent space thus doubling the usable area.

The precast concrete modules consist of reinforced concrete walls, floor and ceiling slabs, and integral columns. The stacked modules are structurally supported by the columns cast into the modules. Independent structural support is not required. Modules may be stacked as high as 25 stories. The module's three-dimensional rigidity and torsion-resisting qualities are valuable protection.

6. Zachry Scores Another Housing Breakthrough, (Concrete Products, June, 1968).
against earthquakes and hurricanes. The boxes are rigid enough to preclude special wall positioning, temporary bracing, or guy-wiring during erection. Where necessary for high buildings, post-tensioning tendons anchored to the foundation can be placed in vertical ducts running through the center of the exterior columns.

The key to the system developed by Uniment is an expanding cement, which was developed by Conrad, and makes possible "chemical prestressing" of three-dimensional units without the equipment usually required for stretching the steel reinforcement. These boxes have walls only 2 in. thick (as compared to Diskin's 5 in. walls).

Each of Uniment's 11 ft. by 36 ft. units consists of three exterior walls and all interior partitions, plus a "roof," which serves as the floor of the unit above. The lightness of the units (15 tons, compared to 90 at Habitat) makes it possible to ship them up to 500 miles and hoist them with conventional equipment. All fixtures and cabinetwork will be installed in the factory.7

The Building Block Modules, Inc. System has been used in Israel for more than a decade and is being introduced to the U.S. This system, invented by Shimon Diskin, consists of 12-ft.-square concrete tubes, cast with a steel inner form that folds up like an umbrella for removal. The tubes are cast standing on end. At the construction site they are tipped up and stacked in a vertical checkerboard pattern.

7Building with Boxes, p. 85.
The voids between them, identical in size to the cast units, become bonus units.

Economics

In the BREAKTHROUGH proposals, the concrete module construction costs range from $7.00 to $15.00 per square foot, land excluded. A major factor is transportation costs. Zachry estimates the maximum shipping radius as 50 miles by truck (1,000 dwelling units or more) and 1,000 miles by rail.

Typical costs of the systems described in previous sections are given below:

H. B. Zachry Company's estimated total costs of motel units in Padre Island, Texas, at $11.00 per square foot. For the Hilton Hotel project, the estimated cost, including building the first five floors with conventional methods, 16 floors constructed with modules and an elevator/service tower was $19.00 per gross square foot furnished. In constructing the Richard Allen Villa apartment development, total project cost was approximately $17.00 per square foot.

Shelly Systems proposals to HUD's Operation BREAKTHROUGH estimate that on a program of 500 to 1,000 dwelling units that they can be produced at approximately $8.00 per square foot.

Uniment constructed a modular apartment house in Richmond, California, for $12,000 per unit or $15 per square foot. Uniment estimates this cost could be cut appreciably for over 800 design units.
Building Block Modules, Inc. has produced a 100 unit apartment house in Oakland, California, for approximately $19.74 per square foot and estimates with mass production costs that price would be under $8.00 per square foot.

**Metallic Construction**

**General**

In constructing metal modules, steel and aluminum are generally used, since their strength-to-weight ratio is desirable, they are economical, and the materials are readily available. Walls, both inside and out, may be prefinished aluminum or galvanized sheet steel. In other modules, steel tubing forms the framing combined with plastic, fiberglass or wood, and insulation.

Some of the recent entrants in factory housing have concluded that the future supply and price of lumber is too risky, and have switched to steel as the primary framing material. Admitting that steel framed residential units may not be as acceptable as wood, nor as easy to tool up for production, as well as other deterrent features, these modular manufacturers claim the constant availability and almost steady price of steel all but offset its less desirable features.

From a pricing viewpoint, it appears that with efficient design of cold rolled steel shapes, the difference between the two building products may be negligible, particularly when volume purchase and production is considered. Today, the number of modular manufacturers using steel as the basic framing material is now small, in comparison to those producing wood framed units.
Availability

In Operation BREAKTHROUGH, contractors submitting proposals for metal or metal-combination modules were approximately 16 percent of the total modular proposals. Typical of firms now producing metal/metal-combination modules are: Housing Research, Inc.; Gulf Reston, Inc.; Hanover Modular Homes; and Insta-Building Modular Structure, Inc.

Size

In Housing Research's Michigan City, Indiana Project two types of boxes are used, both of which can be produced on mobile-home assembly lines. Each apartment consists of two 12 ft. by 30 ft. modules and half of a 12-ft.-square bathroom-kitchen-utility-module. The mechanical module is shared with the next apartment.

Four modules are arranged in pinwheel fashion around each core, supplying dining rooms and bedrooms; and exterior stairways providing two means of egress from each apartment. The structure uses standard steel framing elements, with interior walls finished with vinyl-clad sheetrock. The only wood used is the sub-floors.8

The Gulf-Reston, Inc. modules will be 48 feet by 12.5 feet wide. The exterior siding will be non-combustable wood with gypsom board used for the interior walls. The modules will be factory fabricated of steel components to be assembled into rectangular dwelling units of two, three, and four-bedrooms, complete with kitchen, bath and storage facilities. The dwelling units can be arranged as town house clusters, garden apart-

ments, and high-rise buildings. A common structural and mechanical system, though varying dimensionally, can be used for all these types. For high-rise structures, the units can be supported within a network of steel columns.

In Hanover Modular Homes steel modules, the modules are shipped to the site completed and are joined together to form the single and multi-family dwelling units of this system. The modules, which are room-wide, and in lengths of 28 ft., 40 ft. and 52 ft., in varying combinations, may be stacked two high to form conventional-appearing detached or attached houses. Only the connection of utilities is required at the site, all other work is done in the factory.

Hanover uses 1\(\frac{1}{4}\)-in. diameter corrosion-resistant pipe to make up the structural framework. Made up in jigs, computer programmed, and automatically welded, the steel pipelengths are assembled into room-sized module structure volumetric shapes, to which are added flooring, external siding, interior walls, ceiling, and roof in a highly unitized, assembly-line method which can save up to 75 percent in labor costs. An unusual feature of the Hanover's high-speed assembly of cladding and other components to the pipe frame is the snap sleeve. This is a split circular sleeve of plastic cycolac which, when snapped over the 1\(\frac{1}{4}\)-in. pipe, grips it with a tenacity equivalent to nailing in wood. Six of these snaps, bonded by high-strength adhesive to a section of wall or floor panel, are used to fasten each panel to the pipe frame.

The exterior siding for the modules is roughtex cedar plywood, but other materials such as prefinished siding, painted siding, or brick
veneer can be used. Interior walls normally are mahogany-type 4-ft. x 8-ft. paneling. Sub-flooring for the modules is built up with 1-in. x 4-in. furring strips snapped to the frame, 3/8 in. of mineral wool insulation, and 5/8 in. of plywood or particleboard. This can be finished with vinyl tile or carpeting.

The ceiling is suspended acoustical tile throughout, with the roof deck being 3/8-in. plywood, sprayed-in insulation, and 5-ply built-up roofing. Interior trim, built-in kitchen cabinetry, and bathroom fixtures are included in the house's purchase price and are factory installed.9

Insta-Buildings emphasizes that the prime cost-saving feature of this system is the reduction of field construction to a minimum by nearly total fabrication of the basic module in plant. This concept can utilize a large percent of low-skilled and unskilled labor. Completed modules are shipped from factory with all mechanical subsystems installed and exterior finishes of brick, wood, plastic or aluminum completed. At the site the modules are placed on conventional foundations by crane and locked in place by plate connectors. Each dwelling unit consists of two modules, each module measuring 12 ft. x 36 ft.2 in. x 9 ft.4 in.10 The module consists of a rigid, three-dimensional steel truss, welded to provide firm support for wall, floor, and ceiling panels. This frame provides sufficient rigidity to allow the module to


10 Ibid., p. 114.
be transported to the site and emplaced without additional reinforcing.

The Modular Structures, Inc. housing concept provides for a tubular steel-framed module, completely finished inside and out, which may be joined in a variety of configurations to form housing units. Complete assembly-line manufacture of the modules, with onsite labor held to a minimum, is accomplished.

The module uses 1\(\frac{1}{2}\)-in. diameter tubular steel, joined by welding, to form the structural framework. This framework gives the unit the rigidity to withstand the stresses of transport, handling and placement. It is designed so that virtually all stresses are resolved within the frame, thus relieving the non-structural exterior and interior wall panels of crack-producing or rupturing stresses.

Assembly of the modules starts with assembly and welding, on jigs, of the tubular members for framing three subassemblies: floor truss system, wall system, and ceiling/roof system. These subassemblies then are joined together to form the structural skeleton of the module. Furring strips are fastened by power driven fasteners to both sides of the wall framework and to the floor and ceiling frameworks, followed by subfloor and roof underlayments, and rough-in of plumbing, heating, and wiring.

Polyurethane foam is sprayed over all exposed surfaces to provide insulation and a vapor barrier. Exterior siding of prefinished wood or aluminum is applied and doors and windows are inserted in their framed openings. Finally all finish work on the module's interior is accomplished, which may include: painted, gypsum board or vinyl-clad
walls, carpeting or tile, suspended gypsum board ceiling, prebuilt cabinets, baseboard, plumbing fixtures, light fixtures, and mechanical systems.

Onsite, the modules are set on conventional foundations and joined with others side-by-side, end-to-end or stacked two high. When modules have to be joined, the corresponding exterior and interior skin areas of the modules are omitted during plant assembly.

The modules are 12 ft. wide and vary in length by 4-ft. increments from 24 ft. to 52 ft. 11

Economics

Metal modules have economically been transported up to 600 miles, making this aspect economically competitive with wooden modules. General transportation costs are about $0.40 to $1.00 per mile dependent upon mode (truck or rail) and volume.

Typical of the costs are the following projects: The Housing Research Institute estimates one to ten dwelling units will cost approximately $15.00 per square foot, with costs decreasing to approximately $8.00 per square foot for over 500 dwelling units. Figure 3 illustrates the relationship between the number of metallic module dwelling units produced and cost per square foot.

The Gulf-Reston, Inc. states: "...cost per dwelling unit (1152 square feet) is $10.00 per square foot, an anticipated saving of approximately 10% over conventional cost. Total development cost is

11 Ibid., p. 148.
Fig. 3.—Relationship between Number of Metal Module Dwelling Units Produced and Cost Per Square Foot.
expected to be in the region of $13.40 per square foot.\textsuperscript{12}

The general market area for the Hanover Modular Homes is 200 miles with construction costs of approximately $5.21 per square foot.

General construction costs for the Insta-Buildings, Inc. modular homes are $10,419 per dwelling unit for a quantity of 1,000 units, or $9,000 per dwelling unit for a quantity of 2,000 units. This gives a cost of from $11.50 to $9.50 per square foot.

Modular Structures, Inc. provides their modular dwelling unit for $13,420 ($8.50 per square foot) based on a 1,200 unit per year production rate.

Plastic Construction

Of the 15 percent of BREAKTHROUGH modular proposals that were not wood, concrete, metal or a combination, only one proposal, TRW Systems Group, was accepted by HUD for implementation. Most other attempts to mold plastics and fiberglass come out looking like poor igloos.

The TRW approach consists of on-site, mandrel wrapped fiberglass modules with a draft paper honeycomb core. With an estimated construction cost of $11.50 to $12.00 per square foot and a high minimum production (1000 dwelling units/year) the performance and public acceptance of this new technique remains to be seen.

\textsuperscript{12} Bernheisel, Experimental Housing Projects, p. 19.
III. ADVANTAGES OF MODULAR CONSTRUCTION

Availability

In the past few years the number of dwelling units built has been at least one million fewer than the yearly average needed. With our increasing population, and the amount of housing being constructed becoming increasingly inadequate, this gap will widen.

The U. S. National Association of Home Builders reports that about 85 percent of the nation's single family homebuilders produce less than 50 units per year. Only 5 percent produce over 250 units. While 50 percent of multi-family homebuilders build less than 100 units a year. This reflects that relative to other industries, housing producers are small. Their limited outputs are usually matched to a specific limited geographic market they serve. They are not strong enough to support research into building technology, develop comprehensive management systems or to experiment with invocative techniques. They cannot risk commitment to new methods. As a result, construction methods for most residential housing have not kept pace with the technological advances in other industries.

Construction is slow and vulnerable to uncertainties of weather and climate. Conventional construction techniques call for a high proportion of skilled carpenters, plumbers, electricians, and others.

in the building trades. But skilled workers are in short supply and the shortages are expected to become more serious.

Clearly only industrialized housing, of which modular construction is a major factor, can provide the quantity of acceptable housing required by the demand. Unlike conventional construction the greater the challenge (quantity), the more advantageous is the use of modular construction techniques. Just as the automobile industry is able to meet the variety of automotive needs competently, economically and with a large area of personal choice, modular construction can fill the gap in low and middle-income housing.

Economics

In addition to building at a faster rate, it is also necessary to provide means of decreasing costs of housing so that more units can be made available to people at all income levels.

At the present trend, conventional construction costs are increasing at approximately 7-8 percent per year. This increasingly places housing outside the "pocketbook" of the lower and middle income consumer. An important facet of modular construction will be through competition, to decelerate this increase to be more in line with the general economy.

In general, savings are incurred in modular construction in four ways: lower initial construction costs; shorter construction times; reduction in overall management costs; and savings in future maintenance. There are two items of initial construction cost through which savings can be made--labor and materials. Saving in labor is
the most important of these items. Modular construction and industri-
alized building in general is characterized by the substitution of
capital for labor. Economies in labor are gained by transferring a
considerable amount of the total man hours of labor to off-site assembly
locations and by changing the nature of the labor itself. Figure 4
illustrates the yearly hourly wage increase of the construction industry
and all other industries. Assembly line operations give maximum
utilization of labor, unhindered by weather or travel time to the job-
site. With the repetitive nature of the assembly line a high learning
curve can be expected. The explicit task definition allows employment
of a high percentage of unskilled and semi-skilled workers. This is
confirmed in Operation BREAKTHROUGH where a majority of the proposers
emphasized the use of the lower skill classes.\textsuperscript{14}

The conditions associated with a specific modular system and
location are such that there is no simple formula relating on-site and
off-site labor to total manhours of construction. The total manhours
per dwelling unit is a function of the size of the project the specific
system, more specifically, the amount of pre-assembly/finish, the type
of labor employed, and the type of material utilized, and a whole set of
exogenous variables relating to the region in question such as labor
supply, space standards and the state of industrial development. For
this reason, the same building techniques employed in different geo-
graphic areas can result in different manhours of labor for construction.

\textsuperscript{14}HUD, Operation BREAKTHROUGH, p. ix.
Fig. 4.--Yearly Hourly wage Increase of Construction Industry and All Other Industries.

Source: The Bureau of National Affairs.
Savings in material costs, though less significant than labor costs are high enough to warrant attention. Manufacturer purchase discounts can run as high as 30 percent, with the pursuant saving. In concrete module production material costs are lowered through superior control of pouring and curing, and greater strength per given wall thickness. Precise control of quantities and processes can practically eliminate waste material so prevalent around conventional construction sites.

Shorter construction time can produce savings and gains in a variety of different ways; earlier occupancy; lower taxes, debt service charges and overhead costs; and quick turnover of capital. Spectacular construction times have been recorded for modular construction. An example, the Hilton Hotel, in San Antonio, Texas, scheduled to have 10 rooms a day set. The actual construction set a maximum of 22 rooms a day with an average of 17, even on the top floors of the 21-story hotel.\textsuperscript{15}

Reduction in overall management costs is a function of the industrialized modular construction approach. In conventional construction an architect coordinates the professional expertise in the design of a project, supervises bidding, construction, and contractual obligations. In industrialized building the only body of expertise which need lay beyond the systems itself is the architectural design service, and even this is being incorporated into systems building as

\textsuperscript{15} "Instant" Hotel Sets Fast Pace for HemisFair Construction, (Engineering News-Record, December 21, 1967).
professional codes are revised. By placing the whole range of services and management skills into a single package savings can be made, although they may be hidden in other costs.

Finally, long term maintenance and guaranteed performance over time represent another area of possible savings. The useful life of the modules proposed to in Operation BREAKTHROUGH all equal and most far exceed the useful life of conventional construction indicating that long life maintainability were incorporated in design.

Utility

Housing is for people. Modular housing must meet the needs, and to some extent, the desires of people.

The general public received most of its biased opinion of prefabricated housing during World War II and the boom period that followed. Projects of prefabs with one house like every other one, appeared practically overnight. While all such housing projects were not factory produced, those projects which were built at the site in a conventional fashion did not seem to proportionately share the criticisms. Whenever such conventional projects developed into an eyesore on the countryside, it was always the prefabricator who seemed to get the blame. In looking back, the industrialized housing industry was the unfortunate victim of conventional builders' local influence, who probably feared the competitive encroachment of high quality factory produced housing.

16HUD, Operation BREAKTHROUGH, p. v.
The manufacturers of factory housing, although hindered by the earlier prevailing attitudes, have instigated changes and activities to enhance their products and give the consumer a high degree of livability in their product. Leading architects are designing prefabricated houses with high aesthetic value and sensible floor plans. The home manufacturers are beginning to set an envied design pace in the residential field. They have further improved their position with expanded services including financing, land planning and development, interior decorating, sales and merchandising aids. This systems approach attracts to the residential area the urban planners, landscape architects, architects and engineers required to produce dwelling units and developments, providing quality living conditions.

In modular construction the buyer or renter in the low and middle income ranges generally acquires a better dwelling unit since many of the constraints on materials disappear. Much of what goes into a standard house is, like the methods of putting it together, dictated by expediency. A building product has always had to be something one man, or a man and his helper, could hold up in position and nail in place. But not with prefab modules. A building material can be judged on the basis of its performance maintainability and cost efficiency alone.

In general, modular construction throughout is more rugged than conventional construction because: jigs, forms, mass-multiple-cutting operations, and the use of larger units are possible in the factory. More rigidity and quality are required for the cross-country ride of
the module; it suffers stresses that an ordinary house would never ex-
perience.
IV. FACTORS CONSTRAINING THE EXPANSION OF MODULAR CONSTRUCTION

Technical

One major, if not the most significant, constraint on modular construction today is the difficulties encountered in transportation from factory site. The wooden construction of modulars offers lower weights, but experience frequent damage in transport. Concrete construction resists damage, but increases weight and is still more subject to transit damage than metallic construction. The weight factor for metallic constructed offsets its extreme rigidity for ease of transport to site. Weight alone is not the final factor, actual mass of modular homes can make a relatively low-weight wooden modular a problem if its size prohibits it being transported by truck from rail lines to site because its size exceeds the set limits for highway usage. Some proposed modules would be impossible to transport by any motor vehicle and are usable only in on-site fabrication in high volume projects. 17

Existing management techniques have proved inadequate to solve the transportation problems in addition to other basic modular construction techniques which must be mastered for mass construction for total economy of this method. In addition to the actual production of the modular housing we will require vast complexes of public utilities and services which must be made available on a time scale to agree with the

17HUD, Operation BREAKTHROUGH, p. 16.
modular production schedules. Public transportation, schools, shopping centers, highways, churches and medical facilities are among the services which must be able to keep pace with the population centers forecast by the proponents of modular housing, and yet, at present, we are unable to provide these in a timely fashion to adequately fulfill the needs of conventional housing construction schedules.

At the present time, individual contractors and construction firms who provide the bulk of American housing are not prepared to cope with an influx of factory-built modular housing. Configuration management and interface control are two of the sophisticated management techniques which must be used to successfully produce large areas of modular housing, and these techniques, and additional ones such as Program Evaluation and Review Technique (PERT) scheduling are virtually unknown among single dwelling construction firms and builders.

Economic

An oversimplification of the economic constraints appears to be that enough mass production of modular construction will bring the cost so low that all economic problems will disappear. As discussed in the preceding section, such attempts at building massive numbers of modular housing units would create technical and management problems so expensive that the actual construction costs would fade to insignificance. In addition to these, the modular construction which seems to lend itself most readily to mass production (concrete or metallic construction) requires huge factory complexes with expensive initial tooling costs. At the present time, the transportation problems are making it
impossible to determine optimum factory location, some proponents favor small factories, temporarily constructed near large building sites to cut transportation difficulties. Others favor large permanent factory complexes to minimize initial tooling costs and provide "one-time-only" capital costs to be apportioned over a long period of time. It seems that only the Federal government may be in a position to institute large-scale modular construction of housing because of the initial investment required.

Social/Political

Unions are presently offering modular housing great opposition. Union workers feel threatened by the possibility of the use of great numbers of unskilled workers for the mass production techniques called for in modular housing. Additionally, the union members object to working on-site to install units which were built in a factory at some distance from their local, thus depriving their area of employment opportunities. This problem inter-relates with the economic factors concerning modulars because if the unions choose to bring these issues to an open conflict, the modular housing industry will either lose all monetary gain in using unskilled help in factories and on-site or else face untold expense in work stoppages and subsequent court battles.

The building codes now in force in most communities constitute an additional problem for modular housing construction. The amount of time required to unmake laws may constitute a major hold-up to modular housing if some way cannot be found to readily up-date these codes to
provide for the innovations of technique and materials developed by the modular industry.

Marketing

Lack of diversity is the complaint most often levied by marketing experts at the modular housing industry. This complaint is valid but correcting it is not as simple as appears on the surface since all "customizing" creates a corresponding significant increase in cost of construction.

Since price will be a prime marketing tool to overcoming objection to modulars, there must be a fine balance between providing variety in appearance and floor planning and the increased costs that variety will cause.

Additional marketing problems are the human inertia factor when dealing with something relatively unproved or new. Until more modular housing units are built with successful results, many potential customers are reluctant to enter this new field. In spite of the glowing reports from some projects, modular housing proponents are running into the same problem as the young graduate who cannot find a job because he has no experience.

Even government experimentation and approval of modular housing construction does not seem to offer the final answer to marketing to private individuals.
V. FACTORS TO BE CHANGED TO ENCOURAGE MODULAR CONSTRUCTION

The growth or lack of growth of the modular housing industry will be influenced by certain technical, economic, social, political and marketing factors. Changes in these factors can increase the demand for modular housing, sometimes at the expense of other types of construction. Let us examine these factors from the point of view of someone interested in stimulating the expansion of the modular housing industry.

Technical

The technical problems connected with modular housing are generally of secondary importance and deal with getting construction techniques and systems to produce a cheaper dwelling more rapidly.

Quality control of factory constructed housing is a technical area which needs to be improved. In many cases modular dwellings involve high cost items, such as cast concrete shells, which cannot be scrapped without substantial loss to the manufacturer. In-process inspections must be devised and instituted which will assure satisfactory production of high-cost items without scrappage loss. Factory testing and inspection of other integral, non-removable, sub-systems must be undertaken to assure that no on-site rejection of non-replaceable systems occurs.

Interface dimensions and tolerances must be controlled much more
rigidly than required in the construction industry before. The entire theory and practice of the modular unit concept rests on the premise that the module will fit correctly into the position readied for it. Production tooling and inspection equipment must be devised to ensure conformity to dimensions common to the module and its mounting structure. Introducing tolerance control into an industry where "cut-to-fit" practices have been common for centuries is a revolutionary step.

More advanced management systems will be necessary to coordinate factory work with on-site work. In general, contractorscurrently involved in high-rise or commercial construction have had to develop management systems of considerable capacity; however, contractors dealing in low-volume residential construction have not. In the modular housing concept it is necessary that the factory and the site plan their activities so that neither impedes the progress of the other. This type of management will call on considerable staff support in areas such as PERT plotting and contingency planning.

Economic

Economic factors are certainly to be the determinates governing whether or not the modular housing industry will expand. The consumer's reticence to forego his currently available choices in style, design, and optional features in housing can be overcome only by government compulsion or by savings in housing costs passed along to the consumer. A new series of problems underlies the ability to realize the potential economies of mass production in the construction industry.
Let us for a moment digress and examine the financing of conventional housing. The preponderance of construction in the country is financed by an obligation on the final purchaser against which obligation an investor advances short-term funds to the builder. The funds are made available incrementally to the builder and certain milestones are available to determine that the funding available is likely to complete its objective.

For the factory-built housing industry, tooling costs enter the picture. The requirements for tooling and physical plant are generally substantial and require intermediate-term financing. It may be impossible or undesirable to obtain capital for tooling through the use of purchaser's obligations. Further, the construction of tooling does not result in a partially complete product which may act somewhat as security for investors.

Several avenues in the private capital market are open to obtain investment capital for tooling and plant construction. Issuance of stock, issuance of bonds, or mortgage-type note financing may be considered; however, since the market for factory-built housing is relatively recent, sophisticated investors would assess these investments as somewhat risky and would probably attach relatively high rates to any funds so invested. The alternative to private investment is public or government support. Government guarantees of financing have long been available to the construction sector. Government assistance could take the form of guarantees to investors in a fashion similar to Federal Housing Authority mortgage surety. The method chosen by the government to
assist the financing of tooling costs will be a major determinant toward growth or retardation of the modular housing industry.

Tooling costs, if they are to be recovered, must be equitably distributed over some number of units sold. Establishment of the number of production units over which to pro-rate tooling costs will be a "life-and-death" decision for some manufacturers. In the case of the multi-unit complex, the decision may be obvious; spread the tooling costs over the number of units produced for the complex. In the single unit market, however, the standing dilemma that increasing price to "break-even" on fewer units means lower sales volume will offer a much more difficult management decision. Companies failing to cope with this problem successfully will undoubtedly fail.

Due to the inherent tooling costs for modular construction, the entire subject of residential financing may have to be reexamined. If the current general practice of extending short-term incremental financing to the builder during construction and converting this short-term funding to long-term purchaser mortgage obligation upon completion is to be revised, it is certain that forces fairly powerful in the financial community will have to act. The success or failure of satisfactory arrangements for financing modular construction will certainly be the key point of whether or not the industry prospers. This is without doubt an area where government sponsorship can be most influential and effective.

Another capital requirement necessitating intermediate-term financing is the development sites necessary for single unit modular
home marketing. This type of capitalization may be less cumbersome to arrange, since the land and any improvements thereto (roads, utility service, etc.) can be used as security in a mortgage which represents a very common financial transaction.

Considering another factor influential in keeping costs down, it may be assumed that labor, particularly organized unions, will not stand quietly aside should the modular housing industry threaten a substantial number of jobs in the construction field. Certain of the economies found in factory-built housing stem from the ability to use semi-skilled and unskilled labor for processes heretofore requiring skilled labor. The labor costs per square foot of completed dwelling must be greatly reduced on modular unit construction as compared to conventional construction. It will therefore be necessary for factories producing modular units to introduce policies which will avoid paying skilled-labor rates to unskilled workers and to use these latter in as many operations as possible. Should construction unions oppose the expansion of modular unit building, a series of labor relations difficulties together with market attenuation and even possible effect on available financing could occur which would seriously impede the expansion of the industry.

The economic benefits of modular housing are potentially great, but there are many difficult problems which must be solved before these benefits can be made a reality to the consumer. It will be impossible for the few current manufacturers of modular housing to solve the enormous difficulties ahead. Powerful assistance will be necessary,
especially in the financial community. It will therefore undoubtedly fall to the government to play a sponsoring role of some kind if factory-built housing is to become common.

Social/Political

There are social factors generally dealing with the effect of modular housing on the general public and on purchasers in particular and political factors dealing with laws now restraining the proliferation of modular housing which will have an effect on the growth rate of modular units sold.

The principal social constraint to modular housing is product acceptance by potential buyers. This may be overcome by cost advantage (as was suggested previously), by advertising, or by coercion. Coercion in this context would be associated with urban renewal, ghetto clearance or other programs where large scale demolition of existing residences is performed and an alternate dwelling provided for the inhabitants. HUD's Operation BREAKTHROUGH is planning use of mass-produced housing for this kind of rehabilitation and, if carried through, could gain a measure of social acceptance for modular housing.

Other social factors, however, may have a progressively increasing effect beneficial to factory built housing. The population growth naturally leads to a higher density of population. The trend, especially in urban areas, has been toward the high-rise dwelling. Purchaser's options in such accommodations are restricted at present and therefore purchasers in that market are accustomed to accept without question the most notable limitation of mass produced dwellings. As
the population grows, more and more people will accept the conditions of high-rise dwellings rather than the ever increasing distance between the residential suburbs and the urban commercial center.

The social trend to increase population density brings on the political consideration of land usage. Zoning laws which currently exist generally consider only conventionally built structures. Zoning laws change frequently and are susceptible to frequent exceptions, and as a result zoning ordinances seem to present only a minor problem to modular housing.

Such is not the case, however, with building codes. These ordinances, generally to assure safety in construction, have in many cases evolved into a nearly unmanageable tangle of restrictions providing more protection to the building trade labor than to the purchaser or the community. Many building codes have not kept abreast of advancing technology, and, as a result, retard development of new building materials and techniques. In the conduct of Operation BREAKTHROUGH, the government managers were unable to operate within the confines of local building codes so they made the policy decision to ignore the codes with the result that the Federal government will undertake to insure the safety of dwellings produced under the program. The legal and financial long-term effects of this course are yet to be determined. In any case, building codes as they are currently written will rarely allow mass-produced housing to be built under favorable circumstances. A definite alteration of present-day building codes must occur if modular housing is to greatly expand its markets.
The problem of transportation of housing units is classed as a political problem. Manufacturers of modular housing must either locate their factory at the construction site (possible only in large multiunit complexes) or have access to transportation systems. Rail, water, and highway systems are practical for transporting mass produced housing. However, rail and water transportation can serve only limited sites. Highway transportation is required in most cases. Free access to highways with loads of up to fourteen feet wide is a prerequisite to the modular housing business in its present state of development. Should state or local officials deny highway access of this type to factory-built home manufacturers, the effect would be to isolate these manufacturers from their markets.

Marketing

Marketing must be considered as a principal factor in the general expansion of the factory-built dwelling industry. Marketing plays a minor role in cases where some form of coercion acts to sponsor dwelling occupancy, however, in this country it is necessary for the construction industry to gain public acceptance of its products if growth is to be realized.

The market resistance of the average home buyer to "look-alike" mass-produced housing has been referred to earlier. This market resistance must be broken down if mass produced housing is to gain a general acceptance. The two basic approaches to overcoming this obstacle are: 1) offer more options and, 2) compensate for the detriment by offering other advantages.
The manufacturer who offers many purchaser options is sacrificing some of the advantages of mass production to encourage consumer acceptance. This trend, unless carefully controlled, can result in the worst of all possible worlds for a manufacturer; very similar looking housing priced close to conventional construction.

The course which appears to offer less risk is to accept the conformity of design as an unavoidable condition and to concentrate on offering offsetting advantages such as reduced cost and short delivery. This practice will encounter fewer difficulties in the multi unit field than in the single unit field since conformity in multi unit dwellings has always been the custom.

Selling of mass produced single unit homes can be expected to follow a pattern currently established by the larger builders of pre-fabricated homes. A development containing enough lots to support a small service community, 100 lots minimum, will be subdivided and provided with roadways and utility service. Advertising and sales campaigns will then be mounted to attract purchasers. In the optimum condition, sales would occur in a volume about equal to the factory output capacity. Delivery and on-site set-up would proceed at a steady rate so as to keep the factory and on-site crews busy and at a fairly constant level. To achieve this kind of ideal situation, several developments would be needed operating concurrently.

Since the economies of single unit factory built housing will attract many potential purchasers in the lower income spectrum and from minority groups, developers of communities such as suggested in the
preceding paragraphs must ensure that these residential areas are provided with a proportional share of municipal services such as schools, transportation services, protection services, and maintenance services. It is advantageous before beginning such a project to be certain that the larger existing community is willing or at least not adverse to accepting such a development. To encourage this type of acceptance, a developer can plan to introduce techniques common in the condominium field relating to forming a community association and financing community projects from a mortgage escrow fund. Acceptance of a development into a locale will have a positive effect on the lifestyle of development residents which, in turn, will tend to popularize the trend towards modular housing.
VI. EAST CENTRAL FLORIDA

The East Central Florida area is entering a period of growth and changing population characteristics; the six county area consisting of Brevard, Indian River, Lake, Orange, Osceola and Seminole Counties will undergo an estimated population growth of 887,000 between 1970 and 1990. The required number of new residential housing units will be approximately 327,000. Of this amount approximately 4650 can be anticipated to be filled with mobile homes, leaving a net 322,350 dwelling units of non-mobile homes to be provided in the next 20 years.

Although the income level of the area residents will continue to rise in the next 20 years, the median age of the area will rise sharply reflecting an increase in retirement residents and the skill mix of jobs will reflect its greatest growth in the service/tourist area with a lower income than the past aerospace job growth area. This is reflected in current housing trends of:

A smaller percentage of custom built, single family homes,

A considerably higher number of multiple dwellings such as garden apartments and condominiums,

---


19. Ibid., p. 25.

20. Ibid., p. 22.
A decrease in density per unit to an estimated 2.75 people in 1990 from 1960 average of 3.24.\(^{21}\)

These trends can be summed up dollar wise by the fact that about 67 percent of the non-mobile home housing required (217,700)\(^ {22}\) will be for incomes of under $10,000/year. This is a market of homes in the under $25,000 range and rentals under $200/month including utilities. The area of maximum sales of modular housing.

D&M Modular Homes has a one dwelling unit per day modular production plant in Winter Park, Florida. Their product is wood framed with masonite painted exteriors. The modules are 40 feet long by 12 feet wide by 12.5 feet high, with fixed roofs and eaves hinged for travel. The dwelling units meet the FHA Southeastern Building Code and, so far, are used in single family detached housing. Factory price, including cabinetry, floor covering and electro/mechanical equipment, is from $10 to $11.50 per square foot.

Another factor is the growing tourist trade in the area. With estimates of up to 30,000,000 tourists per year for Florida by 1980, the growth of motels and hotels has accelerated. There will be a demand for an estimated additional 19,820 units before 1990 in East Central Florida.\(^ {23}\) Modular construction has vigorously entered this market as shown by the U. S. Steel on-site construction of the Disney World Hotel and H. B. Zachry's addition to the Langford Hotel in Winter Park.

\(^{21}\) Ibid., p. 23. \(^{22}\) Ibid., p. 26.

It appears that the modular housing industry has a desirable market in the East Central Florida Region. Figure 5 graphically presents the above housing and hotel/motel units required in this region. This market can be acquired through aggressive:

- architectural development,
- community planning,
- advertising and promotion,
- financing techniques,
- expansion to realize the economics of scale.
Fig. 5.—Additional Number of Dwelling Units and Hotel/Motel Rooms required in East Central Florida vs. Year.

D. U. — Dwelling Unit
VII. CONCLUSIONS

There is an approximate 1.6 million dwelling unit deficiency per year in residential construction in the U.S., mainly in the low to middle income range (under $25,000). This, coupled with a competitive area of approximately 50 percent of present residential construction of 1.5 million dwelling units, gives a potential market of 2.35 million industrialized dwelling units per year.

The increasing urbanization of the United States from a present 75 percent of its population today to about 90 percent of the population in urban areas before the year 2000\textsuperscript{24} accentuates the feasibility of high volume, short shipping distance industrialized housing.

In the Operation BREAKTHROUGH evaluation of industrialized housing, 39 percent was of modular construction.\textsuperscript{25} With this figure as reflective of the modular housing industry, it is concluded that there is a market potential of about 920,000 modular dwelling units per year through the next 10 to 20 years. Further future projections, with our increasing population, will be at least as favorable.

The foregoing report has looked at the three major types of modular housing—wooden, concrete and metallic. The following is concluded.

\textsuperscript{24}The Urban Planning Guide, (ASCE, New York, N.Y.) p. 2.
\textsuperscript{25}HUD, Operation BREAKTHROUGH, p. vi.
Wooden construction, while the largest area at present, will decrease in importance due to scarcity of natural materials, poor adaptability to large multifamily dwellings and higher maintenance costs.

Concrete construction will be the major modular area of the future. Its low production costs, minimum maintenance and high versatility will be quite competitive in the high density, short shipment distance, industrialized housing market.

Metallic combination construction will be the major form of modular housing unit in the areas where shipping economics offset the use of concrete construction.

Use of fiberglass, plastics and other new materials for construction of the basic housing module structural unit requires further research, development and actual life performance to demonstrate their general usage.

Modular construction will develop faster in the multifamily/highrise area, and acceptance by the single family purchaser will be slow in developing.

In the East Central Florida Area the modular industry can develop at a reasonable rate to compete for the approximately 12,000 dwelling units per year, including hotel/motel units, in its potential market. There appears to be an immediate market for a 500 to 1000 dwelling units per year concrete modular plant plus an area of further expansion for the Florida mobile home manufacturers into the metallic modular production.
SELECTED BIBLIOGRAPHY


Zachry Scores Another Housing Breakthrough, (Concrete Products, June 1968).