THE EVALUATION OF THE TECHNICAL AND SPATIAL ASPECTS OF SELECTED TYPES OF PREFABRICATED MODULAR CONSTRUCTION

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ABSTRACT

THE EVALUATION OF THE TECHNICAL AND SPATIAL ASPECTS OF SELECTED TYPES OF PREFABRICATED MODULAR CONSTRUCTION

By

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Since primitive times man has been searching for better ways and materials out of which to build structures. One of these ways is a fairly new development, prefabricated modular construction. We proceed to take a look at this new method and its present state of development in Western Europe and North America. Chapter I deals with an overview of prefabricated modular construction and Chapter II goes into greater technological detail. Both chapters examine the differences and similarities, the good and bad of both Western European and North American systems.

An integral part of this thesis is the quest and, finally, the creation of a criteria by which the functional and social space of a structure or structures can be evaluated by the proximic values of a society. Chapter III, with the help of Dr. Edward Hall's proximic's and spatial ideas from Kevin Lynch and Christian Norberg-Schulz,

contains a criteria for the evaluation and design of micro- and macro-space.

In Chapter IV, with the aid of this criteria for the evaluation and design of micro- and macro-space, there is an examination of and an evaluation of various examples of prefabricated modular developments and some of their site plans. Chapter V deals with an urban environment of the future, an environment that is created entirely out of prefabricated modular units.

The Summary and Conclusions makes some essential points: that there are only two types of prefabricated modular systems in use, the panel system and modular unit development, and that the modular unit type of development is being perfected in North America and the panel system is mainly being used in and developed by Western Europe at this time.

To reduce the cost of building a structure and to achieve the highest efficiency one has to take the whole structure into the factory. Presently, there are only two types of plumbing systems being used in the world. The archaic and often used system of pipe runs in conventional buildings that dissipate odors out onto the roof, and the other, Sovent, which is a system that eliminates one whole pipe run and dissipates all odors internally without the distasteful discharge into the atmosphere associated with the conventional method. Sovent has had applications for

modular unit development because it allows for the flexibility and configuration of modular units.

Only a small percentage of the various internal layout possibilities in the three cases presented in this thesis were used (approximately 8 per cent). Thus bearing out some of Dr. Hall's contentions on proximics and arriving at the conclusion that society can plan effectively in advance for particular cultural habits and preferences to a fairly accurate degree.

That new, flexible, and durable materials must be found on the success of prefabricating modular units on site or in a factory.

Without the use and perfection of prefabricated modular construction the technologically advanced countries of the world are going to have a difficult time in keeping up with or creating new housing for their people's needs.

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INTRODUCTION AND GOALS

The following work will try to set forth, among other points, an overall view of the present state of prefabricated modular construction in Western Europe and North America. The two areas of greatest concern, information, and progress in modular development are in Western Europe and North America. Both of these areas (excluding the Soviet Union) have done the most research and practical work in construction systems and therefore have the most to offer this effort.

Next, the examination and consideration of the technological aspects of prefabricated modular construction which will be looked at and discussed in some length. This, most naturally, leads into the type of space and environment that is created by the use of modular units.

Rarely has there been any criteria in our society for the society or individual to be able to evaluate architecture and the functional and social space that is created by structures, there have been mainly aesthetic and economic criteria. The time and necessity have come for society to evaluate the functional and social spaces

created, more accurately put, how does society relate it to the needs and values of the society? Social and functional space must be combined with the value of aesthetics for evaluation.

Through the readings of such people as Norberg-Schulz, Christopher Alexander, Edward T. Hall, Moshe Safdie, Le Corbusier, Kevin Lynch, and others there will be an attempt to put thoughts and create a notation on a criteria for the evaluation of functional and social space. If anyone has been guilty of an overall lack of concern and awareness of the need to be able to measure the value of space and its effect on an area, it is the urban planner. He, as well as architects, needs to have a means by which he can judge his thoughts and designs before committing thousands, maybe millions of dollars to a task, not to mention the countless lives and generations that are affected by his decisions.

After the creation of a notation on a criteria for the evaluation and design of functional and social space there will be an examination and evaluation of actual modular micro- and macro-spaces that exist in Western Europe and North America. Also, there will be created some spaces for the purpose of showing how the criteria can be used before a structure has been built.

What of the future? There shall be created a new unique form of urban environment through the use of

prefabricated modular technology. Through the synthesis of information gathered and through research, it will be endeavored to create this future urban environment.

Throughout this thesis there will be terms peculiar and relevant to prefabrication, architecture, and space. So it is well to have them well defined so their meanings will be clear when they are used. To that end this author has compiled the following glossary of terms that are felt to be essential, they are:

Architectural Space.--" . . . it is related to the space schemata of man's individual and public world. . . . Architectural space, therefore, can be defined as a concretization of man's existential space"[1] (existential space will be defined later). Also, the functional and social space created around and in a building by its very form.

Artifacts.--They are man-made objects which embody symbolic meanings.

Districts.--They are medium-to-large sections of the city, which evoke in an observer a two-dimensional extent which he can enter "inside of," and which can be perceived to have some identifying characteristics in common throughout that district. These identifiable

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[1]Christian Norberg-Schulz, Existence, Space and Architecture (New York: Praeger Publishers, 1970), p. 37.

characteristics from the inside are also used as exterior reference points when they are visible from the outside.

Edges.--Edges are the linear elements not used or considered as paths by the observer. They are the boundaries between two phases, linear breaks in continuity: shores, railroad cuts, edges of development, walls. They are lateral references rather than coordinate axes.

Equipotential Space.--

> Spatial formulations in current usage proceed from a definition of space as a volume and are concerned with its geometrical characteristics. Instead, the definition could be extended to cover changing patterns of relationships. The matrix in which these relationships exist can be called Equipotential Space.
>
> The determining characteristics of Equipotential Space are continuity, flexibility, and articulation. Instead of being planned for a few specific purposes, Equipotential Space can be modulated at will for any purpose.[2]

Existential Space.--Is in part, man's image of the environment. It cannot be defined in terms of geometry alone, the notions of proximity, centralization and closure therefore work together to form a more concrete existential concept, the concept of place, and places are the basic elements of existential space.

Functional and Social Space.--Is that space that man uses in his everyday life for work, recreation, eating,

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[2]Renato Severino, Equipotential Space (New York: Praeger Publishers, 1970), p. 27.

and sleeping. This space is created by a structure or structures and can be internal or external depending upon its orientation to and in conjunction with a structure or structures.

Imageability.--That quality in a physical object which gives it a probability of evoking a strong image due to its specific functions as well as its spiritual meaning; dependent upon the observer's cultural content and on the form quality of the object.

Intimate Distance.--This distance has two phases: a close phase and a far phase. First, the close phase is the distance of love-making and wrestling, comforting and protecting. In this phase is physical contact or the very high possibility of physical contact and involvement, and both parties are very aware of that fact. Some senses become more aware and others become diminished; distance receptors are greatly diminished except for olfaction and the sensation of radiant heat, both of which are more sensitive. Sharp vision becomes difficult except at the outer limits, close vision, if possible, greatly enlarges and stimulates most, if not all, of the retina. Vocalization is usually kept at a minimum at this distance.

The other phase, the far phase, is from six to eighteen inches. Most parts of the body are not easily brought into play; heads, thighs, and pelvis cannot make

contact, but hands can reach out and be able to touch each other. Features, especially the head, are enlarged and distorted. The ability to focus the eye easily is an important feature of this distance for most Americans. At this distance the voice is normally held at a very low level or whisper. Most Americans do not consider the use of intimate distance in public, by an adult, proper. Crowded place, such as subways and department stores can bring strangers into intimate contact, but subway riders and shoppers have defensive devices which take any of the real intimacy out of the contact in public places.

Landmarks.--

> Landmarks are another type of point-reference, but in this case the observer does not enter within them, they are external. They are usually a rather simply defined physical object: building, sign, store, or mountain.[3]

Le Modular.--Created by Le Corbusier, the "modular" is a measuring tool based on the human body and mathematics.

> A man-with-arm-upraised provides, at the determining point of his occupation of space--foot, solar plexus, head, tips of fingers of the upraised arm--three intervals which give rise to a series of golden sections, called the Fibonacci series. On the other hand, mathematics offers the simplest and also the most powerful variation of a value: the single unit, the double unit and the three golden sections.[4]

[3]Kevin Lynch, The Image of the City (Cambridge: The M.I.T. Press, 1960), p. 48.

[4]Le Corbusier, The Modular (Cambridge: The M.I.T. Press, 1954), p. 55.

The measure consists of two series, the red and blue. The numbers of the "modular" are measures; they are facts in themselves. These measures are related to numbers and posses their properties.

Modular.--This is a building component--bathroom, kitchen, apartment unit, wall and floor units, etc.--that are repetative and equal mathematically and in design. These modular units are usually prefabricated for quick assembly on the site and a reduction in the overall costs of a building project.

Nodes.--"Nodes are points, the strategic spots in a city into which an observer can enter, and which are the intensive foci to and from which he is traveling."[5]

Paths.--Paths are channels such as pedestrian walkways, transit lines, canals, railroads, streets, and highways. The observer usually moves along these, more or less frequently depending upon the circumstances.

Personal Distance.--Originally applied by Hediger to denote the distance consistently separating the members of what is called non-contact species. It has been adopted by Edward T. Hall and the definition expanded.

There are two forms of personal distance. The close phase is from one and a half to two and a half feet.

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[5]Lynch, p. 47.

There are no visual distortions at this distance. A kinesthetic sense of closeness is present partly because there is the possibility that each person can do something with the other's extremities. The three-dimensional quality of objects is pronounced. Texture and clarity are at their heights.

The far phase is from two and a half to four feet. This is also known as keeping someone at "arm's length." This is the area that is just outside the easy touching distance by one person to a point where two people can touch fingers if they extend both arms. Topics of personal interest and involvement can be discussed at this distance. All details of the other persons anatomy can easily be perceived. The voice is at a moderate level. No body heat is perceptable from this distance.

Prefabricated.--This refers to any unit or component part of a building that is made previously to its introduction on the structure itself. A prefabricated unit can be made at the building site, such as the modular units that were poured on the site of the Montreal World's Fair for Habitat, Expo 67.

Proximics.--This is a term coined by Professor Edward T. Hall and it stands for the interrelated observations and theories of man's use of space as a specialized elaboration of culture.

Public Distance.--The close phase at from twelve to twenty-five feet affords the opportunity for an alert person to take evasive of defensive action when called upon to do so. Vision becomes flat and the voice gets louder.

The far phase is from twenty-five feet or more. This is the distance automatically set around important public figures. But this distance is not restricted to just important public figures, it can be used by any person on a public occasion. Subtle details of the face and voice are lost so everything must be exaggereated to be effective.

Social Distance.--There are also two phases of social distance. The close phase is from four to seven feet. Another person is perceived as normal in size. Details of the other person's body are clearly perceived, and a person's gaze may shift from eye to eye and eye to mouth. This is the spatial distance of impersonal business, many people use this distance while at a social function or in dealing with previously unknown business associates.

The far phase of social distance is from seven to twelve feet. This is the distance at which formal business and social events take place. At the far phase of social distance, the finest details of the face, such as the capillaries in the eyes are lost. All other parts, in

detail, plus texture of the body are readily visible. The full figure is in view, and the gaze is concentrated towards the area of the eyes and mouth. The voice level rises at this distance, and shouting can have the effect of reducing social distance to personal distance.

> A proximic feature of social distance (far phase) is that it can be used to insulate or screen people from each other. This distance makes it possible for them to continue work in the presence of another person without appearing to be rude. Receptionists in offices are particularly vulnerable as most employers expect double duty; answering questions, being polite to callers, as well as typing. If the receptionist is less than ten feet from another person, even a stranger, she will be sufficiently involved to be virtually compelled to converse. If she has more space, however, she can work quite freely without having to talk.[6]

Space.--"Space is therefore the product of an interaction between the organism and the environment in which it is impossible to dissociate the organization of the universe perceived from that of the activity itself."[7]

To differentiate the concept of space further I will put down five concepts as distinguished by Christian Norberg-Schulz: the pragmatic space of physical action, the perceptual space of immediate orientation, the existential space which forms man's stable image of his

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[6]Edward T. Hall, The Hidden Dimension (Garden City, N.Y.: Doubleday & Company, Inc., 1966), p. 116.

[7]Norberg-Schulz, p. 17.

environment, the cognitive space of the physical world and the abstract space of pure logical relations.

Each one of these concepts is a different part of man's awareness.

> Pragmatic space integrates man with his natural, "organic" environment, perceptual space is essential to his identity as a person, existential space makes him belong to a social and cultural totality, cognitive space means that he is able to think about space, and logical space, finally, offers the tool to describe the others.[8]

The abstraction of architecture and planning into the concepts of space for evaluation purposes enables one to understand and further evaluate those professions. This inquiry into the technological and environmental aspects of prefabricated modular construction is useless without the creation of some sort of criteria for one to be able to differentiate between good and bad, and not just esthetic differences but functional differences as well.

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[8] Ibid., p. 11.

CHAPTER I

AN OVERVIEW OF THE PRESENT STATE OF PREFABRICATED MODULAR CONSTRUCTION IN WESTERN EUROPE AND NORTH AMERICA

Building systems differ from country to country. While one country stresses component prefabrication another will stress modular unit development. Until recently, however, it was unique the way prefabrication developed in North America as compared to Western Europe.

Throughout the fifties and sixties most Western European nations took a "systems" approach. In other words, they concentrated on developing and prefabricating panels; floor panels, wall panels, and ceiling panels. Though in North America this was taking place, to a degree, research and development was concentrating on the overall modular unit concept which is epitomized by Safdie's Habitat.

The early European systems were limited, as all panel systems must be limited, because the greatest amount of cost reduction possible is only 25 per cent. They were

only dealing with the shell of the building, a modular unit development gives you a chance at the other 75 per cent of a building's cost, plus a greater freedom in architectural design. A panel system is a building block system of right-angles, vertical lines and sharp corners. Outside of the Soviet Union (which is not included in this overview) almost all the work being done today in the field of prefabricated modular construction is in Western Europe and North America, and these are the two areas that will be discussed for an overview of this field.

Western Europe

The Federal Republic of Germany

Not surprisingly, the Germans are the most advanced in this field at the moment in Europe. For a number of years they have felt they were behind other European countries and that their housing problem gave them no choice, they embarked on a large scale development of prefabrication systems.

> The programme initiated by the Neue Neimat Group of Housing Societies could help Germany's system builders to catch up with their neighbours. It may also suggest a valuable organizational method for other countries which already suffer from an uneconomic profusion of housing systems.[8]

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[8]"Germany--Prefabrication Programme," Arena/Interbuild (January, 1968), p. 34.

Their program is called NH65 and tries to employ the minimum amount of constructional components, while allowing a large variety of urban planning and internal layout. This housing system was developed in conjunction with some of German's leading manufacturers. To meet the needs of the German people a flexible series of units had to be developed. Units that could take care of the family as well as the single person, to be able to provide shelter in various environments: in the inner city, in the suburbs, recreational units, and rural areas.

So the series of units that they developed can build anything from a single family type dwelling to a high rise building. There will be greater details on this system later, but it is a system based on a unit of room-size slabs with supporting cross walls and solid facade panels.

The way in which NH65 is marketed is unique:

> Since NH65 is simply a master programme, the choice of constructional system lies with the client. When this has been selected, the building programme is then adapted to the specific requirements of each prefabrication system. Slightly varying measurements and room sizes will result from the constructional differences between the various systems. To gain maximum advantage of serial manufacture, the client's choice of systems for any project should obviously be limited as far as possible.[9]

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[9]"Germany--Prefabrication Programme," p. 35.

So far the reactions to NH65 by builders and architects has been favorable. The simplicity of manufacture and the ease of assembly has appealed to them all.

Another German system is also interesting. It is called "Suspended Towards the Sun." This system applies two basic concepts; one being the idea of prefabrication, and the other, the highly desirable idea of detached dwelling amenities in high density housing.

The structure takes on a pyramidal form with a high concentration of dwellings of various types. The title of this project comes from the fact that all the apartments are oriented towards the south. The basic system is totally prefabricated except for the foundations. A mast is erected with main cables attached to it. Along the cables a space net is hoisted into place and then pre-tensioned. The floor slabs are then put in place by crane and the walls are erected on them.

This is the basic idea behind the system used. The system results in many economies; an economy of space, structural economies, construction economies, and an economy of construction time.

It is a most ingenius system. An idea in building attempted by and adopted from the great Italian architect Pier Luigi Nervi, and presently being employed by Moshe Safdie as well. Suspension systems offer varity of form

and spatial placement, and their structural possibilities are just being realized.

Null-Punkt (in German it means Zero Point) is a system deriving its name from the mode of connecting the load-bearing members. Another name for this system is the "Six-Point System." One of the principle advantages of this system is that the points of least stress, zero stress, occur at the weakest points, and that the maximum stress occurs at the point of maximum structural strength.

> The chief advantage claimed for the system is the separation of jointing from the points of convergence of vertical and horizontal load-bearing members. Jointing is at the position of minimum stress, while maximum stress occurs at the point of maximum structural strength, at the prefabricated intersections. Since these are prefabricated, their reliability can be taken for granted, and reinforcement for special conditions is unnecessary: the cross-section of the framework members can also be at a minimum.[10]

Zero Point has a few notable advantages. It is easy to handle, it is relatively light and stacks conveniently for transportation. It does have limitations in height and depth; with a limit of seven units for height and three grid units for depth. But length remains flexible and this is in where lies its great advantage. With its possibilities for factories and multiple-dwelling units and the ease of expansion inherent in the system.

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[10]"Germany--Six-Point Star System," Arena/ Interbuild (March, 1968), 36.

Research into the Null Punkt system has lead people to believe that it has possibilities in town planning projects:

> Using an enlarged version of the corner star unit, it is suggested that raised levels could be constructed to accommodate groups of houses with gardens, shopping centers, parks, or technical installations. Temporary, or even permanent, roads could be built, using units based on a 10M module, to relieve congestion on existing roadways.[11]

The Null Punkt system, as so many of the German systems, are well packaged and marketed. Like the NH65 system, Zero Point offers the client a catalogue from which he can choose the exact system he desires. From this catalogue he can give accurate specifications and unit prices, plus recommended equipment such as kitchens and bathrooms.

But in Germany, however, the most popular building system, and the most durable, is the "Okal-House" system. This system produces 2,000 units per year, more than any other system of building in the Federal Republic of Germany. The Okal-House system has achieved two things: the production of prefabricated components using conveyor belt techniques, and a system that is flexible enough to be able to be arranged in fifty different housing designs.

Why is the Okal-House system so successful? Their secret for success is that:

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[11]"Germany--Six-Point Star System," p. 37.

> The manufacturer found that one of the most difficult problems with the prefabricated house was to strike a balance between the high quality production of the individual elements and the actual assembly of the parts; in other words they had to compromise with ease of handling. Allowance was therefore made for minor tolerances.[12]

To be sure that each unit was erected properly and as quickly as possible the manufacturer hired a special four-man team. This team was paid per house and team members were all craftsmen.

These are four of the basic German building systems now being used. These systems are, on the whole, more advanced than their European counterparts. The other building systems are elementary in design and scope, and as you will see, the rest of European systems, with a few minor exceptions, are of the panel kind and are far from being totally prefabricated.

United Kingdom

So much of British time, resources, and energy are wrapped up in their effort in building New Towns, that they are found lagging in the development of prefabricated building systems is therefore not surprising. What they have is far from being unique and on the main you find panel systems in use. A brief description of a few of the more prominent systems will give you an idea of their present state of development.

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[12]"Germany--The Trouble with Variety," Arena/ Interbuild (January, 1967), 28.

An architectural competition was held for the design of industrialized housing using steel. This competition was sponsored by the very powerful European Coal and Steel Community which is able to influence housing construction in Britain and on the Continent. One of the designs is by a British architect, Robert Fawcett. These units were designed for all income groups; upper, lower, and middle income units.

The units are made from corrugated thin steel sheet containers. The structural system is stressed skin, which avoids the duplication of material required by the conventional frame and panel system where the frame steel gives no cladding effect and the panel steel gives no support to the frame.

A variety of housing patterns can be created with this system:

> The two components can be used in three major patterns. First, a variety of one-, two- or three-story houses, as single units or grouped as terraces, squares and blocks can be erected by simple use of the link and canister.
>
> Second, combinations of links and canisters in grid patterns three storeys high (8 metre levels) where major concrete decks with their own supports are introduced complete with services and access, enabling a further three levels to be placed on top. This produces a lightweight tower of potentially great height.
>
> Third, the link can also be used as a node point to form a rectilinear space grid. That is, from each link, canisters go in any four directions and a further link can be placed over or below the original link to provide changing levels. It is possible to design the structure on sloping gradients by using

different lengths of canister and placing them in various arrangements.[13]

Another British system has been nine years in the perfecting. The original system is called the Mark 36, by Terrapin, and their new development is known as the Mark 45. They claim it to be a major breakthrough in British industrialized housing and building techniques.

The new system differs from the old in a number of ways. The new system is built to permanent specification, the structures are completely extendible and relocatable, and there is a greater flexibility and durability built into the system. This includes dimensional coordination of individual units, a new roofing material, suspended ceilings and self-finished members. The system can be arranged in one and two story units.

Mark 45, despite all the manufacturers claims, is essentially a panel system. And so is the Integer system of industrialized housing. This system uses external wall panels and structural steelwork. There are seven housing designs and two finishes: luxurious and standard.

These examples give you the general idea of the type and state of British efforts in prefabrication. They are not comensurate with the developments in Germany or in the United Stated and Canada and can benefit by original

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[13]"United Kingdom--Living in a Stressed Skin Canister," Arena/Interbuild (January, 1967), 21.

research and development that could ideally take place in conjunction with the continued building of New Towns.

Norway

A system designed by the Norwegian architect Erik Hultberg is one of the most interesting and promising for the future needs of man. The site at Skjetten lies 20 kilometres east of Oslo, and by the time the project is completed in 1974 it will contain some 1,750 dwelling units. About two-thirds, or 1,100 units will be two-story row houses.

What is exciting about Hultberg's plan is that each house may be different as is required by its occupants, he has created an adoptable and expandable building system. "The resulting buildings will be a product of the needs and desires of the occupants and the physical form of the house will reflect their way of life and aspirations."[14]

All houses are developed on the same building system, from which several thousand variations are possible. The width of the site is always the same and the length differs slightly between three variations: type S with access from the south, type N with access from the north, and type NS with access from both sides.

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[14]Erik Hultberg, "An Adaptable and Expandable System for Row Houses," Ekistics, XXXI, No. 183 (February, 1971), 178.

> Each site is divided into a grid with squares of two sizes. The large central square, 4.40 x 4.40 m., is common for all houses regardless of type. Stairs and bathroom-utility rooms, . . . , are always adjacent to the central square. The rest of the site is in principle divided into squares, 3.00 x 3.00 m.[15]

Each one of the row houses is built upon a concrete slab. This is made possible because of the very cold temperatures in Norway, so foundations, which are difficult to dig, do not have to be built. The load-bearing parts of the construction are the party walls and the laminated beam and columns along the center line of each house.

Prefabrication is achieved in the outer wall sections, which are manufactured in a factory and shipped to the site. These prefabricated sections are mounted on the structural members. All of the internal partitions are flexible and any internal arrangement is possible.

Switzerland

Swiss prefabrication in building systems is similar to that of the Germans. Many of the systems are designed with the German market in mind. Norm-Modul is a Swiss precast concrete constructional system developed by two Swiss architects. So far it has been used on various sites in Germany, and now the fully proved system is being used on two projects in Zurich. A freight building is being built for Swissair and is near completion, and the

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[15]Hulberg, p. 176.

other, only in the design stage at present, is a research laboratory.

Norm-Modul is intended mainly for industrial, scientific, and office buildings, and is aimed specifically at projects where future development is envisioned. A very limited amount of freedom is given to the designer, in that he can decide on the materials for the cladding and the nature of the windows. The rest of the structure is predetermined.

> Norm-Modul is designed with only three main elements. The structure is based on point loading, which gives much greater flexibility than the usual load bearing crosswall in precaste concrete construction, say the designers. The building is very carefully detailed so that it can expand at any point.[16]

The elements of the Norm-Modul system are usually cast in a factory, but this can be done on the site. Any type of service, no matter how complex, can be integrated into this system. Unless special reinforcing is used the height of the system is three stories, with the reinforcing eight stories can be attained.

Three principal members make up the Norm-Modul system, the column, with its variants, the beam and the decking elements. A number of secondary elements of a sophisticated nature complete the system.

> Thermal insulation is incorporated in the design. The electrical supply is distributed in the basement and from there, it is carried up in ducts which run

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[16]"Switzerland--'The Mail Order System is Here,'" Arena/Interbuild (January, 1967), 24.

> through a core in the building. . . . Rooms are planned so that partitions can be placed anywhere on the 1.20 m grid without any difficulties from pipes or radiators. Gas, vacuum, high pressure air, steam and water, and any other services used by laboratories are carried up in the core and then, as with the electrical supply, are distributed in the ceiling/floor space.
>
> A range of fourteen different types of partition is available. These vary greatly in cost, sound insulation and flexibility, but all can be fully integrated into the system.[17]

While this is a sound and specialized building system you still have the same situation that is prevelant in Western Europe, that is, a prefabricated system but not a modular unit development.

France

The Office Public d'Habitations a Loyer Modere of the Department de Bouches-du-Rhone initiated a project just outside of Marseille, and the method of construction chosen was the Fiorio system. The system is most unique and worthwhile looking at because of the materials used in construction.

Loadbearing walls have a hollow burnt clay core which takes advantages of the lightness of clay products and their good thermal insulation. Each panel consists of an external layer of concrete with a self-cleaning external finish, a 17 cm or 22 cm brick core containing seven voids and an internal 1.5 cm coating of plaster. The brick on the sides of the panels is left bare, ready

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[17]"Switzerland--'The Mail Order System is Here,'" p. 25.

for joining to the next unit. External windows are incorporated in the panels, which are story-height.

All units are prefabricated in the factory in horizontal steel molds. Each unit weighs approximately 250 kilograms per square metre. Partitions are story-height and have a 5 cm thickness of brick with two plaster coatings. Transportation and handling of the prefabricated units is an integral part of the overall construction process:

> Panels are transported on lorries with trailers adapted to carry them vertically. The panels are unloaded on the site at the foot of each building in racks designed for this purpose. They are then placed in tower cranes. An erection rate of 1.5 dwellings a day was achieved.[18]

This French system does have certain aspects which are different--the hollow burnt clay core--but, on the whole, here is, once again, a panel system for building. Panel systems of building all need supporting structural members to be placed on, thus reducing the effectiveness of their attempts at prefabrication.

Netherlands

What building in general and the prefabrication systems in particular needed was development of new and flexible materials. Designer J. W. H. Jordan built a prefabricated bungalow using as much plastic as possible

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[18]"France--Fiorio System Used in Marseille," Arena/Interbuild (January, 1966), 29.

to provide the lightest possible structure. All this research--which there is not enough of--was part of an overall development program towards the building of lightweight prefabricated units on a large scale.

Internally, plastics, have been used as far as possible for the sanitary equipment. A plastic wash basin is used to give maximum reduction in weight. But there are many problems, mainly because the state of plastic development for building is new and the developments limited. Panels of plastic are used for the walls, but then the problems begin. To quote the designer J. W. H. Jordan:

> There is a good selection of available wall panels, but there is as yet little to be had in the way of flooring and roofing. I should like to use sandwich panels for these, too, provided with a polyester surfacing. In the experimental bungalow I have had to solve the problem by conventional means. Hopeless! The ideal roofing would consist of panels which interlock with the wall panels. Sealing could then be done with mastic and you would no longer need to use bitumen.[19]

The use of plastics in building, specially modular construction, has yet to be fully explored. The possibilities are great, and at present the only work that is being done in the prefabrication of plastic fiberglass bathrooms of plastic panels is an operation breakthrough. The use of plastics for all facets of a building--walls, floors, ceiling, etc.--would reduce weight, transportation

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[19]"Netherlands--Steel and Plastics," Arena/ Interbuild (March, 1966), 37.

costs, erection costs, and overall building costs. An idea that needs further research.

Italy

Generally speaking, systems in Italy are based upon the same steel frame and panel system that is common throughout most of Western Europe. One such system is called the Moviter system, and it is a steel loadbearing structure with wall panels.

The great Italian architect, Pier Luigi Nervi, has not gone into and developed prefabricated units, but a number of his ideas have been adapted to prefabrication. The suspended structural system mentioned earlier in Germany is a derivative of a system developed by Nervi. Nervi was one of the first to use pre-stresses, prefabricated concrete for his structures. One example being his airport hangers at the Roman airport, unfortunately destroyed in World War II.

Europe is just now awakening to the full prospects of modular prefabrication, and a great deal is due to the influence of Operation Breakthrough in the United States and the fantastic works of the architect Moshe Safdie.

North America

In discussing developments in prefabricated modular construction in North America it will be divided into three parts: the first part being a description of Moshe

Safdie's work in the modular field, the second part, an outline of the work being done for Operation Breakthrough under the guidance of the United States Department of Housing and Development, and finally, a brief glance at some of the other work being done independently in the United States in the field of prefabricated modular construction.

Moshe Safdie

Whenever you think of Moshe Safdie you automatically think of Habitat at the Montreal's World Fair--Expo 67. And Habitat is the epitomy and prototype for prefabricated modular construction. Safdie first started working on a Habitat type environment while working on his architectural thesis at McGill University. His graduation and subsequent envolvement with Expo 67 was fortuitous; for both the future development of modular construction and the overall urban plan of Montreal. " . . . I felt we had to find new forms of housing that would re-create, in a high-density environment, the relationships and the amenities of the house and the village."[20]

Before Safdie designed Habitat he studied the various European building systems then in use. He came to the inevitable conclusion that they were all just panel systems that required conventional steel structuring and

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[20]Moshe Safdie, Beyond Habitat, edited by John Kettle (Cambridge, Mass.: 1970), p. 53.

finishing. Thus leaving out a possible 75 per cent further reduction in building costs. Safdie began to work in earnest to develop a modular system that could be totally prefabricated in a factory.

> I concluded, any system that didn't permit you to take 75 per cent into the factory was automatically obsolate. I also felt that the limits on these systems forced the architect to produce a vertically stacked cellular beehive of an apartment building. All the components met at corners, and corners are always the weakest point in the structure. Only in the U.S.S.R. was there further experimentation: instead of prefabricating panels, they were prefabricating whole rooms.
>
> So I came to the conclusion, as others have, that in order to take that 75 per cent into the factory, you had to deal not with panels but with volumes of space. You had to prefabricate cells of space in the factory, and put your mechanical services, plumbing, bathrooms, whatever else there was, into them in an assembly line procedure. You would then assemble the modules on site and, if connections were simple, you would have a 95 per cent-factory-produced building. . . .[21]

But the politics and the limitations of scale at Habitat soon diminished his hopes. Instead of one thousand units it would be 160 units. A lot of the material he required did not exist, so he had to create the material. Not only that, but the techniques and equipment to create his structure had to be created also.

One of the most enduring contributions that Safdie gave us from Habitat was the module. He considered the module his major challenge. The structure would be made up of box-like modules of identical size--a major decision

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[21]Safdie, p. 112.

with far reaching consequences. The modules would be produced in a factory, and they would be grouped in an intricate three-dimensional structure. It is of great interest and a help to us to examine some of Safdie's insights and thought processes:

> Establishing the size of the module was a long process. If it was to be the size of an entire dwelling, it would be too heavy to lift. Another disadvantage was that there would be very little flexibility in design; a module a quarter or a third of a house could be combined in many permutations to achieve a variety of house types. Next we investigated small modules, a room size, sixteen by sixteen; the problem there was that then we would need a large number of connections, and connections are where the money is; it would also increase the number of crane lifts. So we reached the conclusion that the module should be a complete one-bedroom house or one-half, one-third, or one-quarter of a large house. That meant a module of about six hundred square feet.[22]

Because of plumbing considerations and the structural properties involved, a three-foot-six-inch grid as the dimensioning matrix was established for the entire system. It meant that the length of the module had to be twice its width plus the overlaps for utilities and the inclusion of stairs. The final modular dimensions came out to be seventeen-feet-six-inches wide and thirty-eight feet-six-inches in length. This gave Safdie an area of just over 670 square feet, and about 640 square feet of floor area inside the walls. He considered this the minimum size for a one-bedroom unit.

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[22] Ibid., pp. 102-03.

Safdie considers one of the great failures of Habitat is in materials. He wanted to be innovative, to use plastics wherever and whenever possible.

> Working on Habitat I became increasingly aware of a basic shortcoming of the building industry. Its whole tradition is to build with what materials happen to be available. Every other industry defines its requirements and then develops the material best suited to the problem.[23]

But Safdie's success was in his example of what could be done with prefabricated modular construction. From Expo 67 and Habitat Safdie went on to do two other very important modular developments; one in Puerto Rico and the other in Israel.

Because of the economies of scale of Habitat a great reduction in the project's cost was not achieved. But in Puerto Rico he was designing and building for five thousand units, and he had learned alot from Habitat:

> By far the most important conceptual development of the Puerto Rico project was the great reduction in the number of pieces that make up the system. In Montreal the modular boxed units formed approximately half of the total number of precast pieces; in addition, elevator cores, street sections, access stairs, and other pieces had to be manufactured. A substantial percentage of the Habitat costs was in these additional pieces. Dramatic savings could be achieved if, in some way, these units could be reduced in number. It was from this that we evolved the idea that the module, by virtue of its shape, could accommodate some of the functions that had been provided for by the additional pieces in Habitat. If the shape of the roof of the module made it possible for it to act as a stair, one could eliminate the access stairs. If the roofs of some of the modules could form a pedestrian street, one could eliminate

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[23] Ibid., p. 104.

> separate street sections. The module that was eventually designed formed houses, created the internal circulation, created the system of passages, exterior stairs, and pedestrian streets on its exterior surfaces, and practically eliminated the need for any additional pieces.[24]

Also contributing to his success in Puerto Rico was the fact of a mild climate to work in and build for, and the advances state of the art of concrete building in Puerto Rico.

The Israeli project is still in the state of construction. It will be fifteen hundred units when completed. It too uses the art of concrete. The buildings are grouped in various size clusters and provide a roof garden for every dwelling unit. An integral part of the structure is a rotating dome, which adjusts to the time of day and to each season. Being built on a Jerusalem hillside enables Safdie to achieve some of the same economies in prefabricated pieces that he achieved in the Puerto Rican project. An interesting aspect about the two projects is that the one in Puerto Rico is basically backed by private industry and the one in Israel is government backed; but there is no lose in quality or economy for either project.

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[24] Ibid., p. 196.

Operation Breakthrough

A unique American program that for the first time in our long history of building and construction affords a reward for research and development to the building industry. It is our chance to experiment, and possibly provide, the answer to America's critical housing problem.

Operation Breakthrough was started in the summer of 1969, under the leadership of George Romney, Secretary of the United States Department of Housing and Urban Development, and his department. HUD sent out Requests for Proposals to more than four thousand organizations. The response was very gratifying. A total of almost 600 proposals were received from institutions and firms that included many that were new to housing, but most of the companies new to housing teamed up with experienced housing producers. All of the proposals were sorted into two categories: (a) complete housing systems that were essentially ready for production, and (b) advanced components, concepts known as "soft-ware," or needing further research. Each of these categories were evaluated by boards composed of experts from various fields connected with housing, i.e., architects, engineers, land planners, production specialists, and financial and management experts.

A list of four criteria for the evaluation of the proposals was made up:

1. The building system, or technical factors,
2. Management,
3. Financial capability, and
4. The site system or factors that relate the housing system to the building site and create a complete and attractive environment.

From this list of criteria a decision was made, and:

> On February 26, 1970 Secretary Romney announced the selection of 22 Housing System Producers from among the 236 in this category. They all employ, to varying degrees, industrialized techniques ranging from complete production of modules in a factory, to on-site assembly of completed panels and other components, to on-site poured concrete systems. Taken together, these systems attempt to accelerate the industrial revolution in the production of housing. Their generally conventional appearance is necessary to contribute to current marketability and consumer acceptance.[25]

Operation Breakthrough has a great deal of meaning for the future of planning in the United States. For one of the stated objectives of Breakthrough is to develop a sound basis by which future communities can be planned to satisfy the cultural requirements of America's society.

The materials used in the twenty-two various systems is as follows: seven of the systems selected use concrete; six use wood; five use metal as structural framing; two use plastic foam-core panels or modules; and

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[25] Manufactured Housing in the 1970's (Ann Arbor: Institute of Science and Technology, 1970), pp. 10-11.

and two utilize plastic fiberglass materials. The 22 systems will be built in 10 prototype sites across the United States.

> These sites were selected in order to give maximum market exposure to these systems and to maintain a controlled research atmosphere on approximately 3,000 units. Each of the housing systems will be monitored, tested, and evaluated in terms of site and production technology, as well as market acceptance.
>
> The prototype site communities will be occupied by residents on an intended racial, social, and economic mix basis. They are being planned by eleven professional site-planning firms, who were selected from a national competition in which they demonstrated innovative design and planning capability.[26]

Later on in this thesis there will be a description in detail on the type of systems used and the environment that is trying to be created. Now, however, it will suffice to just list the twenty-two companies awarded Operation Breakthrough sites and the type of units proposed.

The Aluminum Company of America: Consortium members and/or participants; Alcoa, Urban Design Associates, Ryan Homes, Urban Systems Research and Engineering, Inc., The Perkins & Will Partnership, Collins & Kroustadt; Slayter Associates, Inc., Andrew T. Kostanecki, Inc., Rohr Corporation, Sectional Structures, Inc., Tappan Co., Bryant Air Conditioning Co., Amstore Corporation, and Crossgates, Inc. They have proposed townhouses and multi-family walk-up garden apartments.

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[26] Ibid.

> The townhouses and garden apartments are constructed from factory-built, three-dimensional modular service cores that serve two living units. The modules, in conjunction with floor, wall, ceiling and roof panels, define economical space that can be freely planned and enclosed with a wide variety of exterior materials.[27]

Ball Brothers Research Corporation: Consortium Members and/or Participants; Ball Brothers Research Corporation, Borg Warner Corporation, Building Officials Conference of America, Inc., Elliott H. Brenner, AIA, Leo E. Zickler, American Fletcher Mortgage Co., American Testing & Engineering Co., Board for Fundamental Education, Oxford Development Corporation, Tectron, Inc., Floyd E. Burroughs & Associates, Ball Corp., Bradley & Bradley, Architects; Jack E. Goldberg, Weing Miller & Associates; Applied Decision Systems, Inc., Bolt, Beranek & Newman, Inc., George Foley, Harbridge House, Beryl Bernhard, The Foundation for Cooperative Housing, Blyth & Company, Inc., and The National Urban League. "Ball Brothers has extensive experience in aerospace and electronics fields, and has developed an industrialized building process. Other consortium members will provide specialized competence in design, planning, mechanical subsystems, and community involvement."

Henry C. Beck Company: Consortium Members and/or Participants; Balency-MEM-Us Corporation, William R. Morris, Henry C. Beck Co., Raymond D. Nasher Co., Borg

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[27] Ibid., p. 97.

[28] Ibid., pp. 99-100.

Warner Corporation, R. G. Greene Development Co., Keyes, Lethbridge & Condon, and Sulton & Campbell. This is basically a precast concrete system. It will use factory built concrete and floor panels, which are assembled on-site into all types of housing: single-family detached, townhouses, deck-house, and high-rise.

Boise-Cascade: Consortium Members and/or Participants; Dalton-Dalton-Little, Frank Hall Association, Computer Applications, Inc., National Building Agency, David Crane Association, Brevard Engineering, MIT-Urban Systems Laboratory. Boise-Cascade has a production capacity of over 1,000 dwelling units per week. They suggest a "product line" of housing units instead of the usual single unit. The company will have six basic building types: one-story single-family units; two-story single-family units; multi-family garden apartments, townhouses, low and mid-rise apartments and community buildings.

> The units will be constructed in factories on an assembly line basis utilizing three fabrication systems-panels, volumetric modules and a combination of utility cores and panels. Both wood and steel will be utilized as structural materials, separately and in combination.[29]

Christiana Western Structures, Inc.: Consortium Members and/or Participants; Christiana Western Structures, Inc., B. A. Berkus Associates, and Mutual Ownership

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[29] Ibid., p. 103.

Development Foundation. Christiana Western Structures can produce 6,000 housing units per year. This company uses a system of shop-fabricated, wood frame panels for walls, partitions, carports, and garages. Both interior and exterior finish materials are shop-applied, while windows and doors are shop-installed in the conventional manner. This system is used for single-family detached and attached dwellings, and can be used for low-rise multi-family structures.

Descon/Concordia: Consortium Members and/or Participants; Descon Management Corp. Limited, Concordia Management Limited, Philip David Bobrow, Arch., Maurice Gamze, Mechanical Engineer-Gamze, Korobkin & Dolphun Associates, Professor Colin H. Davidson, Industrial Systems Spec., Univ. of Montreal, Seymour Glouberman, Prof. of Philosophy, Neal Mitchell, Structural Eng.--Neil Mitchell & Associates, Kenneth Mabuchi, Hackett Housing Systems, Inc., Paul Spindell, Systems Analyst, Michael Brill, Arch.-Researcher Buffalo Org. for Soc. & Tech. Innovation, State University of New York, and George E. Buchanan, Arch. Their system utilizes readily available components or assemblies fabricated by utilizing standard manufacturing processes. "The structural system utilizes a factory-produced reinforced concrete panel system, which is

applicable to all housing types except single-family detached units."[30]

Forest City Enterprises, Inc.: Consortia Members and/or Participants; Forest City Enterprises, Inc., Forest City Materials Co., Thomas J. Dillon & Co., Inc., Top Roc Precast Corp., and Barbites-James & Assoc.

> Forest City will utilize a system of housing construction employing site erected precast concrete bearing walls with precast concrete floor panels. The system has been employed in high-rise apartment construction and has been designed for total flexibility permitting it to be used in single-family multi-level detached homes, row or townhouses, and multi-family, low-rise configuration. Prefabricated wood framing is used for infill exterior walls, all interior partitions, and the roof.[31]

Hercules, Inc.: Consortium Members and/or Participants; Hercules, Inc., Modular Structures, Inc., Armstrong & Salomonsky, Architects, Harlan, Betke & Meyers, Incorporated, and the University of Utah. They propose two systems of housing: for single-family attached, detached, and low-rise dwelling units, a conventional factory-fabricated wood framed volumetric module is proposed, while high-rise structures would use metal module frames and panels around which lightweight concrete will be poured.

Home Building Corporation: Consortium Members and/or Participants; Home Building Corporation. This company uses factory-built modular units. These units are

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[30] Ibid., p. 107.

[31] Ibid., p. 109.

twelve feet wide for highway transportation. They also provide a field-installed transition section which becomes the central hallway in a single-family unit. The principal material used is wood, but other materials can be used as costs permit.

Keene Corporation: Consortium Members and/or Participants; Keene Corp., Warner, Burns, Toan & Lunde, Grumman Corp., Node 4 Associates, Inc., Formigli Corp., Alvin E. Gershen Assoc., Inc., 3H Building Corp., Robert Hughes Associates, Ltd., Lennox Industries, Inc., Portland Cement Association, Ryan Incorporated, and Wickes Corporation. The system is known as the Townland Housing System and it is quite unique.

> The TOWNLAND Housing System stresses the life style that can be expected by its occupants and provides not only for the creation of housing units, but also for the creation of "synthetic land," thereby creating elevated pedestrian "streets" and individual earth-filled "backyards." This created land provides sites for a variety of residential, commercial, and institutional needs. The amenities and architectural variety of private dwellings are combined with the land economy of high-rise construction and the cost advantages of lightweight framing.[32]

The Townland Housing System uses two main subsystems: a main precast concrete structural frame and a lightweight prefabricated housing and modular, mechanical core units. Also, for rapid construction, the system can be used to rehabilitate depressed urban areas with a minimum of

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[32] Ibid., p. 113.

dislocation to the existing tenants by the use of air rights.

Levitt Technology: Consortium Members and/or Participants; Levitt Technology Corp., B. A. Berkus Associates, Inc., The Stanly Works, Auerbach Corp., Dunham-Bush, Inc., Hamilton-Howe, Inc., and Simpson Timber Co. Levitt is a name that has been associated with housing for a long time. This is their first venture in prefabricated modular construction. They propose a factory-built, volumetric, module housing system with flexibility in unit arrangements and floor plans. A various number of unit arrangements are possible; town-houses and both low-rise and high-rise apartments can be constructed. There are two basic modular types; "wet" modules, these include baths, kitchens, and heating and air-conditioning units, and "dry" modules, which are essentially living spaces. Wood-framed sectionalized housing modules are factory produced, and a structural frame allows for a variety of elements.

Material Systems Corporation: Consortium Members and/or Participants; Material System Cor-oration, U.S. Material Systems Limited, U.S. Financial, and Skidmore, Owings & Merrill. Material Systems Corporation uses a construction system based upon the technology of composite materials. They use a system which consists of applying fiber-reinforced resins and fillers in molds in an on-site

factory to produce prefabricated structural and decorative panels and other building components. These units are assembled on the job site.

Their choice of using composite materials allows them an almost unlimited choice in final appearance, depending only upon available designs.

Module Communities Incorporated: Consortium Members and/or Participants; Module Communities, Inc. (MCI), Celanese Corporation, American Standard, Inc., Industrialized Bldg. Systems, Inc., Paul Weidlinger, Consentini Association, U.S. Trust Company, Skidmore, Owings & Merrill, Hudson Institute, The National Urban League, Institute for Urban Environment--Columbia University, Urban Action & Experimentation Program (UAEP) Columbia University, Architects' Renewal Committee in Harlem, Urban Technological International, Association of United Contractors of America, F. D. Rich Company, and Royall, Koegel & Wells. M.C.I's main objective is to provide low-cost, high-volume housing production. Their system uses Tracoba precast concrete, and uses an on-site or near-site factory. They produce concrete panels and slabs and can construct a variety of structures; single-family units, townhouses, and garden or high-rise apartments. Variations of the various elements are possible.

National Homes: Consortium Members and/or Participants; National Homes Corporation, Edward Durell

Stone & Associates, Edward Durell Stone, Jr. & Associates, Semer, White & Jacobsen, Preager-Kavanagh-Waterbury, Cosentini Associates, and Computer Applications, Inc. The basic module used is a fourteen-foot wide factory-produced volumetric module system, and they will be used to mainly build townhouses, garden apartments, and low-, medium-, and high-rise buildings. The high-rise system will utilize a separate structural system for support, even though the modules can be stacked to a height of six floors. Flexibility is built into the system. There are three basic modules; the living module, the utility core module, and the bedroom module. Each module incorporates the architectural and structural elements relevant to its specific function or functions in the dwelling unit. The modular units are brought to the site by truck where they are combined horizontally and vertically to form complete building units.

Special exterior modules can be used to give occupants their own suitably protected and oriented outdoor space in all climate extremes. These can be considered environmental modules which add new dimensions of light and shadow, an important aesthetic element.

Pemton, Incorporated: Consortium Members and/or Participants; Pemton, Incorporated, InterDesign, Incorporated, Lorimer, Chiodo & Associates, 3M Company, Jacus & Amble Engineering, and Community Involvement & Development Associations, Inc. A brief description:

> This firm proposes a factory-produced volumetric module (UNIMOD), utilizing stressed-skin plywood technology. Plywood panels are held together by polymer bond that causes the panel to act as a single structural unit in resting loads. The system in a single panel unit contains the framing material, sheathing, and interior finishing materials, thereby reducing the weight considerably. The flat plywood stressed-skin panel is efficient and easy to handle and suitable for roofs, floors, and walls.[33]

The system is designed to mass produce homes, and to develop total environments and functional communities. The modules can be arranged in an unlimited variety of ways, and, internally, the rooms may be made any size. The modules can be arranged to create single-family homes, townhouses, and low-rise and high-rise apartments. The modules may be stacked to make two or three-story structures. Higher stacking of modules requires additional structural support.

Republic Steel Corporation: Consortium Members and/or Participants; Republic Steel Corporation, Bob Schmitt Homes, Inc., The Tappan Co., American Standard, Inc., Climatrol Industries, Inc., and Emerson Electric Company. Not surprisingly, steel is the principal structural material. A variety of detached, single-family dwellings for families with low to moderate incomes can be provided by combining the components in different ways. The system is made up of components that can be mass produced and assembled on-site. All subsystems in the

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[33] Ibid., p. 122.

Republic system are manufactured independently and assembled in the home preassembled.

Rouse-Wates: Consortium Members and/or Participants; Rouse Development Co. of the Rouse Co., and Wates Systems, Inc. (USA) of Wates Ltd. (London, England). Concrete panels are produced in a factory on-site. This system incorporates a concept of "community building" for the development of the total environment. This system was first developed by Wates Ltd. of Great Britain. Story high, precast concrete wall panels are joined with room size precast concrete floor panels at the site. Low-rise and high-rise structures can be created, and there is a flexibility in the arrangement of units. Rouse-Wates proposes an overall and comprehensive job of community planning, including the separation of automobile traffic from pedestrian paths, cluster units to create more open space, and the arrangement of facilities for twenty-four hour use.

Scholz Homes, Incorporated: Consortium Members and/or Participants; Scholz Homes, Incorporated, and Stiles-Hatton, Incorporated.

> Scholz Homes, Inc. uses a factory-built, sectional housing system shipped to site for assembly into a variety of floor plans. The system is adaptable to single-family, or garden type, multi-family living unit configurations by stacking the sectional units side-by-side or upon each other. The primary structural material is wood, and each modular unit is a complete structural component in itself. Completed house or apartment sections include "in-place" plumbing, heating, and electrical components. All of the

> exterior wall surfaces, integral floor deck systems, and ceilings, with all interior millwork and cabinetry, are completely finished.[34]

An unusual feature of this system is that a structure can be erected in one day with the use of a mobile crane.

Shelly Systems: Consortium Members and/or Participants; Shelly Systems, Inc., Banco Popular de Puerto Rico, Shelly Engineering Corporation, Hampton Development Corporation, Shelly Equipment & Finance, Caribilt Construction Corporation, Shelga Corporation, Carlos Alvarado, Housing Management Consultant, Dr. Luis E. Mora, Prof. of Structural Eng. University of Puerto Rico, U.S. Home & Development Corporation, Dr. H. R. Stanton, Prof. of Soc-Econ., Clark Univ., H. R. H. Construction Corporation, Dr. N. P. Loombay Prof. of Mgmt. (City College), Urban Systems Research & Eng., Inc., Robert Phillips (Chartet Mortgage Co.), Dr. August Komendant, Prof. of Advanced Concrete Structures (Univ. of Pa.), and Dr. S. K. Sc hiff, Prof. of Psychology (Univ. of Chicago). A module system based on precast concrete building block modules that are erected in a checkerboard pattern. This staggered pattern provides spaces between the modules that are the same size as the module itself. These spaces, when enclosed on the ends, provide livable areas, thus effecting a reduction in costs by elimination of the duplication of

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[34] Ibid., p. 128.

walls and slabs. The system allows for internal flexibility, and can be erected to twenty-two stories.

Stirling Homex Corporation: is a producer of factory-built housing for low- and middle-income families. There are two building systems:

> The low-rise system employes a factory-produced, wood framed, modular system consisting of three or four modules, varying with the number of bedrooms. Each module is approximately 12 feet wide by 9 feet high by 24 feet long. At the site, modules are stacked to form two-story individual and multiple dwellings.
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> Sterling Homex will also furnish a concrete and steel high-rise building system capable of rapid application to any selected site. This system employs an integral steel-frame concept which does not require a supporting or supplementary megestructure. The high-rise product, manufactured 90 per cent in the plant, will be erected by applying a unique, newly devised reverse-sequence erection system. The lightweight modules will be assembled at grade level, starting with the top or roof loor and ending with the bottom floor. Erection can proceed at the rate of one floor per day.[35]

TRW Systems Group: Consortium Members and/or Participants; TRW Systems Group, Bldg. Systems Development, Inc., Kaufman and Broad, Inc., and Mid-City Developers, Inc. This is a panel of modular system manufactured off-site, but when required, however, panels can be produced in an on-site factory. Room-sized modules can be produced and they are capable of various configurations. Because of a unique wrapping process, services will readily be incorporated into the module under factory scrutiny. Fiberglass reinforced plastic, cellulose honeycomb, and

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[35] Ibid., p. 132.

gypsum board are also used in the panel and module construction. Site planning is for a planned unit development.

Operation Breakthrough is thorough and comprehensive. All the various areas of industrialized housing are being explored, and the production of units has begun. Comparatively, the rest of prefabricated modular building development in the United States is scattered and not as advanced. Much of it is theory, a few are fact. These are the possibilities that will be explored next.

Other Work Being Done in the United States

Triad, a three-bedroom modular house produced by Hodgson Houses, is technically advanced and unusually aesthetic. This modular system was designed by architect Edward M. Coplon, and it consists of two modules; in one are the living areas, free and open, and, the other, a bedroom wing, separated and quiet. Inserted between the two is a glass-ended entry and dining unit. The architect has created an open and free space, with large window areas.

The house includes insulation and utilities, major kitchen appliances, plus interior and exterior finishing. The cost, not including foundation set-up, transportation, and land is under $15,000. The units are shipped by truck up to a 400 mile radius. Even including the extra costs,

the total price of the modular house is still a great deal less than that of a conventionally built home.

Factory fabricated multi-family housing, by Housing Research Incorporated, proposes to manufacture apartments in the form of two wholly finished components, which are hauled by truck to the construction site. There they are assembled around a third manufactured component containing all the utilities, services, kitchen and bathroom. The individual units are structured to permit stacking one on top of the other.

The heaviest unit weighs about five tons and can be lifted into place by a twenty-five ton crane. A housing development of 100 units, positioning the units on prepared foundations, can be completed in 25 working days.

The basic elements, therefore, are a central utilities core, a living-dining unit and a bedroom unit, all manufactured away from the construction site. The manufactured units are sized for highway transport, which dictates a maximum width of twelve feet. The core unit is 12 feet square and the other two units are each 12 feet wide and 30 feet 8 inches long.

Expotential Space, by Renato Severino, a professor of architecture at Columbia University, is theory:

> The determining characteristics of Equipotential Space are continuity, flexibility, and articulation. Instead of being planned for a few specific purposes, Equipotential Space can be modulated at will for any purpose.

> Inherent in a model of this methodology are two independent and complementary subsystems, both of whose components are industrially produced. The components of the first subsystem define and structure the physical limits of a volume or territory in predetermined scale incrementally.
>
> The components of the second subsystem provide the necessary environmental conditions and apparatus that allow these volumes to be used according to a particular program. We will speak of our methodology as a system of Equipotential Space and of its two subsystems as Frame Components and Function Objects.[36]

Severino calls for a mass production of both Frame Components and Function Objects. The materials chosen should enable the unit components to be fabricated and easily transported.

But Severino's own models show a problem, one of repetition. His environments lack interest and differentiation. His universal call for standardization reduces our freedom of choice and his theoretical efforts show no solution to this problem.

The modular units being built as part of Operation Breakthrough and the work being done by Moshe Safdie offer a great promise for the future of industrialized housing. Discussion has been the overall view--what exists--but what of the critical technical aspects of prefabricated modular construction? Are the hopes and dreams feasible? It shall be seen.

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[36]Renato Severino, Equipotential Space (New York: 1970), p. 27.

CHAPTER II

THE TECHNOLOGICAL ASPECTS OF PREFABRICATED MODULAR CONSTRUCTION

Within the two basic systems of prefabrication there are technological aspects and characteristics that they have in common. In both the panel system of prefabrication and in the modular concept there are many of the same materials and equipment in use. Structurally there are great differences and requirements. The two groups will be discussed individually, without going over every system mentioned in the first chapter, but instead, dealing with basic characteristics and important aspects of materials, construction technique, components, structural aspects, and design capabilities.

Panel Systems

These types of prefabrication systems are prevalent in Western Europe. They all have one very important and basic thing in common, they all require a structural system of support to place the panels on.

The panels themselves are made out of almost every conceivable material. Everything from concrete, wood, steel, glass, and plastics are used. There are also many ingenious methods and materials that are used to build the supporting framework and structures for the panel systems.

"Suspended Towards the Sun" is a case in point. This German system has adopted an idea of Pier Luigi Nervi's into a prefabrication system. All loads are carried by vertical cables, hung from secondary suspension cables, which are connected to main suspension cables directed into the mast and anchored in these masts.

> With the exception of foundations, the structural system is completely prefabricated, the space net itself being preassembled and then raised up the mast. The construction procedure is simple, commencing with the erection of the mast and the main cables attached to it. The space net is then hoisted into position along the cables. After the system has been pre-tensioned, the floor slabs are laid in by crane and the walls erected onto them.[37]

Systems using suspension cables have been used, and are being presently employed, but mostly for modular units, not usually a panel system. That is why this case is so unusual.

Other panel systems have a number of basic things in common. A foundation has to be put in, and this is done in the conventional way. The structural support is usually built out of structural steel or concrete beams

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[37]"Design-Germany--Suspended Towards the Sun," Arena/Interbuild (January, 1968), 20.

and posts. The placement of these steel and concrete supports is by crane. These cranes are also used to place the various panels in place.

> Panels are transported on lorries with trailers adapted to carry them vertically. The panels are unloaded on the site at the foot of each building in racks designed for this purpose. They are then placed by tower cranes. . . .[38]

The lighter the panel material used, the cheaper it is for transportation, ease of erection, and speed of construction. Concrete has been used for a long time, and through research and development the strength has been increased and the needed thickness decreased. Thus a savings in weight, time, money, and transportation costs. This is why the research and development of plastics is so useful and important.

Panels, like modular systems, sometimes have core or component systems. These cores or component systems are self-contained units that have utilities, electrical wiring, heating and air conditioning units, and sometimes even kitchen facilities. An example of this is the previously mentioned Swiss system, Norm-Modul.

> There are a number of secondary elements of a sophisticated nature that complete the system. . . . Gas, vacuum, high pressure air, steam and water, and any other services used by laboratories are carried up in the core and then, as with the electrical supply, are distributed in the ceiling/floor space.[39]

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[38]"France--Fiorio System Used in Marseille," p. 29.

[39]"Switzerland--The Mail Order System is Here," p. 25.

When panels are mentioned, it is not just wall panels that are being thought of, also being referred to are floor panels and ceiling panels. But the real key and common denominator of all the panel systems ia a mathematical system of proportion creating a grid or matrix which allows the system consistancy, flexibility, and the ability for expansion.

The Norm-Modul is once again a good example, this time of a grid system. It is based on the following.

> The structure is planned on a module of 7.20 m and the planning grid is 1.20 m. This secondary dimension is displaced by 60 cm on the larger structural grid, so that the partitions never have a joint with the columns, and internal planning is completely free. The vertical planning dimension is half the standard planning module, that is 15 cm. It is possible to increase the storey heights in increments of 15 cm, but the usual storey height is about 4.20 m.[40]

Another grid system is the adaptable and expandable house by the Norwegian architect Erik Hultberg:

> Each site is divided into a grid with squares of two sizes. The large central square, 4.40 x 4.40 m, is common for all houses, regardless of type. Stairs and bathroom-utility rooms, . . . are always adjacent to the central square. The rest of the site is in principle divided into squares, 3.00 x 3.00 m.[41]

All the panel systems base their mathematical matrix's on the vertical height, the desired story height, and the horizontal distance, which can be based on any number of things. Usually the horizontal distance is

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[40] Ibid., p. 24.

[41] Erik Hultberg, p. 176.

based on a flexibile grid that can easily be used to create the desired spaces, whether a living space, working space, or learning area.

Prefabricated Modular Units

Modular units are much more complex and require different construction techniques, equipment, use of materials, components, and design concepts.

Modular units are three-dimensional while panels are two-dimensional. There is great significance in this simple and obvious fact. All things change because of it; the mathematics, components, weight of units, strength of materials and types, design possibilities, and possible savings in overall construction costs.

An obvious problem that a three-dimensional modular unit has is its great weight--the Habitat modules weighed about eighty tons each--and how to put them in place.

> Establishing the size of the module was a long process. If it was to be the size of an entire dwelling, it would be too heavy to lift. Another disadvantage was that there would be very little flexibility in design. . . . Next we investigated small modules, a room size, sixteen by sixteen; the problem there was that then we would need a large number of connections, . . . it would also increase the number of crane lifts.[42]

The resolution of the problem of the modules weight and flexibility in design was solved jointly. The

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[42]Moshe Safdie, pp. 102-03.

module would be a complete one-bedroom house or one-half, one-third, or one-quarter of a larger house. Its weight of eighty tons was lifted by a completely new technique using the basic principles of physics. The problem of lifting is really two problems; one is the problem of the units weight and, the other, the problem of lifting this weight to the required height called for in Safdie's plans. The solution was the use of two cranes; together they could lift an eighty ton unit 120 feet in the air. In Safdie's words,

> We suggested getting another, smaller crane, then we would put the two cranes opposite each other and the box in the middle, connected them both to the cross bar on which the box would be placed. This would give each crane the proportion of the load it could carry, i.e., it would be proportional to the distance from the end of the cross bar to the box.[43]

Safdie and other architects have adapted this method in the construction of modular unit developments. In the future the idea has been considered that the giant Sikorski helicopters could be used as sky cranes to more easily and quickly lift modules into place.

Modular units can be structural units themselves--they support their own weight and the weight of the units above them--or they can be plug-in units. Plug-in units are modular units that are not structurally supporting and because of this they require a structural system such

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[43] Ibid., pp. 126-27.

as that of panel systems. Hence, with plug-in units the frame work is there but instead of constructing each unit and floor separately as you go along, the modular units are put into place intact and complete.

Because of the different structural requirements, however, these various units are constructed out of different materials or the same materials which are used in different ways and in different quantities.

Architect Robert Fawcett in his design for the architectural competition sponsored by the European Coal and Steel Community was required to use various forms of steel. He came up with a module using corrugated thin steel sheets with a stressed skin structural system. But he had no choice in his materials. Others have found the choice of materials to meet their needs limited, but a choice is possible. For Habitat Safdie was also faced with this decision:

> Once we established the module there came the question of material. We thought about various plastics, fiberglass, and combinations of materials. But the plastics were too expensive, they were unpredictable technically, and above all, they melted at low temperatures. We considered steel too. Sheet metal had to be fire-proofed and, once fire-proofed, it became extremely costly and heavy. That led to concrete.
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> Concrete, unfortunately, is a very restricting material. It can take hardly any tension, it's relatively heavy and porous, and the most advanced methods had to be used in order to be able to construct a complex three-dimensional building at all.[44]

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[44] Ibid., p. 104.

Such is the state, however, of technical advancement in the United States, including the building industry, that Safdie was able to build modular units in Puerto Rico only six years later with walls of concrete half the thickness of Habitat.

Materials used for Operation Breakthrough give a good idea of the general direction being taken; seven systems use concrete, six use wood, five use metal as structural framing, two use plastic foam-core panels or modules, and two use plastic fiberglass materials. The ideal material for building prefabricated modules exists today, but only in laboratories, for as yet it is too expensive and experimental for general mass use. This material is a member of the hydrocarbon family of polymeric materials. It would have approximately one-fifth the weight of concrete, twice the strength of steel, it would have compressive strength and density, it would be able to provide insulation, and it would be able to be impermeable to water.

Ball Brothers Research Corporation, a participant of Operation Breakthrough, has come up with a new variation on the use of plastics, a very interesting one. They are building a system with a foam plastic core, structural panel system which can utilize standardized doors, windows, and other hardware.

> The aluminum extrusion serves as both the edge of the panel and as a major component of the panel locking system. After foaming, and before the panel is allowed to cool completely, the exterior surface is covered with a coat of epoxy matrix and stone aggreate. Internal surfaces may be pre-finished with either paint, wall paper or integrally surfaced hardboard.[45]

The TRW systems group is also a highly advanced plastic/fiberglass system. The units have a unique wrapping process, services are easily incorporated into the modular under factory conditions. Utilized is fiberous glass reinforced plastic, cellulose honeycomb, and gypsum board. The TRW system is highly flexible in configuration and interior design.

But the use of new material and ideas has taken the greatest leap forward in the area of components and interior prefabrication. From Habitat came a number of advancements, none more technically advanced and practical as the prefabricated modular bathroom.

> From the outset I had hoped to have the bathroom, kitchen and partitioning system as pre-manufactured components. Fuller designed a prefabricated bathroom in the thirties for his Dymaxion house, and there had been attempts at prefabricated kitchens, but none had been commercially produced. The Habitat components, I felt, must conform with codes, or a revised code, and had to be within industry's capabilities.
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> The bathroom had to come as a complete room. We rejected metal because we realized the tooling cost would not be realistic for a 160 units. Eventually we concluded that gel-coat fiberglass was the best material.[46]

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[45] Manufactured Housing in the 1970's, p. 100.

[46] Moshe Safdie, pp. 107-08.

When bids were sent out they got only one offer, from Reff Plastics and Tielemans in a joint venture. For sometime Reff Plastics had been working on their own fiberglass bathroom. Safdie and Reff Plastics designed the prefabricated fiberglass bathroom over a period of time together. Following Expo, the bathroom was modified to overcome the difficulty of shipping it. It was changed from two to three sections that fit into one another so that it could be shipped in a small package. The bathroom was put on the market after Expo and sold for approximately six hundred dollars. Later, the Crane Company bought out Reff Plastics and put the fiberglass bathroom on the international market.

A prefabricated kitchen was desired for Habitat, but the total units were not of a practical number and the technology was not quite ready. Presently, prefabricated kitchen units are appearing, noticeably in Operation Breakthrough.

The Descon/Concordia system utilizes prefabricated kitchen element. Both kitchen and bathroom components are made up of modularly coordinated elements to provide a variety of assemblies and arrangements in order to meet a great variety in unit layouts.

The Levitt system consists of two basic modular elements, a wet module and a dry module. The wet module is the unit that contains baths, heating and air conditioning equipment, and kitchen elements. These kitchen

elements can be completely prefabricated in the factory, delivered to the site, and placed on the foundation by a crane.

Both the Shelly Systems and Rouse-Wates build modular units that contain almost completely prefabricated units, including the kitchen elements as well. They are put together at the factory and put into place on-site by the use of cranes. The Levitt system is a more complete system of kitchen facilities, while the other systems require work done--to a degree--when put into place.

There are many new types of kitchen and laundry equipment for use that did not even exist six years ago when Habitat was being created and modular development really began moving in North America. Now Operation Breakthrough and other prefabricated modular systems can use these new and more compact units to completely prefabricate a kitchen. There are thirteen units, and while some are mundane and others, perhaps a little bit unnecessarily exotic it seems, they all go to make up a desirable kitchen for any typical American who is used to the middle-class and affluent way of life. Other, full-size units are available too, but these units because of their compactness offer a unique opportunity for modular and core development. They are:

1. Water purifier, by Westinghouse, $130
2. Toploading washer, by Maytag, $289
3. Chafing dish to cook food or keep it warm, by Oster, $40

4. All-in-one mini-kitchen in one compact unit, by Sub-Zero, $450
5. Tall and skinny trash compactor, by Tappan, $229
6. Ready-when-you-are tea-maker, from Hammacher Schlemmer, $140
7. Super-flexible "Quintisserie" is a five-in-one unit, by Ronson, under $100
8. Side-by-side refrigerator/freezer, by Topp, $189
9. Lightweight countertop dishwasher, by Kenmore for Sears, $50
10. Latest toaster/browner/oven, by General Electric, $40
11. Trash compactor, by Amana, $230
12. Microwave oven, by General Electric, $400
13. Compact washer rolls around on casters, by General Electric, $219[47]

A large number of the modular systems rely on a core. This core contains some of the essential elements of a unit, if not all of them. Typically, a core contains the heating and air conditioning units, plumbing, electrical wiring, waste disposal unit, and sometimes kitchen facilities.

Most of the equipment in a core unit is pre-assembled in a factory, while connection are made on site. The core is lifted into place by a crane and acts as another modular unit in construction. Ball Brothers uses a core in their system.

> A central core, containing the heating, bathing, air handling, food preparation center, and waste provisions for the dwelling, is prefabricated and delivered to the building site as a complete modular unit. The building concept permits the erection of single-family attached dwellings, multi-family

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[47]"Ingenious Equipment--New, Electric, Versatile, Compact," House and Garden (February, 1972), 68-69.

> low-rise dwellings, and the possibility of high-rise, multi-family dwellings.[48]

Many systems use a variety of core modules, some with less or more contained in each one depending on the system. But the more that can be prefabricated and assembled into a core unit at the factory the closer a building system moves towards total prefabricated modular construction. Other systems in Operation Breakthrough and Western European systems rely on cores, they are an integral part of systems building.

A unusual and very important system is plumbing, and modular construction can, depending upon the mathematics of the grid system employed, make the use of the typical and often used plumbing system impossible. Moshe Safdie found this to be true while working in his plans for Habitat.

> One of the problems of piling up boxes in a complex three-dimensional pattern is the plumbing. In conventional building each fixture has a vent to the atmosphere to eliminate the vacuum that is created when the water is sucked out of the toilet, tub, or sink. These vents are traditionally carried to the roof, where the odor is dissipated. If we had used this conventional method little pipes would have stuck up in people's gardens and vented the stink of the neighbor below. We asked our mechanical engineers, Huza-Thibault and Nicholas Fodor, to tackle the problem; they suggested Sovent, a system that had been developed in Switzerland. It had never been used but its inventors claimed it could eliminate the need for a vent. It is a funnel-shaped piece of pipe that stirs up the water as it goes down the drain and mixes

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[48] Manufactured Housing in the 1970's, p. 100.

it with air so that it does not create a vacuum in the trap.[49]

The Sovent system has great potential for the whole building industry. It serves a necessary function for traditionally constructed buildings as well, it saves one complete pipe run. This system is now owned by the Copper Pipe Manufacturing Institute and only permits its use in projects that have the entire plumbing system in copper.

At the heart of the new impetus of prefabricated modular construction are two things; one is the new materials being developed and the technical ability to be able to apply them, and the other is the mathematics of prefabricated modular construction, or the grid system. This grid system is nothing more than the application of production line techniques and the practice of standardization to create for the first time a true building industry. An industry that does not build piece meal, a building here, a development there. It can now build a structure or group of structures anywhere in North America using the same knowledge and production techniques without reinventing them every time.

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[49]Moshe Safdie, p. 119.

CHAPTER III

MICRO- AND MACRO-SPACE AND OUR ENVIRONMENT

"Space, the final frontier." Says Captain James T. Kirk of the Starship Enterprise. Functional and social space is the last frontier of architecture, the last holdout against critical evaluation and a criteria for the social and functional needs of man and the space he creates by his structures. Since the primitive periods of architectural design there have been aesthetic criteria and evaluations. Requirements and functional needs were incorporated into a design, or at least the reasons for the buildings existence--its functional purpose--were supposedly put into the design of the structure. The social and functional needs of man for the internal layout and external design were supposedly considered and evaluated. However, there has been no criteria of effective notation for the evaluation of a space created before a structure is built. The worth of a structure has previously only been measured by how it meets a

number of non-spatial criteria. That criteria being one's judgment of an architect's work on aesthetic and economic standards in use at that time. Even then when people are evaluating the space created by, and the spatial relationships of people to the structure, they notice it as if by accident. If an architect is successful it is attributed to the aesthetics of his building not to his understanding of functional and social space, nor is it assumed that he created the feelings that surround the use of that space about his structure intentionally. How can society judge the spatial affects that a structure creates without having to actually build that structure?

Now that society is approaching that new frontier and is about to cross it. The tools for the creation of a criteria for the functional design space are at hand. Through the works of such men as Edward T. Hall, Christian Norberg-Schulz, Christopher Alexander, Kevin Lynch, Moshe Safdie, Le Corbusier and others we will put down a notation for a list of criteria to evaluate architectural space. Distances, perception and man's role in space and his cultural habits, which vary from society to society, are taken into consideration. Society must know in advance if a housing project or planned development will succeed on the social/functional level. Society cannot afford the disasters of urban renewal housing projects and the money and lives wasted. Our time is not great, and our resources

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are limited. Our society must be able to make rational decisions based on hard information.

In such an overall evaluation of architectural space one must come to the modular concept and the questions it might create. Will modular construction tend to create a repetative and dull environment? Can the modular form of construction create desirable internal layouts of space, with variation enough to meet the differences inherent in every population? Will modular units be of a high quality, use quality materials, and allow for flexibility of external design? And, will the external space created by modular units be able to meet man's social functional needs?

Micro-Space

Now man uses space and shapes is just another aspect of his particular culture. An object such as a building does occupy space, define that space, but it also creates a relationship to and defines the space around it. Proximics is the term Dr. Edward T. Hall has coined to describe man's use of space in relationship to his culture.

Man, like all animals, has a minimum space requirement, without which tensions and hostility develop. Dr. Hall's studies gives us an insight into this phenomenon, and using his research for a basis one can begin to develop a logical system for evaluating the architectural

spaces created by a structure. Dr. Hall has been delving into the urban environment too, and this has lead him to some interesting observations and conclusions.

> Today, one's unconscious picture of one's self--the life one leads, the minute-to-minute process of existence--is constructed from the bits and pieces of sensory feedback in a largely manufactured environment. A review of the immediate receptors reveals first that Americans who live urban and suburban lives have less and less opportunity for active experiences of either their bodies or the spaces they occupy. Our urban spaces provide little excitement or visual variation and virtually no opportunity to build a kinesthetic repertoire of spatial experiences. It would appear that many people are kinesthetically deprived and even cramped. In addition, the automobile is carrying the process of alienation from both the body and the environment one step further. One has the feeling that the automobile is at war with the city and possibly with mankind itself. Two additional sensory capacities, the great sensitivity of the skin to changes in heat and texture, not only act to notify the individual of emotional changes in others but feedback to him information of a particularly personal nature from his environment.[50]

In Dr. Hall's research he has found that there are four distances, each having a close phase and a far phase. They are mathematically discernable and consistant, varying only by culture. Most of man's actions comprise a spatial aspect. To further his intentions man has to perceive spatial relationships and then be able to create a concept for the evaluation of space.

The closest distance is intimate distance. This ranges from contact to about six inches, and is associated with comforting and protecting, lovemaking and whispers.

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[50]Edward T. Hall, The Hidden Dimension (New York: 1966), p. 59.

The far distance is from six inches to eighteen inches. Both of these distances are not used by Americans in public, except in crowded places such as on a mass transit line. And if people are forced into an intimate distance they react defensively to protect themselves and disallow any real intimacy out of the contact.

Personal distance in the close phase is from one and a half to two and a half feet. Vision is not distorted at this distance, but a feeling of closeness does exist. Texture is extremely clear at this distance. The far phase is from two and a half to four feet. This is the distance of discussions and personal interest, the anatomy is easily perceived and the voice is level.

From four to seven feet is the close phase of social distance. Impersonal distance is carried out at this distance, while details of another person are clearly perceived. The far phase is from seven to twelve feet. This distance can have an interesting use, it can be used to insulate or screen people from each other, enabling them to continue their work.

The close phase in public distance is from twelve to twenty-five feet. The voice rises and vision becomes flat. An alert person has the opportunity to take evasive or defensive action when required. The far phase is from twenty-five feet or more. This distance can be used by

anyone at public occasions and is the distance automatically set around important public figures.

These four basic distances are the beginning of a basis for an evaluation of micro- and macro-space. They tell us a great deal about concrete distances and how man reacts to people at these distances. Yet this is not enough, Dr. Hall's research must be intergrated with other concepts to bear fruit. How does man perceive a space?

In his book, Existence, Space and Architecture, Christian Norberg-Schulz puts forth the idea that space is not a particular category of orientation, but an aspect of any orientation. So, to have man carry out his intentions, man has to understand spatial relations and unify them. One way of looking at space still omits certain aspects.

> From remote times man has not only acted in space, perceived space, existed in space and thought about space, but he has also created space to express the structure of his world as a real imago mundi. We may call this creation expressive or artistic space, and it finds its place in the hierarchy next to the top, together with cognitive space. Like cognitive space, expressive space needs a more abstract construct for its description, a space concept which systematizes the possible properties of expressive spaces. We may call this "aesthetic space." The creation of expressive space has always been the task of specialized persons, that is, builders, architects and planners, while aesthetic space has been studied by architectural theorists and philosophers.[51]

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[51]Christian Norberg-Schulz, Existence, Space and Architecture (New York: 1970), p. 11.

A criteria for structures and the space that is around them must be a combination of the functional requirements of that space incorporated with aesthetic values. Individuals, however, usually interact with other individuals and/or groups and we must progress to a notation that includes and encompasses man and groups occupying larger areas of space.

Macro-Space

Both Kevin Lynch and Christian Norberg-Schultz deal, in part, with areas of expressive space. They break up an area or city into its various component parts. Lynch into districts, edges, imageability, landmarks, nodes, and paths; Norberg-Schultz into places (proximity), directions or paths (continuity), and areas or domains (enclosures). It seems that Norberg-Schulz has reduced Lynch's notations and simplified them.

These notations suffice for already existing spaces and structures, but what of the yet unbuilt structures and spaces? These require a notation for prediction. A combination of Hall's theories with a way of looking at larger areas of space offers a method of establishing a criteria for areas immediately surrounding a structure, an area that could encompass part of a city or a city itself.

What is trying to be achieved for micro- and macro-space is a specific orientation and therefore an

evoked feeling from the various spaces. Man's structures and spaces have been created on purpose for a specific purpose, and the creation of a notation for the evaluation of space will be a guide towards this end. People must be observed as Dr. Hall has done, note the proxemics of a culture, and create micro- and macro-spaces accordingly. Norberg-Schulz sees space and function as: "Space is therefore the product of an interaction between the organism and the environment in which it is impossible to dissociate the organization of the universe perceived from that of the activity itself."[52]

As Le Corbusier called for, we must link man, the person, to the spaces that are being created. His scale of functional and social space, his individual measurements and his proxemics for the paths, nodes, districts, edges, and domains or enclosures of micro- and macro-space.

Geometry and grids are not the measures that are going to be dealt with, it is the integration of mathematics with culture to arrive at proxemic values. Geometry and grids alone cannot solve a problem that is rooted in social and cultural variations.

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[52]Norberg-Schulz, p. 17.

Notations on a Criteria for the Evaluation and Design of Micro- and Macro-Space

By the use of some basic examples, with the potential for their variation and inter-changeability, this author will create a criteria to be used for the creation of functional and social space with an architectural structure or structures.

How does one go about evaluating the space created around a structure and what impact does it have on the surrounding area of the city?

There are two spatial concepts to be dealt with--micro- and macro-space--when evaluating a structure and the space created around a structure. Under micro-space there are five types of space possible, and they are derived from Dr. Hall's work:

1. Intimate Space
2. Personal Space
3. Social Space
4. Public Space
5. Or any Combination of the Spaces Above

Under macro-space the five types of spatial arrangements are:

1. Nodal Promintory
2. Focal Point to be the Basis of a District
3. Edge
4. An Enclosure
5. Path

Presume it was desirable to build a government complex, and as part of this complex of structures a large outdoor square is to be an integral part. First, if there is complete control over where one will be able to build (in reality highly unlikely) our structure or structures, what type of macro-space is desirable to create?

Can one design the structure or structures to be able to influence the area in which it will be located to create the desired effect? An enclosure, a focal point to be the basis of a district, a path, etc. Any one of the various types of macro-space requires a thorough researching of an area to determine its consistency: does the area consist of single-family detached dwellings; is it an area of high-rise apartments; is it some combination; there are numerous possibilities. Will the structures that are going to be erected be able to physically or mentally dominate an area, like the John Hancock Building in Chicago. Will it be so economically important so as to attract further development of the same or similar aspects? All of these are decisions that are based on a value judgment of what exists by a architect or planner. Drawing a sketch or map of the area with the object in mind of determining the paths, landmarks, edges, districts, and nodes that exist is a necessary requirement. Once this is done one is then able to determine the impact of

one's project by superimposing one's plans on the area that has been thoroughly mapped, and by so doing so to be able to determine if one's project will be in a position to create any of the five types of macro-space. For instance, the new government complex in Boston is large enough and economically important enough to dominate that part of Boston and create a district. By placing the plans for this complex on a map of the area and examining its economic impact before construction, one would have been able to determine that this would be the case.

These are judgments, but not necessarily subjective judgments. Economic and physical impact can and have been examined by Kevin Lynch in this manner, and correct conclusions have been reached on determining the effect a structure or structures will have on a district of a city.

In the government complex that is going to be built, let it be said, for example, that a government district can be created by the building of a complex of structures. In this governmental complex it has been already decided to create an imposing public square which will be the focal point of this project, and to be the take-off point for future development in this area to create that governmental district.

Finally, one must evaluate the space and determine its potential for fulfilling its social and functional

space requirements. Its design potential can be determined and social/functional value for its use as a public space by two means, they are: one is by one's "aesthetic" judgment of the architects' or planners' designs (form, shape, proportion, perspective, color, materials used, etc.); and two, by the application of Dr. Hall's research into proxemics that gives us definite measurements and conditions for each of the previously mentioned distances.

As stated before, the close phase of public distance is from twelve to twenty-five feet, and the far phase from twenty-five feet. If the architect has created a large dominating public square it will obviously be over twenty-five feet. But within the total volume of that space the architect will have tried to break-up the area by the use of such materials as plants, shrubs, trees, benches, a monument, etc. All for the purpose of trying to create a closer feeling within the public space, and yet have it remain a public square. Does he have areas that provide rest but are so arranged with the landscape so as not to force conversation upon someone, but to have a distance that does allow for social contact if desired? The use of the far phase of social distance, from seven to twelve feet, will accomplish this aim. These areas surrounding and yet being a part of the overall total square will make for a well used public square that will fulfill its intended purpose.

A less obvious example is that of a restaurant that desires to create intimate spaces for dining and a complex of personal and social spaces for dining in larger groups. It is the creation of self-contained enclosure, which is entirely separate from the surroundings outside of the restaurant walls.

With the use of the intimate and personal distances it is possible to create the intimate dining areas from contact to up to four feet. If these areas are separated from each other and appointed with the right decor and lighting, one has created a space to meet its required function.

It is a bit more complicated to create the larger areas. The spatial delineations for areas of this type are from one and a half feet up to twelve feet. With the emphasis for design on the upper extremities an area of up around twelve feet will be ideal for the larger groups, and four to seven feet for smaller "social" groups. Part of social distance is:

> Another person is perceived as normal in size. Details of the other person's body are clearly perceived, and a person's gaze may shift from eye to eye and eye to mouth. This is the spatial distance of impersonal business, many people use this distance while at a social function or in dealing with previously unknown business associates.[53]

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[53]Dr. Edward T. Hall, p. 116.

Here is the offer of a guideline. A guideline such as Le Corbusier offered in his book Le Modular but freer in form and content. Le Corbusier's matrix are mathematically precise, based on the human form. The view that is held is based on the human scale of culture and man's actions at precise distances.

The use of materials and aesthetic design are always in the judgment of the designer, and therein lies the major reason for employing a particular architect or planner. But his use of space can be evaluated and checked to see if his plans meet certain basic criteria.

Another example is a proposed project, here the object is to redesign a park to create a path from the university on one side and a shopping district on the other side. Included are spaces for playing, open spaces, and intimate and social spaces for interaction.

The creation of a path is a relatively simple matter. Since paths are the channels along which a man normally, occasionally, or potentially moves, the creation of a walkway through the park to link-up both of the sides is the answer. This pathway must have only one logical conclusion; one side or the other, with no major deviations or turnoffs other than to social or play areas.

The interaction spaces, those intimate and social spaces, can be based on the data provided by Dr. Hall. With the actual vegetation and materials based upon the aesthetic judgment of the designer. No space is entirely

isolated from the space next to it; a wall divides that space but those spaces still interact. Dr. Hall has found that different cultures have different space perceptions, and our society is made up of a great number of ethnic groups. All efforts must take their various cultural differences into account, balanced on the other hand by the fact that structures--their use and occupancy--can always be subject to change. One must be flexible. A person must design and plan for sensory awareness.

> How far can we afford to travel down the road of sensory deprivation in order to file people away. One of man's most critical needs, therefore, is for principles for designing spaces that will maintain a healthy density, a healthy interaction rate, a proper amount of involvement, and a continuing sense of ethnic identification.[54]

With this awareness a person can plan apartments, parks, towns, districts of cities and be able to evaluate space before he builds.

Summary

Any system in design for an evaluation of space must be based on our two criteria: aesthetic judgment and proxemics. With proxemics one can deal effectively with variations in culture--black and white, German and American, oriental and western man, etc.--and plan internally and externally for spaces to meet a particular function that the space is required to be used for.

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[54] Ibid., p. 157.

In this case form does follow function. Each one of the distances; intimate, personal, social, and public with their close and far phases, has a function. The form our designs take should reflect these facts, the study of proxemics. Spatial form can be evaluated on a functional basis, depending only on the function desired of a space. Certain inalterable measurements exist for each culture, they measure space in a tangible way and can be translated into numbers. The use of the criteria presented to evaluate space on a proxemic basis will greatly enhance our ability to build accurate spatial groupings without relying on the designer to have intuitive knowledge of who he is building for. When the designer or architect has been right you have a Falling-water, when he has not understood you have urban renewal housing projects like the Robert Taylor Homes on the south side of Chicago. The possibilities are great for the use of proxemics in architecture and planning, and our society would be remise to pass up this chance.

CHAPTER IV

AN EVALUATION OF THE MICRO- AND MACRO-SPACES CREATED BY PREFABRICATED MODULAR CONSTRUCTION

There are many unanswered questions about prefabricated modular construction, especially about the quality of design and the quality of the space created. Will the structures created be repetitive in their architectural design? Will the internal and external space meet the requirements and have the flexibility to be able to be of equal quality and sell as well as standardly built dwelling units? With the use of the criteria for the evaluation and design of space there will be an effort to find out some of the answers to these questions by examining some examples of prefabricated modular construction. To remind the reader of that criteria we will reiterate it once again, it is:

Micro-Space	Macro-Space
1. Intimate Space	1. Nodal Promintory
2. Personal Space	2. Focal Point to be the basis of a District
3. Social Space	3. Edge
4. Public Space	4. An Enclosure
5. Or any Combination of the Spaces Above	5. Path

Habitat, an Example

Habitat is unique, unique in many ways, and a good place to begin because it is one of the first substantial examples of prefabricated modular construction in North America. The basic premise of Habitat is highly unusual, it was not constructed by a developer to make a profit in the housing market but, instead, was part of a country's exhibit--Canada's--for their own World's Fair. So innovation and experimentation were possible and design quality was of critical importance. For this example of Canadian housing would be seen by millions of people from all over the world.

Internally (micro-space) Habitat was typical, the room sizes and partitions were set and inflexible. For at the time Safdie was " . . . unable . . . to work out a dimensioning system that worked both inside and outside

the house. Yet a comprehensive dimensional system is critical to the success of any building system."[55]

Therefore the internal structure is typical of affluent apartment dwellings. The basic module is about 640 square feet, a one bedroom unit. The various rooms are similar to what we all are accustomed to. The living room meets the requirements for the two phases of social distance, for the living room is the social room. The two phases of social distance span from four to twelve feet, and the living rooms of Habitat meet this size fairly closely. Obviously the width is greater than four feet, but the common habit for a North American is to move his chair into the desired position to meet the social requirements on hand.

All of the other rooms are the same in that they are typical of the various sizes that we have become accustomed to. The kitchen is of practicle size, while the dining room is approximately at the close phase of social distance--four to seven feet--and can be arranged in a more intimate manner. The more intimate arrangement would correspond to personal distance, or from two and a half to four feet. Bathrooms are of intimate size, they are not designed for personal interaction.

Externally (macro-space) Habitat comes alive socially, functionally, and aesthetically. The most

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[55]Moshe Safdie, p. 104.

talked about and unique feature is the garden that every dwelling has. This garden offers a place to retreat to and be alone, a place of intimate space, and yet a place to socialize with friends. The rooftop garden gets much of its feeling about intimate and social space from the natural materials that make up this garden. Their use of grass, shrubs, flowers, and the tenants own gardening inclination created space of privacy by their size, any where from a foot and a half which is the intimate distance to the social distance maximum of twelve feet. The various arrangements of the natural materials dictated the quantity and juxtaposition of the spaces. Public distance was only a possibility at first glance, for the garden does have the size (it is over twelve feet wide and long) but the spatial arrangement of the natural materials divided the space into other proxemic distances.

The architectural space created by Habitat is also very successful. At first glance Habitat looks in chaos, but a definite spiral pattern of boxes piled one upon another soon emerges. The integration of function and environment is as close as possible.

> In Habitat, because the building is air conditioned and this requires water-cooling, we were able to have fountains in the landscape that the kids could play in. The cooling of the building and the playing of children were integrated with terraced pools and sprays of water. In the same way the grouping of the houses in space created complex and changing patterns

> of sunlight. The public responds by saying Habitat is like a sculpture! But no, Habitat is environment, not sculpture.[56]

Habitat was designed to be a focal point for a whole district, the actual creation of a symbol for the Montreal World's Fair, Expo 67. By placing Habitat on an island, built upto 120 feet in the air, landscaped and prominant by its visibility and seclusion, the world soon agreed with Safdie and Habitat became the symbol of Expo 67.

Triad, by Hodgson House

Triad, a three-bedroom modular house that is delivered by truck, is built by Hodgson Houses. This particular design is by the architect Edward M. Coplon, " . . . is composed of two modules; the living areas, in one, are free-flowing. The other, a bedroom wing, is closed off, quiet. Between the two, Coplon inserted a glass-ended entry-dining unit."[57]

The pictures of Triad in House and Garden are professionally done, the interior decor perfectly matched and coordinated with the most modern styles in furniture, but does the spatial arrangement of this modular house

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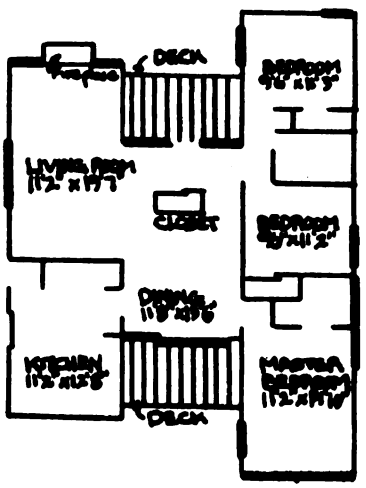
[56] Ibid., p. 167.

[57] "A Three-Bedroom Modular House That Arrives by Truck," House and Garden (February, 1972), 62.

TRIAD, A MODULOR HOUSE BY HODGSON



[illegible]

meet the standards and criteria created in the notations on a criteria for the evaluation of space?

The three bedroom units are not unusual, there are two standard and one master bedroom. With only an inch difference between the two standard bedrooms there is no real difference at all. One is nine feet six inches by eleven feet three inches, and the other is nine feet six inches by eleven feet two inches. These standard bedrooms offer the usual opportunities for the social functional use of space; a bed, desk, draws, shelves, and a chair will all fit comfortably while leaving room for walking to and from various pieces of furniture only.

Think of the bed as a minature room, offering unique spatial aspects within a larger room, the bedroom. If one does this you can then break the bedroom down into two main size components, each with their two phases. The bed encompasses the two phases of intimate distance; the close phase being from intimate contact--lovemaking and wrestling--and the far phase from six to eighteen inches. The rest of the bedroom adheres closely to the two phases of personal distance; the close phase being from one and a half to two and a half feet--a sense of closeness exists at this stage--and the far phase which is from two and a half to four feet. The later distance the distance that topics of personal interest can be discussed. Both of these distances, the intimate and personal distance, are

well suited for the size of a bedroom. They fit form to function very well.

The master bedroom is eleven feet two inches by fourteen feet ten inches. The bed in this bedroom serves and accomplished the same purposes as the bed in the other bedrooms. The difference here is, however, that there is a good deal more space left over in this bedroom which therefor pushes the spatial aspects into the social distance. The two phases of social distance are from four to seven feet and from seven to twelve feet. This is the distance of impersonal business, formal business, and dealing with unknowns--an extremely unlikely distance for a personal bedroom for two intimate people.

The living room and dining room run together, with only a free standing closet to break up and define the two spaces. Individually, the living room is eleven feet two inches by nineteen feet seven inches, and the dining room is eleven feet eight inches by thirteen feet six inches. With the elimination of the free standing closet the dimensions actually read eleven feet eight inches by nineteen feet seven inches for the dining room. In any event there is a very large free flowing space that has been created. This space encroaches on the boundaries set for the far phase of social distance and the close phase of public distance. Unless furniture is used to create smaller more personal distances, the effect of these

rooms with their large dimensions will be one of creating an impersonal and formal feeling. A place where conversation and closeness will be impeded. Not the exact ideal for a dining and living room, is it?

The rest of the modular house consists of two bathrooms and one kitchen. All of these rooms are unexceptional in size, are no way unique, and tend to be acceptable for the purposes they were built for.

The Triad modular house meets one of the two criteria, it is aesthetically pleasing, but it does not fulfill all the social and functional needs in its spatial arrangements. With one small alteration the Triad house could better meet these requirements. The creation of a free-standing wall between the living room, dining room and entrance way is all that is needed (see sketch).

"Okal-House" System Micro-Spaces

The "Okal-House" system of Germany is the most popular in the Federal Republic, can it be because of the desirable living arrangements its internal layout creates?

The houses are produced in two basic types, with type two being supplemented by a terrace, a study and a dining nook. On the whole, fifty variations in internal layout are possible. The interesting thing is, however, that 76 per cent of their scales have been for only four of the designs.

With the great flexibility of the layout of this system one has people being able to create their own social and functional space arrangements. That only four of the possible fifty internal design variations were used substantiates Dr. Hall's belief in proxemics. The spatial requirements and preferences of the German people are remarkably consistant, they chose only 8 per cent of the possible variations in internal living patterns.

Operation Breakthrough, An Evaluation of the Micro- and Macro-Spaces Created

Within the site at Kalamzoo, Michigan, chosen by the United States Department of Housing and Urban Development for its Operation Breakthrough examples in this area are seven different housing systems: the Levitt Building Systems, Inc., Inland-Scholz Housing Systems, Hercorform Marketing, Inc., Material Systems Corporation, Republic Steel Corporation, FCE-Dillion, Inc., and National Homes Corporation.

The Operation Breakthrough site is situated just on the outer eastern edge of Kalamazoo, thus tending to separate it from the main influences of traffic, congestion of people, and the poor quality of the housing and commercial structures in Kalamazoo. One can see from the drawing of the site plan that the site is insulated from the surrounding area by trees and open land. The site is internalized, it looks inward upon itself. Through the

NEW HORIZON VILLAGE

2307 GULL ROAD
BET. RIVERVIEW
NAZARETH RD./
ODELS OPEN DA
SUNDAY

THE COMMUNITY

SCHOOLS

1 Spring Valley Elementary *(Kdgn—3rd Grade)*
3530 Mt. Olivet Road
2 Burke Elementary *(4th—6th Grade)*
1912 Birch Avenue
3 Northeastern Jr. High *(7th—9th Grade)*
2433 Gertrude Street
4 New Central High School *(10th—12th Grade)*
W. Drake Road

COLLEGES and UNIVERSITIES

5 Western Michigan University
W. Michigan Avenue
6 Kalamazoo College
Academy Street
7 Nazareth College
Gull & Nazareth Roads

CHURCHES

8 Our Redeemer Lutheran
2500 Gull Road
9 Sunnyside United Methodist
2800 Gull Road
10 Eastwood Church of God
2929 E. Main Street
11 East Main Church of Christ
2528 E. Main Street
12 St. Mary's Roman Catholic
939 Charlotte Avenue
13 Galilee Baptist
908 Gull Road

The Kalamazoo Directory of Religious Organizations and Fellowship Centers will be provided on request.

SHOPPING

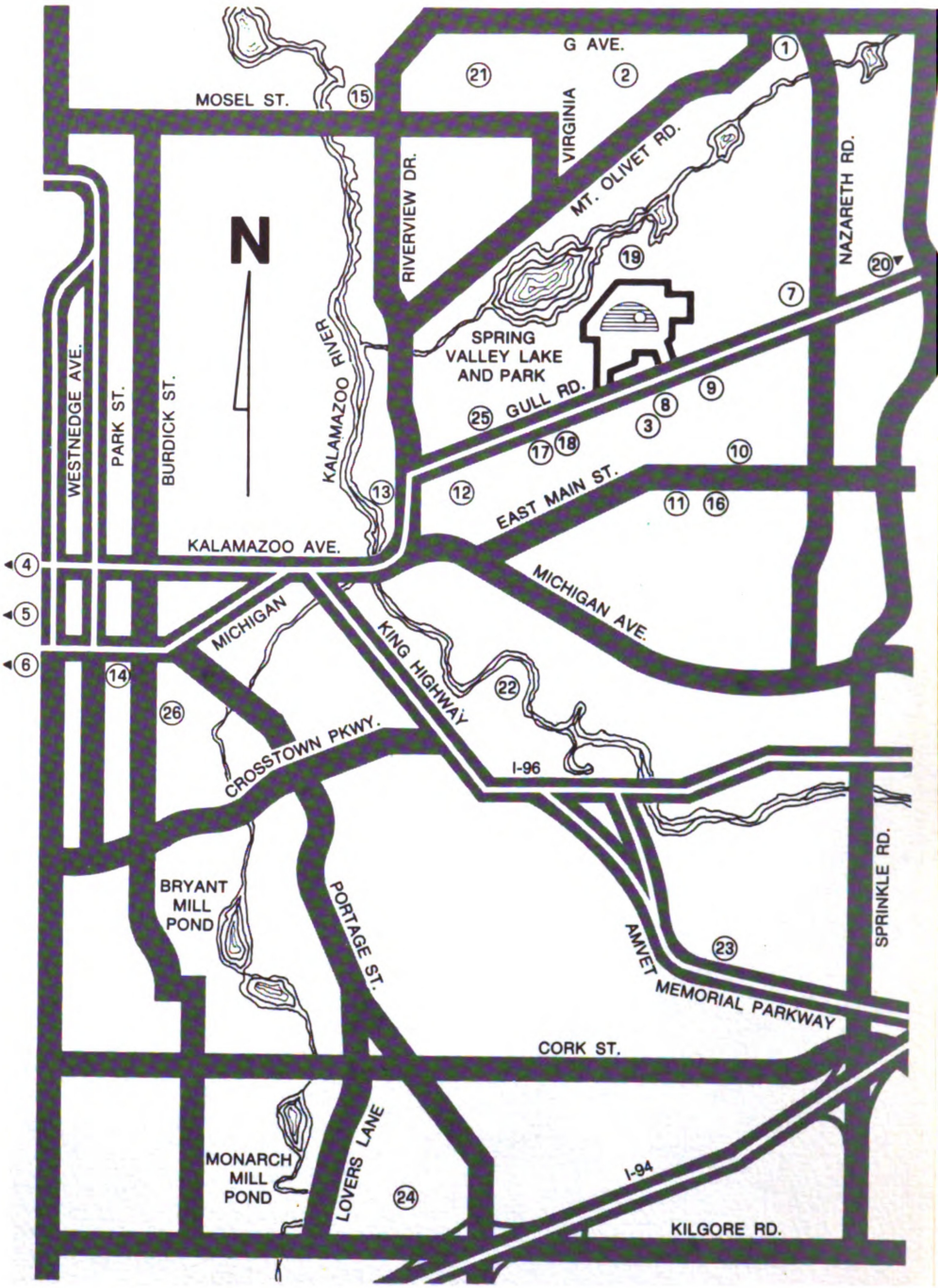
14 Kalamazoo Downtown Mall
15 Parchment Shopping Area
16 East Main Shopping Plaza
17 Pharmacy
1502 Gull Road
18 Super Market
1904 Gull Road

PARKS and RECREATION

19 Spring Valley Park & Lake
Adjacent to Community
20 Eastern Hills Golf Course *(City)*
Gull Road
21 Kindleberger Park *(Parchment)*
Park Road
22 Riverview Park
Kings Highway
23 Recreation Park
Lake Street
24 Milham Park & Golf Course
Lovers Lane & Kilgore

HOSPITALS

25 Borgess Hospital
1521 Gull Road
26 Bronson Methodist Hospital
252 E. Lovell Street



FCE-DILLON, INC.

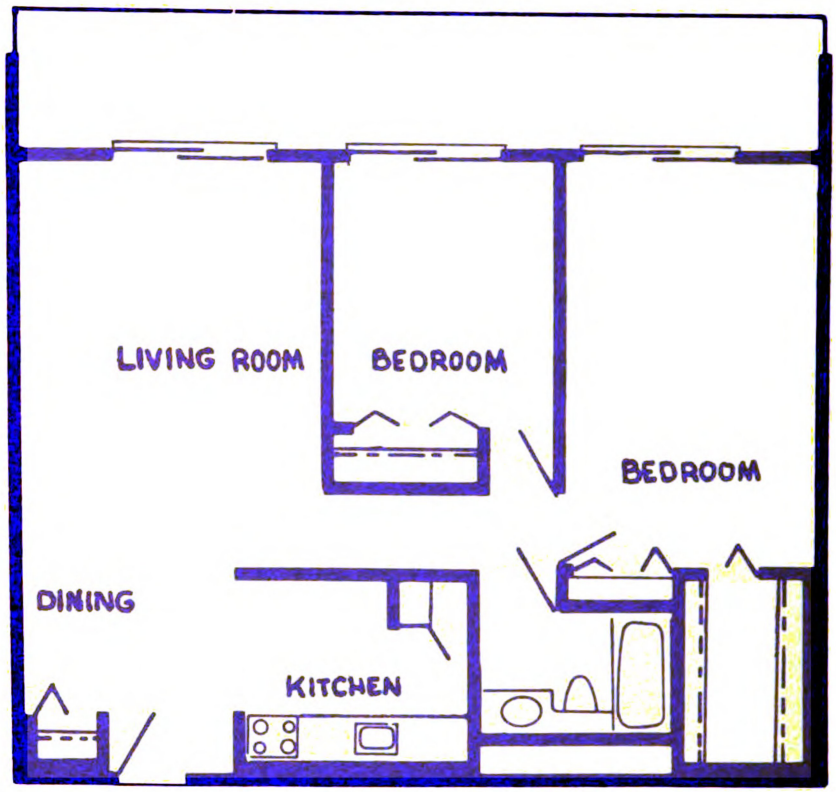
CE-Dillon research and develop-ent efforts have produced the new illon Industrialized System which tilizes modules and panels to re-sult in buildings that require even shorter periods of construction and that promise stabilized costs.

The Dillon system responds to the need of the changing shelter indus-try. It is designed to meet very strict standards of quality and livability. Dillon strives to retain the highest standard of workmanship, inside and out. Quality and comfort are as-sured by careful selection of mate-rials and equipment.

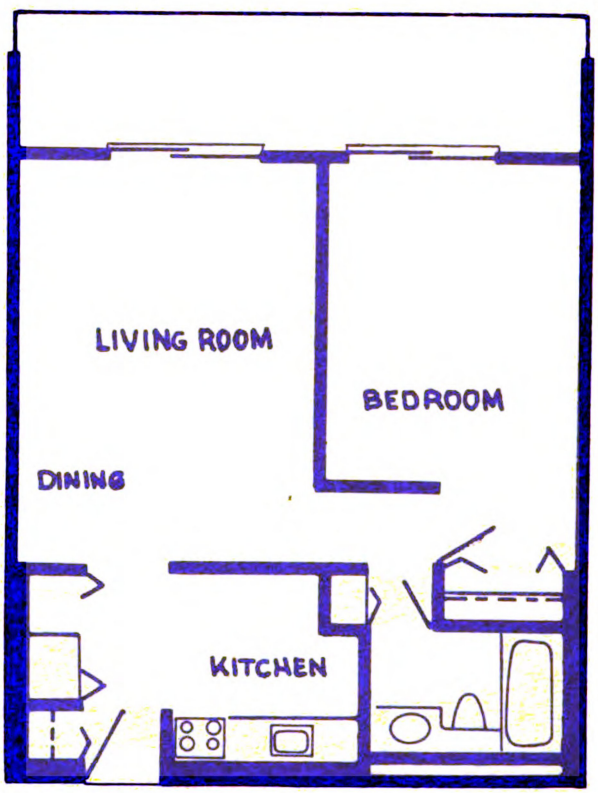
The Dillon apartment building for New Horizon Village is a four story medium-rise structure containing 51 one-bedroom apartments and one two-bedroom apartment.

Features

□ CONVENIENT ELEVATOR WITH CARPET AND FORMICA WALLS □ KITCHEN CABINETS OF WALNUT FORMICA □ PRIVATE BALCONY WITH TWO SLIDING GLASS DOORS □ VANITY IN THE BATH □ COMMU-NITY RECREATION ROOM WITH KITCHENETTE □ CONVENIENT LAUNDRY FACILITIES INCLUDING FREE WASHERS AND DRYERS □ DISHWASHER, STAINLESS STEEL SINKS, AND DISPOSAL IN EACH KITCHEN □ AMPLE STORAGE AREA AND PRIVATE LOCKER □ COMMU-NITY LOUNGE



2 BEDROOM APARTMENT



1 BEDROOM APARTMENT

NATIONAL HOMES CORPORATION

National Homes Corporation has 18 plants serving builders in 39 states utilizing a wide range of industrialized building systems.

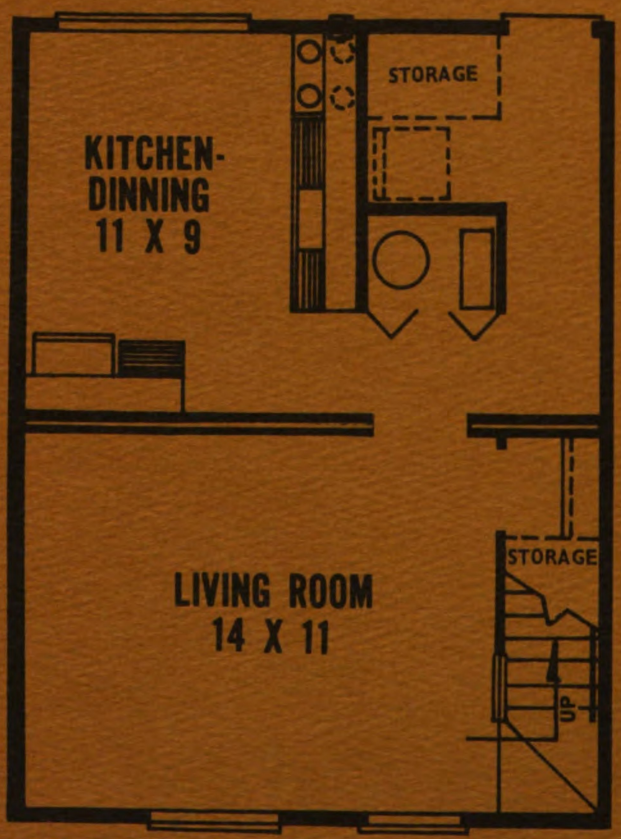
Their capabilities, developed over 31 years of leadership produce a distinguished collection of National Homes. This 3-dimensional modular home collection includes ranches, townhouses, and garden apartments utilizing techniques developed for Operation BREAKTHROUGH building systems. All have an excellence in style, design and quality for which National Homes has become famous. The National Homes in New Horizon Village include both two and three bedroom townhouses.

Features

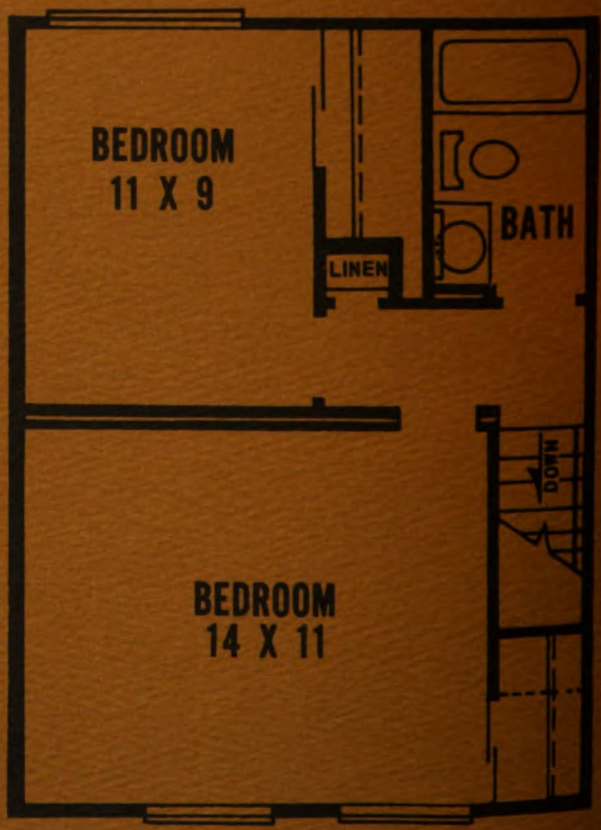
☐ STEEL FLOOR JOISTS AND WALL STUDS ☐ MAINTENANCE FREE ALUMINUM EXTERIORS WITH ROUGH SAWN CEDAR ARCHITECTURAL TRIM ☐ TEXTURED ACOUSTICAL CEILINGS ☐ VINYL-COVERED INTERIOR WALLS ☐ BIRCH-FINISHED WALL AND BASE KITCHEN CABINETS ☐ ONE-PIECE FIBERGLASS TUB AND SHOWER

3 BEDROOM TOWNHOUSE FIRST FLOOR

SECOND FLOOR



2 BEDROOM TOWNHOUSE FIRST FLOOR



SECOND FLOOR

REPUBLIC STEEL CORPORATION

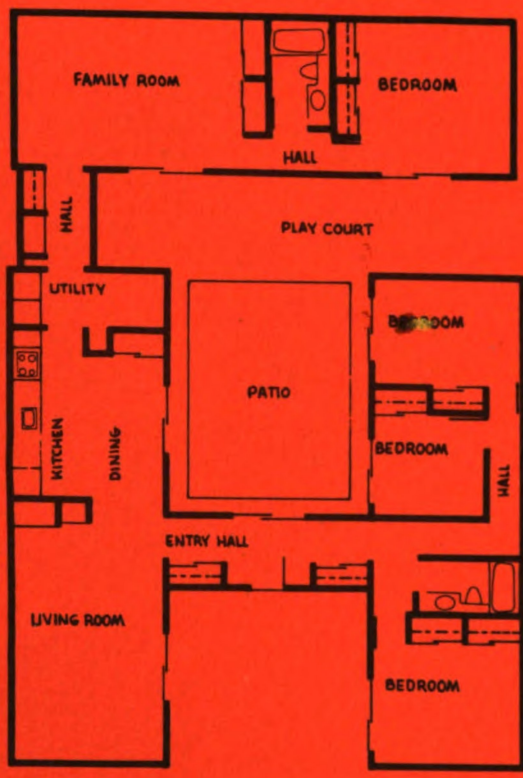
Republic Steel, with a reputation for quality earned through years of experience in providing building and construction products, has selected experienced companies to supply subsystems and professional help in building the Environmental Home.

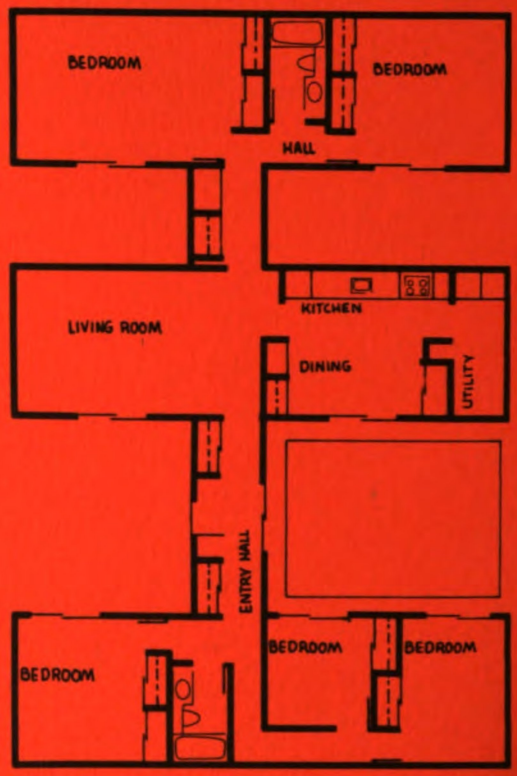
Building housing components in the factory permits very close control over quality. The result is a precision built quality home that gives your family spaciousness, privacy, convenience, ease of maintenance, and quiet. Indoor and outdoor living are pleasantly combined in the Environmental Home to suit the most discriminating modern ideas.

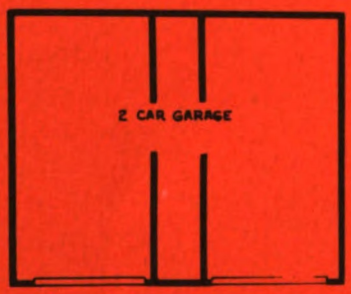
Republic Steel has created four homes for New Horizon Village including three, four, and five bedrooms.

Features

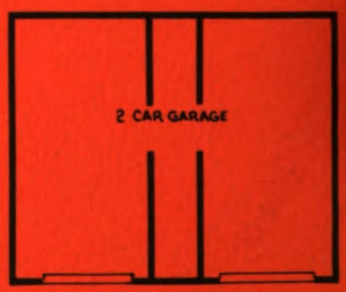
□ TWO CAR GARAGE WITH STORAGE AREAS □ PRIVATE FENCED PATIO AND COURTYARD □ SLIDING GLASS DOORWALL IN EACH ROOM □ INNOVATIVE DESIGN THAT ENSURES PRIVACY □ TWO BATHS IN FOUR AND FIVE BEDROOMS □ FULL SOUND-PROOFING □ UNIQUE INDEPENDENT AIR CONDITIONING HEATING SYSTEM FOR EACH MODULE □ BUILT-IN WASHER AND DRYER IN UTILITY ROOM □ CUSTOM BUILT TAPPAN KITCHENS WITH DISHWASHER, DISPOSAL AND AMPLE STORAGE SPACE



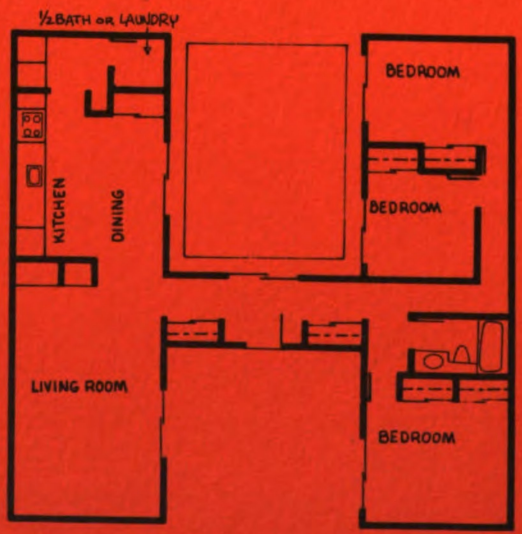


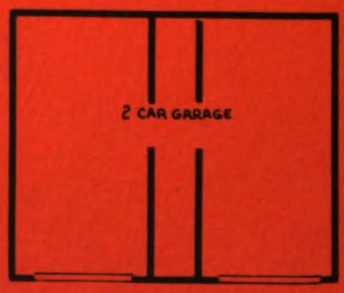


4 BEDROOM HOME



5 BEDROOM HOME





3 BEDROOM HOME

further use of landscaping and a closed system created for the purpose of better showing-off the seven different types of modular units, they have created an enclosed district with the focal points being each of the seven groupings of the prefabricated modular units.

The site plan is a good plan. It accomplishes the main objective of showing-off the various housing systems in the best possible environment. Hence, the reason for creating an enclosed district. The internal layout of the site is one of no choice, one drives into ten dead-end courts where one has to make a U-turn to go out. Each one of these courts is used as an independent area--an enclosure--within the overall site to show-off a different housing system or a combination of the housing systems.

FCE-Dillion, Inc.

Within the total site plan there is only one modular high-rise structure, and even this structure is only four stories high. Even at four stories, however, the high-rise is noticeable, and its placement near the main club house and swimming pool is no accident. Together they make up a focal point, not the one and only physically dominating focal point which is visible and recognizable at a distance outside of the site or district, but a focal point for those coming into the site and living on the site.

There are two main roads; one road, St. Albans Way, passes right by the high-rise and club house, and the other road, Inverness Lane, has the only unobstructed view unhindered by trees or dwelling units along the line of sight looking towards these two structures.

The nine other courts are too insulated and protected by their landscaping and inward orientation to be able to see and recognize the FCE-Dillion high-rise and club house from a distance to become their focal point by sight. But by the placing of three main recreational areas (swimming pool, baseball field, and multi-purpose sports area) on either side and in back of the high-rise and club house (see the site plan) there is generated a physical stream of people towards, and a mental attitude towards, this area. Thus creating the image of a focal point without actually being an imposing and dominating structure.

To increase this effect of having the club house and high-rise as a focal point a number of automobile and pedestrian paths were created. There are three main paths: the two previously mentioned automobile roadways, St. Albans Way and Inverness Lane, and a pedestrian sidewalk (number four on the site plan) which runs from St. Albans Way through the entire length of the site to the north, and ends at the Levitt Building Systems dwellings units. This pedestrian pathway runs along the left side of the

club house, swimming pool, high-rise, adventure playground, and passes by on the right and left side five out of the seven bulding systems on the Operation Breakthrough site. The pedestrian pathway turns-off leading to the various dwelling units and play areas, and is the only path that a pedestrian or bicycle rider can take to reach any of the previously mentioned places. This is an especially good example of what Keven Lynch refers to as a path, and to what has previously also been labeled as a path in this criteria.

The FCE-Dillion high-rise is a four-story structure built for the elderly. There are only one-bedroom and two-bedroom units. Internally there is nothing unusual in the size of, and the layout of, the units. The bedrooms, living room, kitchen, bathroom, and dining area all are of typical standard American sizes. That size being what is expected by, and has been internalized by, our culture for the use of social and functional space in an apartment.

Both units have the same size rooms. The bedrooms fulfill their purpose of providing for intimate and personal space. They are all approximately ten feet by twelve feet. The living room/dining room occupies one continuous space and meet the general requirements of social and personal space by being approximately eleven feet by sixteen feet all together. What is unique is the

fact that this four-story high-rise has elevators, necessary to fulfill its function as housing for the elderly. Also of interest and functional use for all people, not just the elderly, is the balconys they have that are the entire length of each apartment. With access to the balcony in each two-bedroom apartment from the living room and both bedrooms, and in the one-bedroom unit from the living room and bedroom.

On the whole it is an interesting structure fulfilling its social and functional spatial requirements. Not in an exciting and new way as far as the internal layout is concerned, but exciting and radical in the fact that this is a prefabricated modular high-rise. A high-rise with eight inch thick concrete walls that are put into place minus six inches out of the eight inches and the rest of the concrete is poured in later when the structure has been assembled. Thus providing for a lighter and easier load during construction, shortening construction time, and literally, providing a high degree of sound insulation.

Levitt Building Systems, Inc.

The Levitt Building Systems dwelling units ring the Operation Breakthrough site to the north and north-west. Shannon Court is the northern most cluster of Levitt dwelling units. Here there are thirty-four units, both townhouses and garden apartments. As we observed

earlier, all of these units look and are oriented inwardly --towards Shannon Court. The landscape on the inward side of the units and the outward side of the units on the south have a lot of trees and shrubs to block out the ugly site of the court and its parking lot. But on the outward side of the northern units it is essentially clear of trees and shrubs. This has been done for a good purpose, it allows a clear view of Spring Valley Park and Lake. This enclosure has created around Shannon Court a small district, a show piece for Levitt Building Systems, Inc., inside a larger district. This is true for all of the seven housing systems. Together they create "New Horizon Village" on the Kalamazoo site, which is a district showing off Operation Breakthrough. The site (district) offers the unusual opportunity for marketing prefabricated modular dwelling units, for each builder has his own district, all within the context of the larger district which is "New Horizon Village."

Internally the Levitt townhouses are well planned. There is a noticeable difference there room sizes compared to the other developers units. Room size is larger, living rooms and combination kitchen/dining rooms. This is a good change. All to often the kitchen has been thought of as a "personal" room, yet it is not, it is a "social" room where many members of the family may be in contact with one another. With the inclusion of a dining

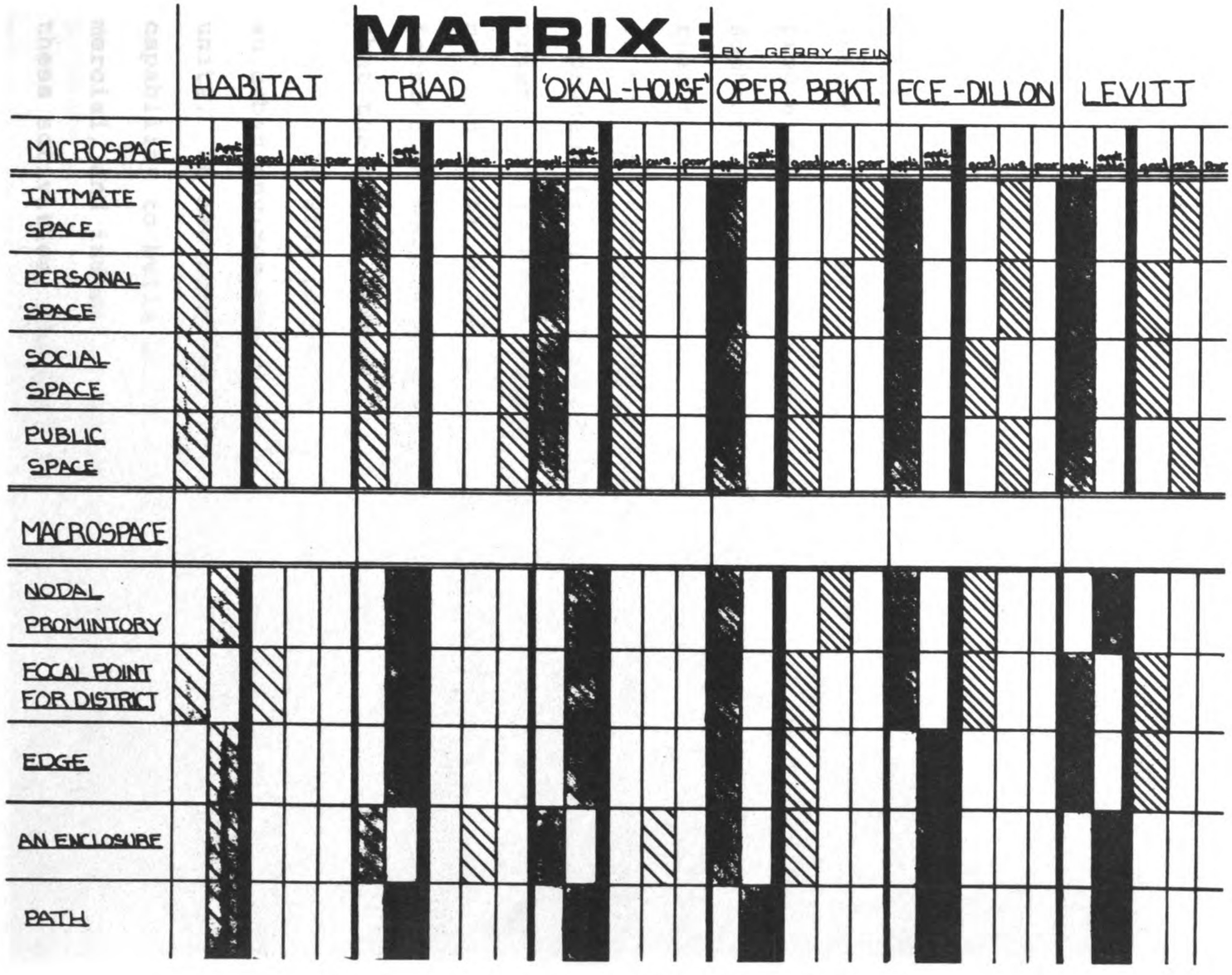
room the effective size of the kitchen has been extended. The dining area itself is ample enough to avoid giving a closed or crowded feeling or the feeling of intruding on the kitchen.

The living rooms, especially in the four-bedroom townhouse, is extremely large. Large enough to achieve social space, enough space for family activities--a large family. One does not own a three- or four-bedroom townhouse without having a large family. Yet the large social space created by the living room is not large enough to move into the relm of becoming public space, which is in its close phase a clear space of from twelve to twenty-five feet, and its far phase from twenty-five feet. The bedrooms and bathrooms are standard for the American market and culture, not in anyway unusual. On the whole Levitt has created the most liveable dwelling units as far as meeting the social and functional spatial needs of man.

More and more of the building systems being put together have flexible internal design patterns. The Norweigian architect, Erik Hultberg, created an adaptable and expandable house which allows for external as well as internal variations. One Swiss system, the "Norm-Modul" system, is a flexible system created to meet the various space requirements of laboratories. Eight out of the twenty-two companies participating in Operation Breakthrough

have designed flexible living systems that allow for variations on the internal spatial arrangements. They might not be conscious of the science of proxemics, but they are following some of Dr. Hall's basic findings in his study of proxemics. All of these systems are responding to a public that has argued that the units previously built did not meet all their needs, their needs on the functional and social level. Not being sure what designs were wanted, they responded by offering a number of possibilities. With the use of proxemics a number of the less desirable variations could be eliminated and time and money saved.

To sum-up the application of both of the criterias for micro- and macro-space is a matrix on the following page. This matrix rates each of the six examples of modular construction previously discussed. This rating is done simply from poor to average to good, and only if the particular micro- or macro-space is applicable.


MATRIX :
BY GERRY FEIN
HABITAT
TRIAD
'OKAL-HOUSE'
OPER. BRKT.
FCE-DILLON
LEVITT
MICROSPACE
INTMATE SPACE
PERSONAL SPACE
SOCIAL SPACE
PUBLIC SPACE
MACROSPACE
NODAL PROMINTORY
FOCAL POINT FOR DISTRICT
EDGE
AN ENCLOSURE
PATH

CHAPTER V

A GLIMPSE INTO A FUTURE URBAN ENVIRONMENT

Prefabricated modular construction is in its infancy. Yet the art of modular construction has progressed remarkable fast, and is now reaching a very sophisticated level. In ten years it has gone further than the automobile in its first ten years. The comparison is not an idle one, they are both innovations of, and the representatives of, our technical age on the highest order. It is unfortunate, however, that most people have not and still do not realize the possibilities for prefabricated modular construction in our technical age, that the art of building is a science.

It will be possible in the near future to create an urban environment totally out of prefabricated modular units. As has been shown, there is at the present the capability to build units for dwelling, research, commercial, and industrial activities. It is the scale of these activities, the lack of big markets for industrialized

housing, the complicated and numerous building codes with archaic requirements, and the lack of public funding for pilot research projects have all added up to retard the previous prefabrication attempts. Now that phase is over, with Operation Breakthrough and the impetus gained from Habitat at the Montreal World's Fair we can now look to the future and its myriad of possibilities.

Our society has the capacity to build any type of environment it wants to today. The Houston Astrodome allows people to play baseball indoors, the rocket assembly building in Houston is so big that it has its own weather, it actually rains inside this building. Moshe Safdie sees this capability too.

> But society today has the means, in terms of resources and productive capacity, to build whatever environment we choose, just as we obviously have the resources and the capacity to feed the whole world. We underestimate the real volume of potential food production we are capable of; just as we underestimate our capabilities in making our environment. Buckminister Fuller has been constantly reminding us what we could do in terms of productivity if we used our resources properly. Fuller has been saying, in the context of an extrapolitical reality, unique to our time, that environmental systems must be applicable to the total global population. To provide more for more with ever decreasing natural resources, we must rely on the potential of technology. I would add that fulfilling this "bare maximum" also creates the welcome burden of having to establish city structures that can give fulfillment to all.[58]

From a German building system that produces two thousand prefabricated modular units a year one can see

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[58]Moshe Safdie, p. 223.

the eventual replacement of the contemporary German building industry by prefabricated modular techniques. With a little vision the German experience will become the American experience, then a world wide phenomenon.

Somewhere in the not to distant future lies a city, a city completely constructed out of prefabricated modular units. A new town if you like. This city can be a linear development, a green belt town, any form at all, for out of this city-form will rise a modular development. All sorts of buildings are visible; single-family detached dwellings, high-rises, commercial and industrial facilities.

A part of this city itself is a prefabrication factory. All of the structural units are prefabricated in this factory, non are designed along the panel system--this is an antiquated method--but, instead, they are all made into modular units. These modular units are load-bearing and constructed out of a polymorphic material. This material has one-fifth the weight of concrete, twice the strength of steel, it would have compressive strength and density, it would provide insulation, and it would be able to be impermeable to water.

The modular units allow for internal flexibility, choices are limited by the use of the science of proxemics. Externally there are an infinite amount of design possibilities; some modular units will be plug in type,

mostly for buildings of great height, and the others will be self-supporting loadbearing modules. Since all of the units are totally prefabricated in factories, the cost of units will be greatly decreased. Housing for the poor will be able to be provided, good housing, housing of good design and quality material and construction.

The scale of a city is important, we need different scales to achieve a certain quality to life. Moshe Safdie observes this also:

> The metropolitan city is a new scale city. Parts of it have existed in earlier cities but the problems were different because the numbers were different. . . . The metropolis also needs a hierarchy. There should be places on the scale of a thousand families and on the scale of a million people and maybe there should be meeting places on the scale of ten million people. That hierarchy is very important. It's the lack of hierarchy that really makes our cities so unworkable. It's the fact that you are a part of ten million people often, but you are not part of five families or a hundred families or twenty thousand people, which are workable communities in which you can function with a quite different kind of participation and control over your environment than you can with ten million people.[59]

The city that will be built will have that hierarchy of scale. There will be areas arranged around central places; parks, halls, museums, government structures and centers, schools, etc., in an ever increasing scale to create a city. But every individual will be able to interact with other individuals and families on a smaller

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[59] Ibid., p. 226.

scale, the scale of the community based on a school or a park area.

The structures of the city will reflect the different scales of the city. A prefabricated modular school set in a community park might well be the central theme or hub of an area, just as a piazza was in Italian cities. In this neighborhood there will be single-family detached dwellings, multi-family structures, and commercial facilities--all with different scales. The scale of the single-family detached structure will be smaller in height than that of the multi-family structure, but scale is not just in height. The commercial facilities might well be the same approximate height of single-family detached structures, but its horizontal scale will be much greater, creating a different feeling and environment.

Perhaps the most unique thing about this modular city is its flexibility. Any structure, no matter what type, can be added to with great ease, quickness, and cheaply when modular units are used. The time of erection for a new structure or group of structures is greatly reduced by the use of prefabricated modular construction, everything is pre-assembled in a factory and shipped to the site only requiring for it to be put together like some giant tinker toy. A structure such as a school or concrete hall may call for an increase in size on limited occasions, modular units allows for this increase by

making it possible to add units based on the modular principle for these occasions and removing them when they are not needed. A sort of a plug-in type of arrangement that lets one add or take away modular units whenever necessary.

Prefabricated modular construction is not the only answer for housing and it is not capable of meeting the housing problems of the present and near future for the entire world. But it can be the answer to the housing shortages of the industrialized and technically advanced countries of Western Europe and North America. Renato Severino believes the following:

> Above all, the emergence of a mass society means a tremendously enlarged need for architectural production, a need for millions of homes, schools, and hospitals. It is important to realize that sheer quantitative need, now of crises proportions, has always existed. But there is a new qualitative need. Mass consumption is very different from mass existence. The new situation demands that architecture provide not for an elite but for the masses. . . .
>
> Architecture from now on must be totally integrated with technology, because that is the only medium that can be used to provide the necessary production levels in terms of quality, quantity, and economy. . . . That advanced technology can be applied to architecture has already been proven. European experience and recent American studies have shown that industrialized building technology can lead to higher quality, faster production, and reduced costs.[60]

It is possible and conceivable that a city could be made up entirely of prefabricated modules. What is more likely to take place, however, is the reconstruction

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[60]Renato Severino, pp. 7, 15.

of our present cities, step by step.. And the speed and quality of this renewal, not to mention the reduction in its cost, will be because of the use of highly advanced prefabricated modular units. Even now the first traces of its use and effectiveness can be found. In New York City a rehabilitation of kitchens in old buildings took place by removing their roofs and dropping in by helicopter prefabricated modular kitchens. All of this taking place over just a few hours. The full potential and application of prefabricated modular units has yet to be reached, but that time is coming.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The form and content of this thesis remains essentially intact from its origins even though it has been evolved slowly and subtly changed. With the addition of more and more information and the understanding and insight that goes with it, the original goals have been slightly altered. Instead of the technical and environmental aspects of prefabricated modular construction, the author has seen this thesis evolve over time into the study of the technical aspects of prefabricated modular construction and the evaluation of functional and social space. It has evolved into the design and functional use of space in conjunction with prefabricated modular construction. It became necessary to create a notation on a criteria for the evaluation and design of functional and social space, for one cannot talk of space without being able to define and then apply it so it can be used for the evaluation and design of structures. Most importantly, however, the premise of this thesis has

remained intact. That is, by the study and evaluation of prefabricated modular techniques, functional, and social space we can then use this knowledge for the creation of a spatial notation on a criteria for the evaluation and design of functional and social space.

It can be concluded from the research into the present state of prefabricated modular construction in Western Europe and North America that there are only two types of prefabricated modular systems in use, the panel system and modular unit development. That the panel system is indigenous to Western Europe on the whole, and that the modular unit type development is being examined and perfected in North America by such projects as Operation Breakthrough, Habitat, and the 5,000 modular unit housing project in Puerto Rico designed by Moshe Safdie.

To reduce the cost of building a structure and to achieve the highest efficiency one has to take the whole structure into the factory. And one can only bring the whole structure into the factory by using prefabricated modular units, for panel systems require on-site work and therefore can only effectively reduce the cost of a building by as much as 25 per cent.

In all the world, for the present, there are only two types of plumbing systems. One, the archaic and often used system of pipe runs in conventional buildings that dissipate odors out onto the roof. The other, Sovent, is

a system that was designed in Switzerland and is now owned by The Copper Institute in Denver. This system eliminates one whole pipe run and dissipates all odors internally without the distasteful discharge into the atmosphere associated with the conventional method. Sovent has had applications for modular unit development because it allows for the flexibility and configuration of modular units without creating the problems of unsightly pipes sticking up on roofs or in gardens. Plus the discharging of foul odors which could interfere and be imposed on neighbors due to the design of modular structures is also eliminated.

We can conclude from the experiences in Norway, "An Adaptable and Expandable System for Row Houses," in Germany, "Germany O The Trouble with Variety," and in Switzerland, "Switzerland--'The Mail Order System is Here,'" that only a small percentage of the various internal layout possibilities in all three cases were used, approximately 8 per cent of the possibilities were used. Thus bearing out some of Dr. Hall's contentions on proxemics and arriving at the conclusion that society can plan effectively in advance for particular cultural habits and preferences to a fairly accurate degree, all through the use of the science of proxemics.

The flexibility found in the external design of space for prefabricated modular units can also be found in

their internal design of space. It is necessary to offer a limited variety of internal variations to attract renters and/or buyers to prefabricated modular units. People are demanding more, society cannot give them less. The use of proxemic studies of various cultures is aimed at this goal.

That new, flexible, and durable materials must be found for the success of prefabricating modular units on-site or in a factory. Two such materials exist now, and one is just in the dream stages. Plastics are being used more, both in Western Europe and the United States. A couple of the consortium members of Operation Breakthrough are using plastic and have made it an important and intricate part of their modular units. An on-going research project in the Netherlands is using plastics to reduce the weight and cost of panel and modular units. Moshe Safdie and his design group have developed concrete half the thickness and weight of the concrete that they used for Habitat. This is essential if building time, costs, and flexibility of design are to be achieved by prefabricated modular unit development. The dream is a polymorphic material with one-fifth the weight of concrete, twice the strength of steel, it would be able to provide insulation, it would have compressive strength and density, and it would be able to be impermeable to water.

After taking a look at the specific work being done in Western Europe and North America there still is no clear cut way of evaluating an essential part of the structure, the space that is defined by it. One can discuss costs, quality of materials, construction techniques--one can evaluate them--but unless society can accurately evaluate and design social and functional space before a structure is built society still will not have a method for the evaluation and design of a total structure. To meet this end this author has created a notation for the evaluation and design of micro- and macro-space. This was essential, all was meaningless without this. It would be modular units and panel systems but only a personal aesthetic judgment and an economic one for measuring their value without the notation.

With the creation of this notation it then became possible to evaluate and design spaces. This was done in both Chapters III and IV using existing structures on one hand and creating others by the use of the criteria on the other.

Society must realize it is necessary if we are going to continue to survive in this world without revolution and misery, without homeless peoples or people living in inadequate shelters, that one has to have the means for providing good quality dwelling units at a low cost in massive quantities. And to evaluate these units

before their construction so as not to waste time, money, and, most importantly, countless lives that have had their hopes and aspirations first raised, then dashed, by our inability to be able to provide the necessities of life.

This is why one can see the advantages, the downright necessity and urgency for the further development and refinement of prefabricated modular dwelling units. It might very well be one of our few remaining hopes, already too many people are homeless or inadequately sheltered. Society has the means at hand, it would be unfortunate if we did not use them.

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