SYSTEMS FLEXIBILITY AND USER CHOICE IN THE HOUSING PROCESS

by

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Chapter I

INTRODUCTION

The need to involve the user in the housing process has been recognized by many architects and social scientists over the years. Habraken, Turner and Zuk are but a few of those who have attempted to develop industrialized building systems which respond to the needs of the user. While each have proposed their own methodologies to approach the problem, their goals are essentially the same.

Some of the most important work that has been conducted in this area is by SAR (Stichting Architecten Research) under the direction of N. J. Habraken. This group has formulated an alternative housing concept known as "Supports." The Supports concept assumes that there are a multiplicity of decision makers who operate independently in the housing process. In acknowledging these differing roles, SAR has proposed a means for each to mutually respect the requirements of the others. The practical manifestation of this work has been to distinguish between Support (structure) and dwelling (detachable unit). In this way, the Support acts as a permanent framework to guide the future housing options available to the user.[1]

The successful application of industrialized housing within the context of the Supports concept has yet to be demonstrated on a large scale.[2] One of the basic flaws of the system is the lack of opportunities available for the dwelling to develop outside of the parameters generated by the Support. In reality, there are actually very few choices that the user can make. A review of the design characteristics of proposed Support structures would readily point this out.[3]

John F. C. Turner has made an observation that can be applied to understanding the weaknesses of the Supports concept. Turner draws an important distinction between autonomous and heteronomous housing methods by stating that autonomy in housing allows for user choice throughout the entire process, while heteronomous systems are supplied from "above" and allow little room for the user to exert his influence.[4] The Supports system is primarily a heteronomous system since future choices will always be dictated by the initial framework already in place. Whatever options are offered to the user have already been systematically determined by the designer well in advance.

To counter this continuing trend, William Zuk has proposed a "kinetic" architecture that can transform over time in response to user needs. The goal in this case is to achieve a level of flexibility that is not dependent upon pre-determined growth patterns, Much of Zuk's work parallels that of the Archigram group with Peter Cook. Both approaches consider architecture as an organic and evolutionary process with the potential for adaptation.[5] To date, however, the implications for a systemized housing concept have not been fully developed or validated.

Countless others have also made their contribution towards the realization of an architecture that can directly respond to changing human needs; yet, all have run into problems for one reason or another. Often, a system that shows great promise may be thwarted by high costs, building codes, or even the consumer for which it was intended. It is apparent that there are no simple solutions to the housing dilema. Each new advance can only hope to break the problem down into more easily comprehensible aspects.

Chapter 2

CONCEPTUAL AND ORGANIZATIONAL BASIS OF STUDY

2-1. A Conceptual Framework

The opportunity now exists to re-evaluate the entire process of conventional housing delivery methods in light of the many problems currently facing the industry as a whole. Within this framework would be those aspects which generate an affordable and adaptable housing concept.

The adaptability of living environments is a significant issue in the development of a viable alternative to existing housing strategies on the market today. This is especially true when the forces guiding social and technological change are considered. For a housing method to be of long term usefulness to its inhabitants, it must necessarily respond to changing user needs over time.

2-1.1. The concept of change

The concept of change is most immediately applicable to changes in user family composition and orientation within society. Families grow, develop, and children do eventually move away. Through this life-cycle process, the values and ideals of each person within society are subject to continuous re-definition and change. Changes in user needs and lifestyles are likely to proceed as rapidly as those of the latest styles and fashions. The dynamic nature of human beings resists constancy, since adaptation to change is the essence of survival and progress.[6]

With the traditional methods of housing, there has always been a time lag between recognizing the user's needs and the development of spatial forms to complement those needs. The usual tendency of architecture is the pursuit of permanence in order to poetically freeze a moment in time. It is this notion of permanence which often leads to premature obsolescence.[7]

2-1.2. A need for identity

Humans seek through identification with their environment to be in harmony with the greater social context of the world around them. Today this need is expressed through the choice of a lifestyle which complements a person's spiritual and social being.

The need for identification with the home has historically been a strong factor in society. The dwelling not only serves as a haven from the stresses and strains of the outside world, but also as a focal point from which personal and social growth emanates. In this respect, housing must not only address the functional needs of the inhabitants, it should also serve personal needs as well by accenting moods, expectations, and goals in life.[8]

2-1.3. Architectural adaptability

In order to encourage transformation and growth over time, architecture must be adaptive. The concept of an adaptable and flexible architecture relies upon the integration of human needs and spatial characteristics. Through the addition, subtraction, or substitution of these elements over time, a powerfully dynamic housing concept can develop in which changes relating to user needs are directly translated into complementary living environments.[9]

The acceptance of such an approach seems inevitable in an era when almost every aspect of man's existence is subject to continuous re-evaluation and change. Housing design can be regarded as a process which really only begins when the user is allowed to exert his influence in the determination of his environment. Only then will a more humanistic and individual architecture be developed.[10]

2-1.4. The potential of industrialization

The industrialization of building components has the potential to enhance user choice over time. It is possible to visualize future living units composed of various additive, subtractive, and substitutive elements provided by a continuously changing technology. Many industries may then compete and develop alternatives for a consumer-oriented society. Within each group of components, variations in finish, design, and cost could respond to practically every aspect of the housing market. Such a system would allow the user to choose a housing package suitable to personal needs, initially, and over time, as function or preference dictates.

2-2. An Organizational Framework

To effectively implement the concepts presented thus far, an organizational framework is necessary in order to determine the extent to which the user may participate in the housing process. The method to be established seeks to provide an alternative to the concept of mass housing as currently practiced in many industrialized nations. It is recognized that many of the elements composing the dwelling unit are beyond the decision making or implementation capabilities of the user. The approach developed is not meant to represent a self-help housing program. Instead, it is meant to expand the choices available to the user in the determination of subsequent dwelling characteristics and configurations. Where possible, the user will be given the opportunity to directly participate in this process.

This method is targeted for middle income persons who are excluded from the housing market at this time. To reduce costs, it is proposed that only the most essential dwelling functions be included within the initial unit provided. As the user accumulates sufficient funds, later additions or modifications can be implemented on an "as needed" basis. In this way, the user would have the freedom to choose only what is necessary or desirable over time, as income allows. It is anticipated that a system which seeks to optimize the freedom of the user will find the greatest acceptance in the Western world.

For a housing system to be flexible, each component which goes into the system, whether initially or at a later date, must also be flexible. Therefore, each of the major sub-systems composing the dwelling are analyzed with a view towards increasing their potential for flexibility and subsequent user choice. Through this process, the range of opportunities available to the user can be ascertained. The sub-systems examined include the following:

- structure
- enclosure
- electrical
- heating and cooling
- plumbing

The potential for dwelling flexibility, and the factors acting to limit user choice are evaluated on the basis of the following considerations:

- simplicity of sub-systems components
- availability of these components
- ease of handling and assembly
- ease of maintenance or replacement
- sub-systems inter-compatability
- relative economies

The analysis which follows will attempt to demonstrate that recent advances in building technologies and methods of construction have the potential to increase dwelling flexibility and user choice in the determination of living environments.

Chapter 3

SERVICES TO THE DWELLING

Services to the dwelling encompass the electrical, plumbing, and space conditioning systems. Each of these will be analyzed to determine their potential for enhancing dwelling flexibility and user choice. Where applicable, corresponding relationships between the various sub-systems are considered as well. Diagrams at the end of each section summarize the findings developed.

3-1. The Electrical System

Flexibility of the electrical system is necessary to allow for changes in user needs and dwelling configurations over time. The elements composing the electrical system are divided into the following main categories:

- power supply and metering
- distribution and use
- switching

3-1.1. Power supply and metering

As the names suggest, the power supply and metering functions refer to the electrical service coming into the dwelling. The supply cable passes through a meter and is then connected to the main distribution panel. The locations of these elements are determined by the designer in the initial planning phase.

3-1.2. Distribution and use

From the distribution panel, secondary branch circuits carry electricity throughout the home. In conventional electrical systems, wiring is drawn through the enclosure elements and attached to outlets or fixtures during the course of construction. The permanent nature of this method, however, severely limits the potential for future changes in the electrical distribution system.

Recent advances in electrical systems point towards far less on-site labor and increased simplicity through the factory pre-wiring of the spatial enclosure components. Changes in dwelling configurations affecting the wiring system could easily be accommodated through the use of clip-together connecting devices similar to those currently utilized for the electrical systems of automobiles. These have now been developed specifically for this purpose in buildings. Similar surface-mounted electrical distribution systems are also available, but they are often less aesthetically pleasing.[11]

With either of the above methods, the wiring system is incrementally built upon from the permanent distribution panel within the dwelling quite easily. Limitations that do exist with such methods concern the relationship between wiring and enclosure. The use of pre-wired wall elements may impose certain limitations on dwelling flexibility in this respect, since a continuous path for the wiring to follow throughout the dwelling is necessary. Partitions carrying electrical wiring, then, must be planned so that openings or other similar discontinuities do not interrupt branch circuits leading to the outer-most spaces within the home. Locating the electrical wiring within continuous floor assemblies or suspended ceilings could help to minimize these restrictions.

Secondary wires for telephones, intercoms, or television antennas are related aspects pertaining to the electrical distribution system. These can simply become part of a multi-purpose wiring harness.[12]

3-1.3. Switching

Switches occur in series with the distribution circuits in order to control power going to the outlets and fixtures. In practical terms, this means that wiring for an outlet or fixture must first pass through a switching device. With a traditional system, changes in the location of any of these components will require considerable rewiring. Therefore, it is desirable to eliminate the high degree of wiring coordination necessary between the switching and distribution systems.

There have been numerous approaches developed to simplify this task in flexible office and school design, but these entail greater complexities than might be needed for residential applications. One way to easily solve this problem is to incorporate relay switching controls within the main distribution panel. Portable switches located at the ends of low voltage wires leading to the various spaces throughout the dwelling can then activate these.[13] This method may have some aesthetic drawbacks since the wires will be visible unless they are hidden under carpets or along the joints between floors and walls.

A less cumbersome switching method is possible through the use of remote control switching devices. These are widely available at a fairly low cost. In this manner, the need for conventional switches and the associated wiring is eliminated entirely. Remote control units perform the switching function by transmitting a pulsating signal through the distribution wiring to receivers located within the outlets and fixtures themselves. Appliances, security systems, and other electrically powered household items may also be activated by these units as well. The newest models can control up to one hundred different use locations. Several of these functions are pre-programmable to automatically operate at certain times of the day for the user's convenience.[14]

3-1.4. Potential for user choice

New developments in electrical systems for housing present the opportunity for a high level of user choice and spatial flexibility. Limitations on user participation primarily stem from technical abilities and planning considerations. For instance, the user would not have a role in the design, location, or implementation of the initial power supply to the dwelling unit. These decisions are fixed, designer selected elements. Similarly, the design and implementation of the distribution system are responsibilities outside of the user's scope. However, the flexibility of the wall panels conveying electrical circuits suggests that the user could have a voice in the future location of these elements. This is an aspect that will require a high degree of interaction between the user and designer in subsequent planning decisions. Incorporating the electrical distribution system within floors or ceilings can grant the user more freedom in the determination of dwelling configurations by increasing the fiexibility of the interior partitions. It is also apparent that remote control switching devices optimize user choice in this regard.

Figure I summarizes the potential for user participation in decisions concerning the electrical system. The flexibility of this system, and its interrelationship with the other systems composing the dwelling unit are illustrated in Figure 2. Comparisons have been based upon various manufacturer's catalogues and previously quoted sources.

	DESIGNER PARTICIPATION		USER PARTICIPATION	
	Fixed Elements	Flexible Elements	Flexible Autonomous Elements	Flexible Designer Coordinated Elements
ELECTRICAL SYSTEM				
Power Supply & Metering				
Design	●			
Location	●			
Implementation	●			
Distribution & Use				
Design		●		
Location				●
Implementation		●		
Switching				
Design		●		
Location			●	
Implementation			●	
Fixtures & Appliances				
Design		●		
Location				●
Implementation				●

Figure 1. The potential for user participation in decisions concerning the electrical system.

	SYSTEMS FLEXIBILITY	Simplicity	Availability	Assembly Ease	Replacement Ease	Relative Economy	Sub-Systems Compatability	SYSTEMS INTERFACE	Foundations	Structure	Enclosure	Heating/Cooling	Plumbing	Electrical
ELECTRICAL SYSTEM														
Power														
Supply		●	●	◒	⊕	◒	●				●			●
Metering		●	●	◒	⊕	◒	●				●			●
Distribution														
Panel		●	●	◒	⊕	◒	●				●			●
Circuits		●	●	●	●	●	●				●	●	●	●
Connections		●	●	●	●	●	●							●
Outlets/fixtures		●	●	●	●	●	●				●	●	●	●
Switching														
Relay		●	●	●	◒	●	●					●		●
Remote		●	●	●	●	●	●					●		●

Low ⊕ Moderate ◒ High ●

Figure 2. Systems flexibility and interfacing of the electrical system.

3-2. The Heating and Cooling System

An important consideration in the development of a flexible housing system is the necessity to incrementally heat and cool the interior environment. The possible addition or subtraction of spaces composing the dwelling unit suggests a system which can respond to a variety of spatial configurations while also being relatively simple to install and subsequently remove or reposition. To optimize the potential for dwelling flexibility, it will also be advantageous to select a self-contained heating and cooling unit that does not rely upon permanent mechanical spaces or ducting systems. Methods which correspond to these criteria are outlined below:

- heat pumps
- thermoelectric heat exchangers

3-2.1. Heat pumps

The heat pump is a very efficient means of heating and cooling spaces using a single system. These electrically powered units draw a large part of their energy from the latent heat present in the outside environment. In winter, heat energy is extracted from the outdoors; while in the summer, heat is pumped out of the dwelling to cool the interior spaces. A reversal of the refrigeration process within the same unit eliminates the need for two separate systems to perform the heating and cooling functions.[15]

Heat pumps may utilize any of the following heat transfer principles: air to air; air to water; or air to earth. Of these, the air to air units are currently the most widely developed for residential applications.[16] Within the air to air systems are the centralized and individual space conditioning types. The feasibility of using a centralized unit for a flexible housing system is questionable, since the design of its ultimate capacity would be highly subjective. The need for ducting provisions with this method also poses additional problems of coordination with the spatial enclosure components.

Individual, through-the-wall heat pumps offer greater potential with respect to increasing the opportunities for dwelling flexibility, since these can simply be added as needed without requiring ducting systems. Units of this type have been extensively used in hotels, schools, and apartment houses to incrementally heat and cool separate spaces. Many manufacturers are now producing small, self-contained heat pumps similar to portable air conditioning units. These may either be mounted in a window or through a wall. The appearance and noise levels of the newer models have markedly improved over the familiar window mounted air conditioners of the past.[17]

Restrictions on placement flexibility essentially concern the necessity to place the unit in an exterior wall where a grille is required for air intake and exhaust. This will limit the opportunity to sub-divide interior spaces which are remote from the exterior surfaces of the dwelling. The location of these units is also highly dependent upon the flexibility of the electrical distribution system.

3-2.2. Thermoelectric heat exchangers

Thermoelectric heat exchangers are a high-technology approach towards heating and cooling equipment. This is a system of thermoelectric semi-conductors where electricity is sent through bi-metal plates in opposite directions to either heat or cool. There are several advantages to this method over the heat pump, although, the principles are very similar. In terms of optimizing dwelling flexibility, the most important of these is a reduction in weight through the absence of heavy compressors and heat transfer coils. This is significant when the need to reposition the unit over time is considered.[18]

As with the heat pump, thermoelectric units must also be located in an exterior wall. Further information about these systems is limited, insofar as it appears that they are not currently manufactured.

3-2.3. Potential for user choice

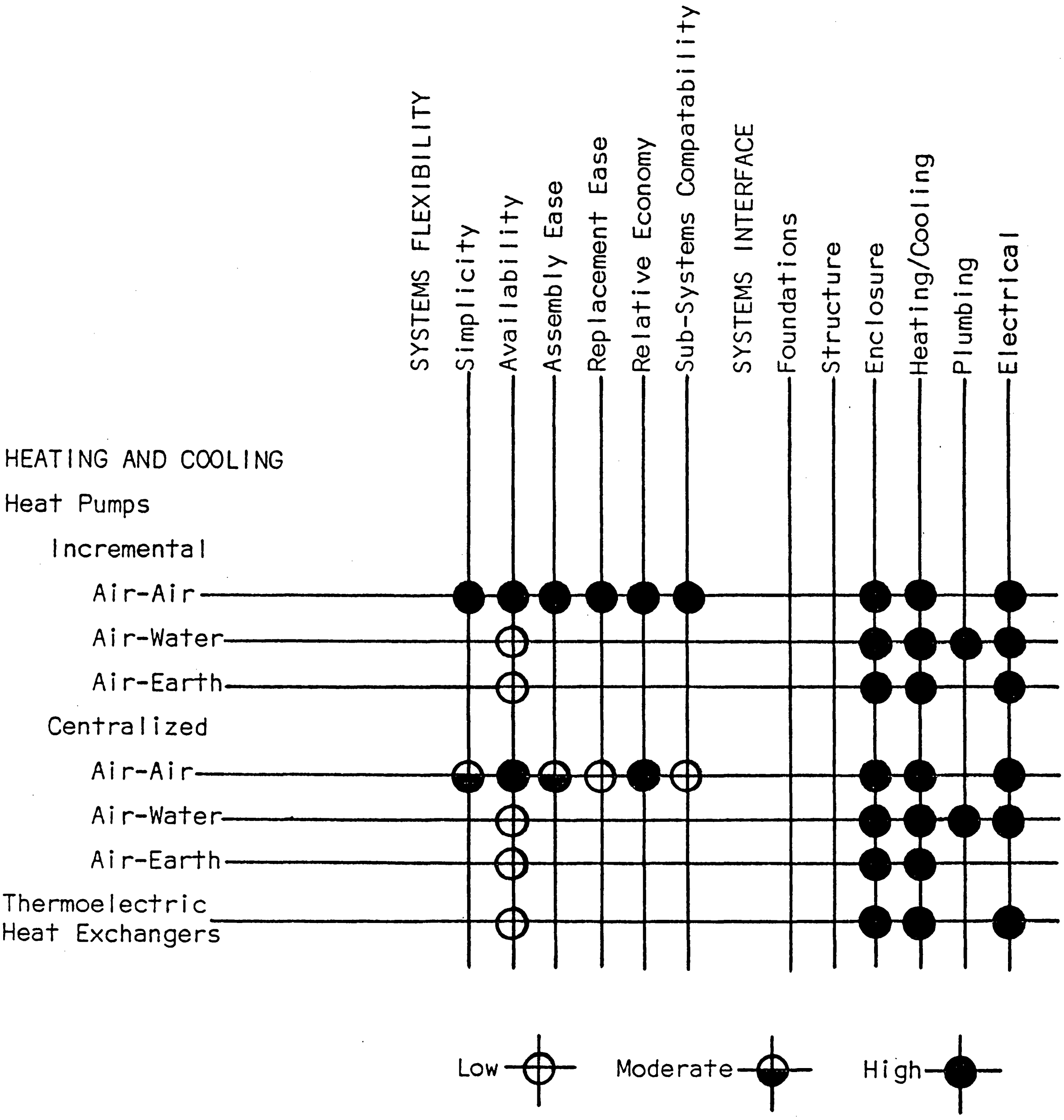
Incremental heating and cooling units offer the user considerable choice in relation to cost, quality and flexibility. Systems of this type can easily be installed and repositioned to correspond to a variety of spatial configurations. The small size and manageable weight of these units lend themselves to optimum placement flexibility and user implementation.

Limitations on user choice may result from constraints imposed by the electrical system. If interior partitions are utilized to convey the distribution wiring, they will have to be planned so that electricity can reach the exterior walls. In view of this consideration, the user may require outside assistance in coordinating the space conditioning and electrical systems with desirable spatial arrangements. Again, the use of floor or ceiling elements as wiring chases offer greater flexibility with respect to increasing the planning options available to the user.

Figures 3 and 4 indicate the potential for user choice and systems flexibility regarding the heating and cooling equipment. The data presented has been developed from sources quoted earlier in this section and various manufacturer's catalogues.

	DESIGN PARTICIPATION		USER PARTICIPATION	
	Fixed Elements	Flexible Elements	Flexible Autonomous Elements	Flexible Designer Coordinated Elements
HEATING AND COOLING				
Equipment				
Design		●		
Location				●
Implementation			●	
Power Connection				
Design		●		
Location				●
Implementation			●	

Figure 3. The potential for user participation in decisions concerning the heating and cooling system.



	SYSTEMS FLEXIBILITY						SYSTEMS INTERFACE					
	Simplicity	Availability	Assembly Ease	Replacement Ease	Relative Economy	Sub-Systems Compatability	Foundations	Structure	Enclosure	Heating/Cooling	Plumbing	Electrical
HEATING AND COOLING												
Heat Pumps												
Incremental												
Air-Air	●	●	●	●	●	●			●	●		●
Air-Water		○							●	●	●	●
Air-Earth		○							●	●		●
Centralized												
Air-Air	◒	●	◒	○	●	○			●	●		●
Air-Water		○							●	●	●	●
Air-Earth		○							●	●		
Thermoelectric Heat Exchangers		○							●	●		●

Low ○ Moderate ◒ High ●

Figure 4. Systems flexibility and interfacing of the heating and cooling system.

3-3. The Plumbing System

The requirements of an adaptable plumbing system closely parallel those of the electrical system. As the dwelling develops, the ease with which elements may be repositioned will largely depend upon the simplification of components and connections. The flexibility potential of the following plumbing sub-systems are examined:

- venting
- supply
- return

Since these are highly interrelated, it is first necessary to establish the parameters guiding the development of a flexible plumbing system.

Traditionally, plumbing components have been produced with a high level of versatility. This has been achieved through the use of a wide range of standardized elements which are then assembled at the site to conform to particular needs. Improvements in this existing method may best be implemented by reducing the number of elements required to make the plumbing system function, and the labor needed to assemble them.

Progress in this direction is evidenced by pre-manufactured bathroom and kitchen modules which simply connect to the main supply, return and venting risers.[19] One of the drawbacks with a system of this type is the necessity to place the fixtures in close proximity to the wet-wall; since, for venting purposes, this distance is generally limited to five feet by code.[20] The choices available to the user in selecting desirable fixtures locations outside of this short radius are non-existent with this method. Thus, increasing the options for fixtures placement flexibility is the primary objective in the design of a flexible plumbing system. The following discourse will examine methods of resolving this problem and related aspects which can serve to optimize user choice in the determination of spatial configurations.

3-3.1. The venting sub-system

The benefit of the wet-wall concept is its ability to provide supply, return and venting risers within a compact space. The necessary fixtures are then later attached. To optimize the flexibility potential of the fixtures distance from the plumbing riser, a first consideration is to eliminate the restriction imposed by the venting requirement.

The development of a patented aerator mixing fitting is a significant contribution towards the attainment of this goal. This fitting mixes wastes coming from the horizontal drain branches with the air in the main stack so efficiently that fixtures placed greater than five feet away need no further venting provisions.[21] Approval for use of this method in the United States was granted in 1968. At the present time, single vent systems are permitted only in projects where the entire plumbing system is copper.[22] Application of this method must be weighed against the benefits of utilizing alternative plumbing materials such as plastics or other metals. These are examined under the subheading "Materials and Connections."

3-3.2. The supply sub-system

Water is usually brought into the dwelling by means of a small one inch pipe. This pipe first passes through a meter and then branches off to the various fixtures locations. To increase flexibility, it would be advantageous to reduce connections and materials, and the space given over the equipment such as the hot water heater. One way to achieve this is through the de-centralization of the water heating function so that only one (cold) water supply pipe must run to each fixture. The means with which to do this is demonstrated by the development of compact gas or electrically powered instantaneous hot water heaters that operate on demand as the faucet is opened.[23] These have been available in Europe for some time now and have only come into recent use in the United States. The potential to eliminate one-half of all the supply plumbing and related connections for the dwelling not only allows for greater simplicity and flexibility, but, considerable economy. Water heaters of this type also resolve the fundamental problem of sizing a centralized system when demand is subject to change over time.

There are some shortcomings associated with the heating units currently produced worth noting. A small under the sink or in the wall model has a heating capacity of approximately one and one-half gallons per minute. This may limit its applicability for the tub or shower, since the Department of Energy has estimated that the average American shower uses two gallons of hot water per minute. To close this performance gap, shower head flow restricting devices or larger, less flexible, heating units are necessary. In addition, the economic advantages may not be as significant as first appears. Each fixture, except the commode, will require an instantaneous heater which costs almost the same as one household size heater. This high initial cost must be balanced against anticipated future savings on plumbing and energy expenditures.[24]

3-3.3. The return sub-system

Possibly the single greatest constraint on achieving unlimited fixtures location flexibility is the necessity to slope the drainage return lines down towards the permanent house drain. The amount of slope required for this depends upon the diameter of the pipe and the number of fixture units served by it. In most cases, a one-eighth to one-quarter inch fall per foot is suitable for the majority of residential systems.[25] With floor drains, such as the shower or commode, the depth of the floor will then govern the length of travel. For instance, a six inch drain pipe passing through a ten inch floor assembly has a maximum length of approximately thirty-two feet. A one-quarter inch fall per foot would halve this distance.

For wall drains, the path back to the house drain must be continuous such that openings do not occur through partitions carrying the return lines. This poses problems in achieving unlimited fixtures flexibility, since the plumbing system is integrated with, and dependent upon, the configurations of the spatial enclosure partitions. These same considerations also restrict the flexibility of the water distribution system. Placing the supply and return lines within the floor can optimize user choice in subsequent dwelling configurations by increasing the flexibility of the interior wall elements.

3-3.4. Materials and connections

Comparisons among the various materials suitable for plumbing systems concern the ease with which connections can be made, the relative costs, and the influence of codes upon their use. Another related aspect includes differences in weight which could become an important consideration when attempting to optimize dwelling flexibility through the easy manipulation of the various components.

Plumbing systems may be composed of copper, steel, brass, cast iron, or plastic. Plastics generally have an advantage over these other materials in every one of the above items except universal code acceptance.[26] Often, a combination of plastic and copper piping is used for the drainage and supply systems, respectively. This practice has resulted more from the pressures of special interest groups than any other reason.[27] In fact, plastics are certified by the National Sanitary Foundation for use in all supply, return and venting applications within the dwelling. The use of plastics in plumbing systems has also been recently approved by the National Plumbing Code. As a result, local codes are slowly accepting plastic piping as well.[28]

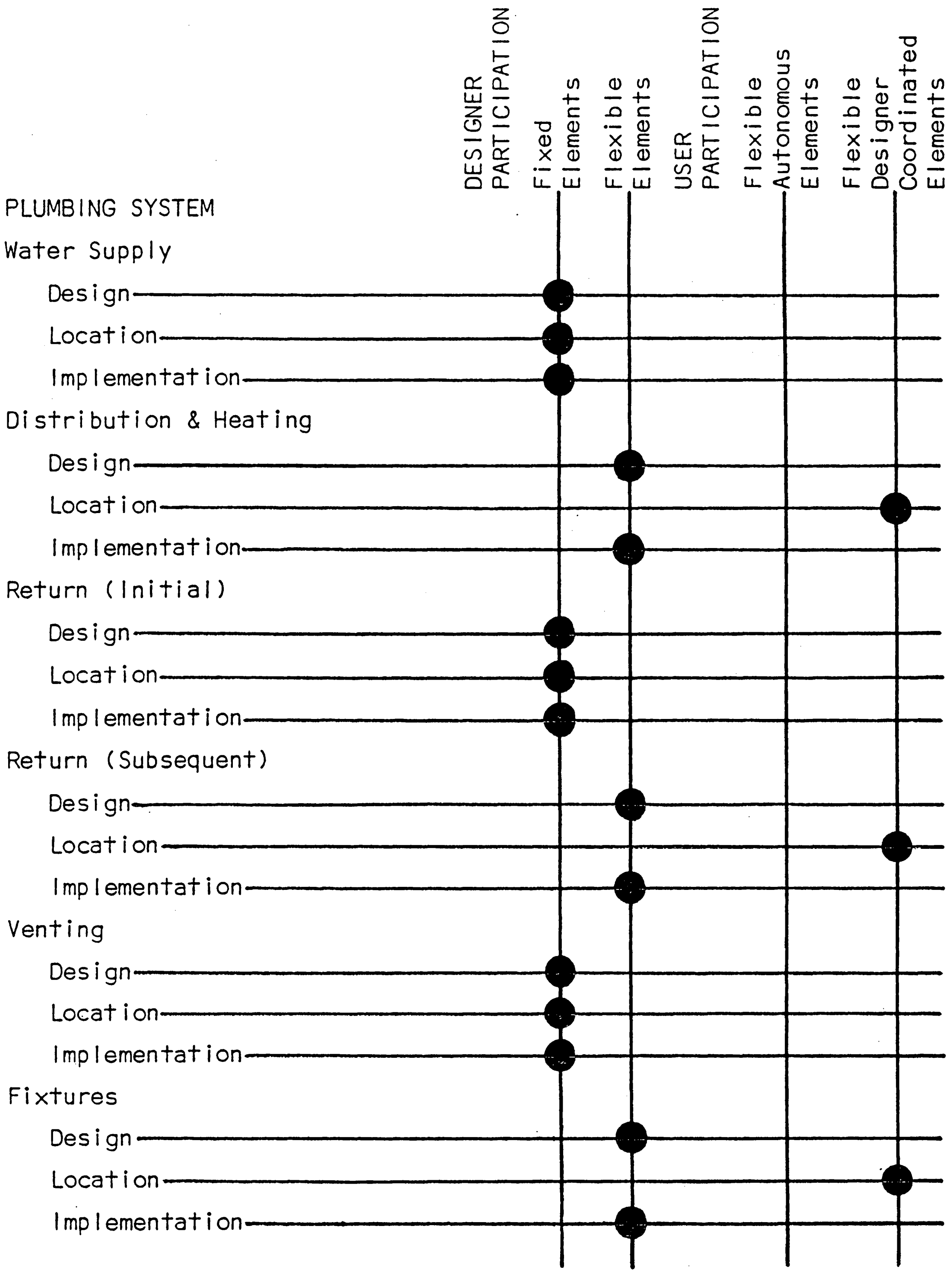
Connections between plumbing elements are usually made by means of threaded, soldered, or glued fittings. Threaded and soldered joints have an advantage in that they may later be disconnected, while glued connections are much more permanent. One of the disadvantages of threaded connections is the necessity to turn one of the pipes coming into the joint. This can be overcome by utilizing a special union fitting when future dismantling and re-assembly of the plumbing system is expected. These are available for all types of piping.[29]

3-3.5. Potential for user choice

The elements composing the plumbing system have the potential to offer the user considerable latitude in choosing desirable fixtures locations. There are, however, certain pre-conditions which must be fulfilled in order to assure this. The selection of a single vent plumbing system by the designer is the most important of these. One of the concessions that the designer must make in selecting a single vent system is the obligation to specify copper as the only plumbing material. This decision, in turn, will determine the range of choices subsequently available to the user.

Assuming that the designer decides in favor of dwelling flexibility over initial cost savings, restrictions on user choice then essentially concern the interrelationship between plumbing and enclosure. Enclosure elements which carry the supply and return lines will require outside assistance in their planning and implementation. For this reason, it is advisable to minimize these restrictions by locating the plumbing in floors or partitions that are not subject to continuous user implemented flexibility. The versatility of the plumbing components themselves can be enhanced through simplified connecting devices and the elimination of unnecessary piping. Further planning considerations include the necessity to coordinate desirable fixtures locations with the electrical distribution system when instantaneous water heaters are utilized.

Figures 5 and 6 summarize the flexibility potential of the plumbing system and opportunities available to the user. The information presented is based upon references cited earlier within this section.



PLUMBING SYSTEM	DESIGNER PARTICIPATION		USER PARTICIPATION	
	Fixed Elements	Flexible Elements	Flexible Autonomous Elements	Flexible Designer Coordinated Elements
Water Supply				
Design	●			
Location	●			
Implementation	●			
Distribution & Heating				
Design		●		
Location				●
Implementation		●		
Return (Initial)				
Design	●			
Location	●			
Implementation	●			
Return (Subsequent)				
Design		●		
Location				●
Implementation		●		
Venting				
Design	●			
Location	●			
Implementation	●			
Fixtures				
Design		●		
Location				●
Implementation		●		

Figure 5. The potential for user participation in decisions concerning the plumbing system.

	SYSTEMS FLEXIBILITY						SYSTEMS INTERFACE					
PLUMBING SYSTEM	Simplicity	Availability	Assembly Ease	Replacement Ease	Relative Economy	Sub-Systems Compatability	Foundations	Structure	Enclosure	Heating/Cooling	Plumbing	Electrical
Supply												
Metering	●	●	◒	◒	●	●					●	
Piping	●	●	●	◒	●	●			●		●	
Distribution												
Piping	●	●	●	◒	●	◒			●		●	
Connections	●	●	●	●	●	●					●	
Fixtures	●	●	◒	◒	◒	●			●	●		●
Water Heating												
Conventional	●	●	◒	◒	●	◒			●		●	●
Instantaneous	●	●	●	●	◒	●					●	●
Return												
Piping	●	●	●	◒	●	◒			●		●	
Venting												
Single Vent	●	●	●	◒	●	●					●	
Multi-Vents	●	●	◒	○	◒	○			●		●	

Low ○ Moderate ◒ High ●

Figure 6. Systems flexibility and interfacing of the plumbing system.

Chapter 4

DWELLING STRUCTURE AND ENCLOSURE

Dwelling structure and enclosure serve to spatially define the living environment of the user. The flexibility of these systems and their potential to increase user choice are evaluated. Another consideration in this analysis is the interrelationship between structure and enclosure with the services distribution systems required for the dwelling. Findings are diagrammatically correlated at the end of each section.

4-1. The Structural System

The development of a flexible structural supporting system is essential for a systemized building method to accommodate changing user needs. Such a system should have the capability of adapting to a variety of dwelling configurations over time. The following structural systems are examined to determine the extent to which this may be possible:

- frames
- building panels
- volumetric modules
- space frames

4-1.1. Structural frames

Frame systems consist of pre-manufactured steel or concrete columns and beams with infill panels of either a structural or non-structural nature. Concrete is often a prefered method over steel since there is no need for a separate operation to fireproof the structural members. When lightweight concrete is used, the building components are frequently light enough to place without elaborate construction machinery.[30] Further reductions in weight are possible through the use of gas concrete. This material is suitable for structural applications with a density of less than one-fourth that of conventional concrete.[31]

Frame components are produced for a variety of configurations and spans. The incremental characteristics of the structural elements offer the designer a wide range of initial planning opportunities. This same aspect also serves to facilitate transportation and placement ease.[32]

Interior planning versatility is largely due to the distinction between structure and enclosure. Non-load bearing partitions can be placed at desirable locations anywhere within the clear spans. Mechanical and utility chases running through hollow floor assemblies or suspended ceilings easily adapt to changes in spatial arrangements.[33]

Once the frame is in place, however, flexibility outside of the initial structural configuration becomes rather limited. Lateral expansion could only take place through the addition of foundations and supporting elements; while vertical flexibility is dictated by the bearing capacities of the original columns. Design for future expansion in the initial planning phase can be expected to result in higher costs for these items.

4-1.2. Building panels

Building panels are load bearing elements classified on the basis of their weight. Heavyweight systems are principally of the reinforced concrete type, while lightweight systems predominantly consist of stressed skin panels.[34] For stability and speed of assembly, these elements are usually fabricated as large as possible. A single concrete panel may weigh up to twelve tons. As opposed to structural frame systems, the transportation and placement of heavyweight panelized components often requires special construction machinery.[35]

Past experience has shown that the design versatility of load bearing panels is fairly limited. Interior planning configurations are restricted by the spans possible and the necessity to vertically stack the bearing walls. Further restrictions are generated by the incorporation of doors, windows, and mechanical chases during the manufacturing process. Future changes in the desired locations of any of these elements can only be achieved through the replacement of the entire panel.[36] Since panelized systems are designed to carry static loads, the removal of a supporting wall could ultimately lead to structural collapse.

Lightweight, load-bearing stressed skin panels exhibit similar deficiencies, although, they are easier to transport and place. With stressed skin panels, loads are transmitted through the outer facing materials. Depending upon the structural requirements, these may be composed of plywood, aluminum, plastic, or even cardboard. The core is usually of a coarse foam material of honeycombed aluminum. This building method is derived from the aircraft industry, where honeycomb structures have been used for many years in wing construction.[37]

Expansions in height or width for either the lightweight or heavyweight panelized elements are constrained by the same factors governing frame systems. As such, design for future changes will likely result in higher initial costs for these components.

4-1.3. Volumetric modules

Modular systems consist of three-dimensional structural volumes that are referred to in relation to both size and weight. Within the lightweight and heavyweight categories are also the intermediate and large sizes. Irrespective of these differences, all modulars are manufactured in a factory. In the case of large, heavyweight systems, the factory is often located on the building site. Large, lightweight systems, on the other hand, are usually transported in sections from a centralized plant.[38]

Final assembly at the site takes very little time with modular systems. In many cases, all that is required is placement and connection to utilities. This is achieved through the total pre-assembly and finishing done within the factory.

Lightweight systems are typically of the mobile home or sectionalized housing variety. They may be grouped horizontally or stacked with the addition of a demountable frame or strengthened wall. Units of this type are primarily wood stud or stressed skin construction. Applicability of lightweight modules is most often limited to low rise usage as a result of fire and structural codes, and materials economies.[39]

Heavyweight modules are fabricated out of concrete, steel-sandwich or fiber-reinforced plastic. Systems of this type can be stacked in almost any number of ways.[40] The major drawback of this method is the inevitable duplication of structural walls when the units are placed together. Some systems try to overcome this by using three-sided modules, slab-sharing or checkerboard stacking. A further limitation is simply the size and weight of these units. Extraordinary equipment must be used to lift and place them. This task becomes proportionally more difficult as the height of the stack increases.[41]

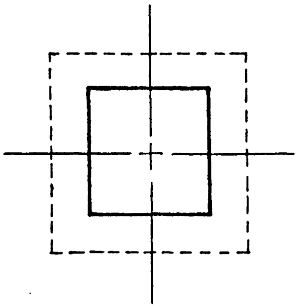
In terms of subsequent planning opportunities, modular systems are very restrictive. Universal placement flexibility is only achieved through the uneconomical means of designing each module to sustain the greatest load. As with panelized elements, the removal of any one unit could adversely affect the structural continuity of the entire grouping.

4-1.4. Space frames

Essentially, a space frame is a lightweight, three-dimensional truss made out of aluminum or steel. These are composed of small, standardized elements, that may be connected in a variety of ways. The spatial resolution of forces results in greater economy through lighter weight members. The main advantages of this method include the potential for large spans between required supports, and components adaptability to incremental changes in spatial configurations.[42]

One of the most notable attributes of space frames is their capacity to cantilever up to thirty percent of their span without additional ground bearing support.[43] It is conceivable, then, that an initial structural configuration that is not cantilevered could later be added onto. New members can simply attach by way of screw-in or bolt together connecting elements. The actual increase in area will depend upon the original span. This is determined by the optimum depth to span ratio. For floor supporting space frames, a one to twenty ratio is an acceptable rule of thumb.[44] On this basis, a simple rectangular or square bay with a 30% cantilever in all directions, yields a 128% increase in area without any additional support. In effect, a dwelling within a space frame bay could expand to approximately two and one-half times its original size independently of other units above or below. However, placement of dwellings within a series of connected bays would reduce the possibility for lateral expansion in at least two directions. This relationship is illustrated in Figure 7. The selection of bay geometry and orientation within a cluster is the final deciding factor in determining the range of expansion options. It should be noted that the selection of a rectangular bay allows for structural optimization only along one axis. This will likely result in higher initial costs by a reduction in support spacing along the shorter axis. As with the previous structural systems reviewed, the design of the original supports must anticipate increased loads due to future additions.

To date, innovative solutions towards the design and engineering of space frames have had more to do with the development of the components themselves than with the design of appropriate housing



SQUARE BAY

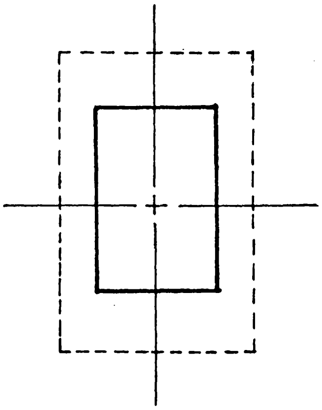
Initial bay = X^2

Expanded bay = $2.56X^2$

$(X + .6X)(X + .6X)$

$X^2 + .6X^2 + .6X^2 + .36X^2$

$2.56X^2$



RECTANGULAR BAY

Increase in area is proportionally similar to square bay.

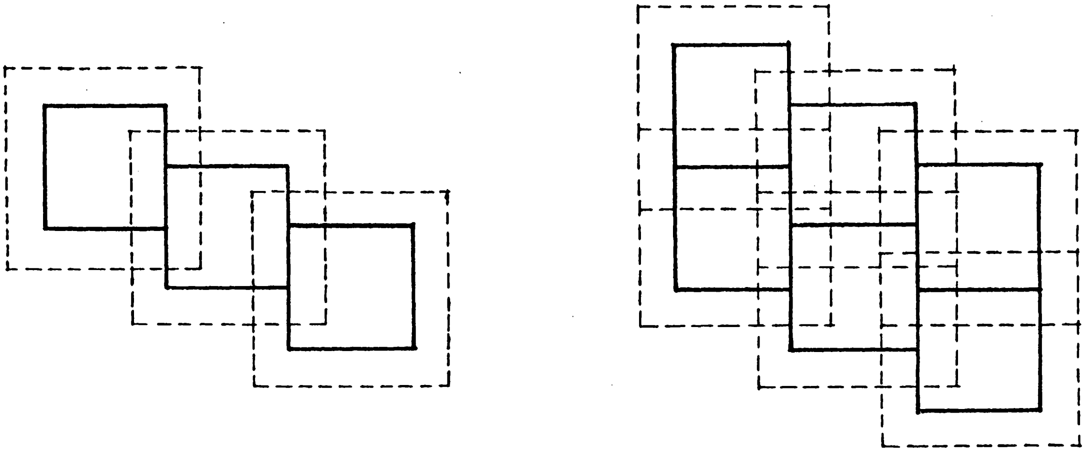


Figure 7. Lateral expansion potential and limitations of the space frame.

applications.[45] The feasibility of such systems for housing still remains largely unproven. Problems which must first be overcome include the need to protect the exposed members from corrosion and fire. Future developments in materials technologies may aid in eventually resolving these difficulties.

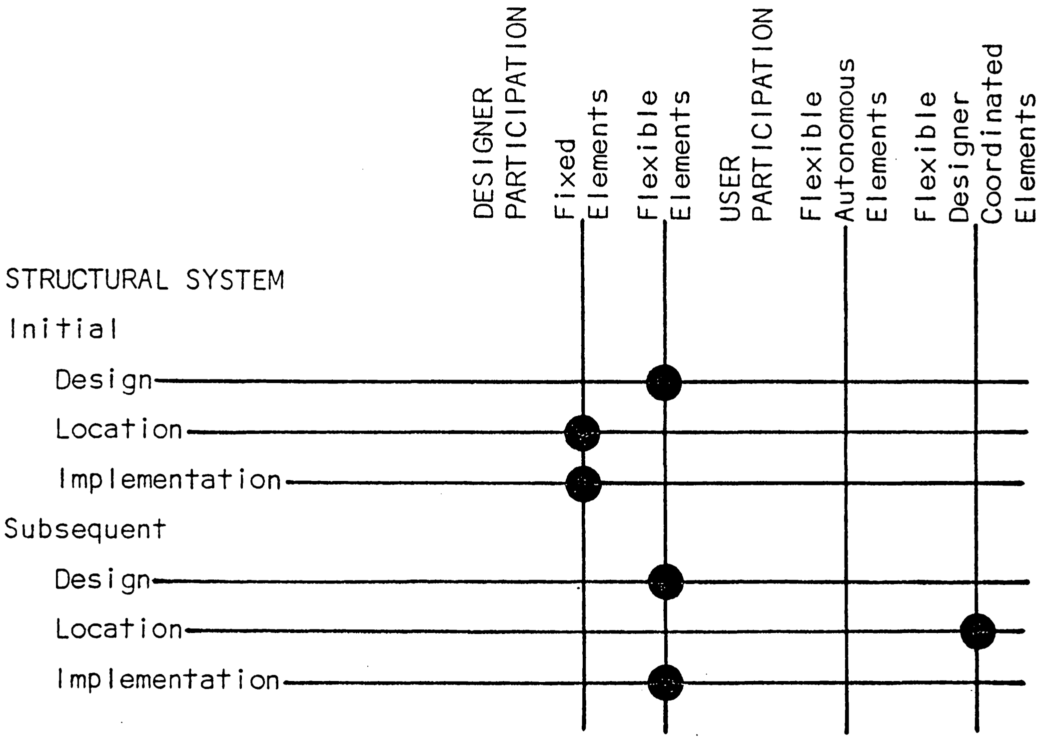
4-1.5. Potential for user choice

The potential for user choice in the development of the dwelling unit inherently relies upon the extent to which enclosure elements may be manipulated without jeopardizing structural integrity. Only then can decisions concerning spatial flexibility approach the level of freedom required to allow for user participation in the housing process. This is essential since decisions concerning structural implications are outside of the user's scope. In this respect, building panel and modular systems prove to be inadequate. With these methods, the integration of structure and enclosure acts to limit the range of subsequently available planning options. Instead, these systems are more suited to achieving a wide range of initial configurations.

Frame systems offer a somewhat broader range of spatial configuration possibilities over time. This can be attributed to the separation between the structural and enclosure components. Limitations on flexibility, however, become apparent if the dwelling must develop outside of the original parameters generated by the structural system. The alternatives in this case are to either build the frame larger initially, or add new foundations, columns and beams at a later date. Both methods have their relative weaknesses. Building the frame larger than necessary will increase the initial costs and give the impression of an unfinished building. Adding onto the frame at a later date poses problems if, for example, a family on an upper floor wanted to expand their dwelling, but the ones below did not want to pay for the structure in-between. To generate greater opportunities for dwelling flexibility and user choice in subsequent spatial configurations, a more incrementally adaptable structural system is needed.

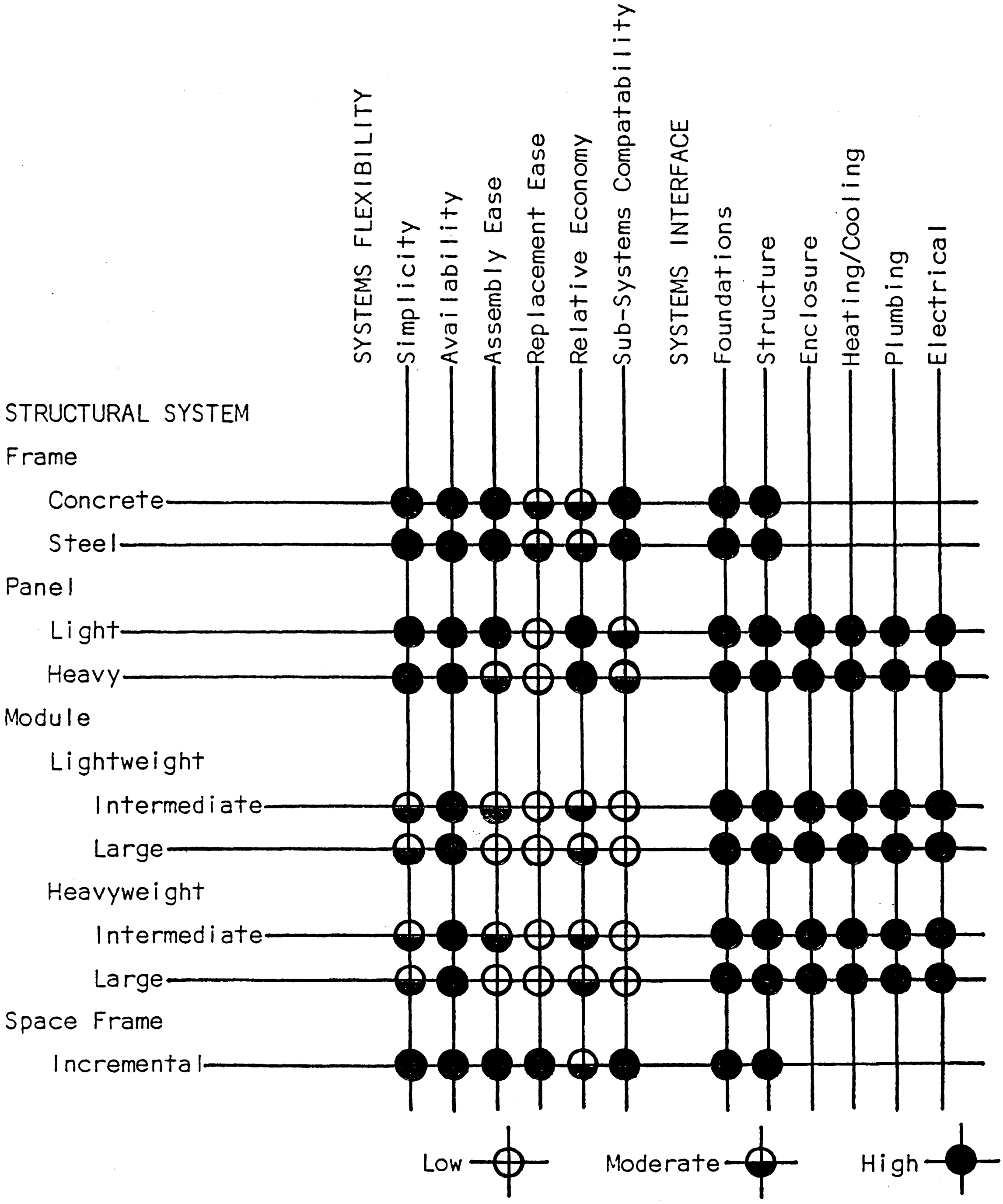
Space frames fulfill many of the requirements necessary for a genuinely flexible housing system. The separation of structure from enclosure and the incremental adaptability of the components have the potential to offer the user substantially more choices than any other method studied. Unfortunately, space frame supporting systems have not reached a state of development that lend their use to housing applications without costly measures. For the time being, conventional frame systems appear to be the most feasible alternative currently available.

Comparisons among the various structural systems studied, and their potential for user choice are tabulated in Figures 8 and 9. These findings have been derived from references listed in the preceeding analysis.



	DESIGNER PARTICIPATION		USER PARTICIPATION	
	Fixed Elements	Flexible Elements	Flexible Autonomous Elements	Flexible Designer Coordinated Elements
STRUCTURAL SYSTEM				
Initial				
Design		●		
Location	●			
Implementation	●			
Subsequent				
Design		●		
Location				●
Implementation		●		

Figure 8. The potential for user participation in decisions concerning the structural system.



STRUCTURAL SYSTEM	SYSTEMS FLEXIBILITY						SYSTEMS INTERFACE					
	Simplicity	Availability	Assembly Ease	Replacement Ease	Relative Economy	Sub-Systems Compatability	Foundations	Structure	Enclosure	Heating/Cooling	Plumbing	Electrical
Frame												
Concrete	●	●	●	◒	◒	●	●	●				
Steel	●	●	●	◒	◒	●	●	●				
Panel												
Light	●	●	●	⊕	●	◒	●	●	●	●	●	●
Heavy	●	●	◒	⊕	●	◒	●	●	●	●	●	●
Module												
Lightweight												
Intermediate	◒	●	◒	⊕	◒	⊕	●	●	●	●	●	●
Large	◒	●	⊕	⊕	◒	⊕	●	●	●	●	●	●
Heavyweight												
Intermediate	◒	●	◒	⊕	◒	⊕	●	●	●	●	●	●
Large	◒	●	⊕	⊕	◒	⊕	●	●	●	●	●	●
Space Frame												
Incremental	●	●	●	●	◒	●	●	●				

Low ⊕ Moderate ◒ High ●

Figure 9. Systems flexibility and interfacing of the structural system.

4-2. Tne Enclosure System

The spatial enclosure elements include the wall, floor and ceiling or roof components. To facilitate user choice and dwelling flexibility, it is important that these components are of an incrementally additive and subtractive nature. The determination of an optimally sized building component for this purpose is beyond the scope of this study. Instead, the current state of the art in materials and methods of application is examined in relation to reducing the user's dependence on outside assistance. In this way, the user will be provided the opportunity to effect changes in spatial configurations with a higher level of independence and expediency.

Building elements which closely correspond to these requirements consist of lightweight panelized enclosure components. These are classified on the basis of the following types:

- frame
- expanded core
- stressed skin

4-2.1. Framed panels

Panelized frame systems are often the simplest and least costly means of enclosing space.[46] These are typically composed of wood or aluminum studs to which drywall, paneling or other similar finish materials are applied. Mechanical chases and insulation can easily be incorporated within the interior of the panel. However, a high degree of on-site labor is often required with this method for installation and finishing; while the materials themselves are susceptable to damage in the course of removing or re-positioning the elements over time.[47] Frame systems used for floors or roofs are also usually too heavy and permanent to be considered as flexible building components.

More innovative, durable, and flexible enclosure methods are available which increase the potential for user implemented dwelling flexibility. Panels of this type are described below.

4-2.2. Expanded core panels

Expanded core enclosure components consist of a foam or honeycomb core with plastic, fiberglass, wood, metal, or cardboard facing materials. The honeycomb core material is commonly of a high strength Kraft paper or aluminum. Where high thermal insulation is required, the honeycomb cells are filled with polyurethane or other similar expanded foams to yield a lightweight exterior enclosure panel.[48]

Panels of this type are manufactured by pressing or rolling the facing materials onto the core structure, and securing by means of special adhesives to ensure the stability of the laminated composite. This procedure resulted in some early production problems when dissimilar materials were used for the core and the face. These have now been overcome by using higher strength adhesives and heat treatments.[49]

Expanded core components can sustain the loads associated with floors and roofs when the core is of sufficient strength. For these applications, cores of aluminum or cardboard impregnated with phenolic resin are typically employed. Chases for mechanical services are either incorporated during the manufacturing process or "drilled-out" in the field. Special fire resistant panels are also available to lessen the possibility of toxic gas formation when plastics are used in the core.[50]

The light weight and overall versatility of expanded core panels make them an ideal method for a flexible enclosure system.

4-2.3. Stressed skin panels

As opposed to the expanded core concept, stressed skin panels are designed to transmit loads through the outer facing materials. The stressed skin method of panelized construction is one of the most efficient means of producing lightweight, load bearing enclosure elements at this time.[51] These have found wide use in lightweight construction as previously described. In systems utilizing a separate structural system, the use of stressed skin panels would be a redundant and uneconomical application of materials.

4-2.4. Connections

For panelized enclosure elements to be highly flexible, the means with which they are connected and disconnected is of fundamental importance. To simplify this process, the development of universal connecting devices was initiated as early as 1941.[52] Universal, (three-dimensional) connections are required so that vertical wall components may either be attached to each other at various intersecting angles, or to horizontal floor and ceiling components. Today, similar clip-together connecting elements have been extensively developed to join panels three-dimensionally without the need for special tools or skills.[53]

4-2.5. Potential for user choice

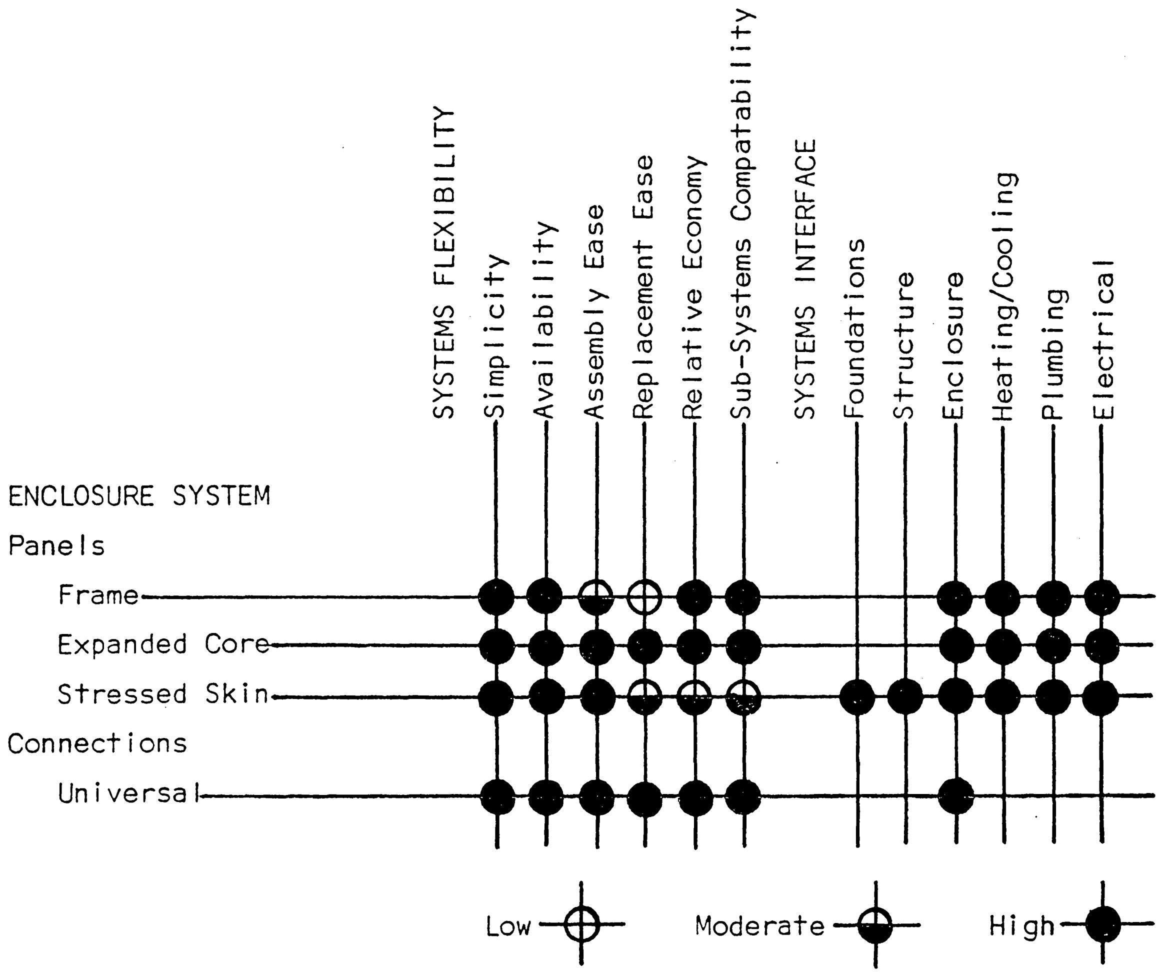
Non-structural spatial enclosure components offer considerable flexibility in relation to cost, finish, quality, and mobility. The use of simple, three-dimensional connecting devices also increases the potential for user choice in subsequent dwelling configurations. To determine the extent to which the user may directly participate in this process, it is first necessary to consider the relationship between the enclosure elements and the other sub-systems composing the dwelling.

The incorporation of the electrical, plumbing, and space conditioning systems within certain enclosure panels serves to define the role of the user in greater detail. For reasons already mentioned, panels containing wiring, plumbing or heating and cooling equipment are subject to lower levels of user choice and planning flexibility. It is necessary, then, to differentiate between enclosure elements in relation to their service and/or spatial functions. Spatial enclosure elements without services incorporated within them have the potential to be manipulated by the user without requiring outside assistance. If floors or ceilings are used as much as possible to convey services, the user could be granted greater self-determination in the planning and implementation of desirable spatial configurations through the manipulation of the flexible wall components. Although, the extent to which this is possible will ultimately depend upon the separation of structure from enclosure, local planning regulations, and user motivation.

Figures 10 and 11 summarize the potential for user choice and flexibility of the enclosure system. Sources quoted earlier within this section have been utilized to correlate the data.

	DESIGNER PARTICIPATION		USER PARTICIPATION	
ENCLOSURE SYSTEM	Fixed Elements	Flexible Elements	Flexible Autonomous Elements	Flexible Designer Coordinated Elements
Partitions (Spatial)				
Design		●		
Location			●	
Implementation			●	
Partitions (Service)				
Design		●		
Location				●
Implementation		●		
Floors/Walls/Roofs				
Design		●		
Location				●
Implementation		●		
Doors & Openings				
Design		●		
Location				●
Implementation				●

Figure 10. The potential for user participation in decisions concerning the enclosure system.



	SYSTEMS FLEXIBILITY						SYSTEMS INTERFACE					
ENCLOSURE SYSTEM	Simplicity	Availability	Assembly Ease	Replacement Ease	Relative Economy	Sub-Systems Compatability	Foundations	Structure	Enclosure	Heating/Cooling	Plumbing	Electrical
Panels												
Frame	●	●	◒	○	●	●			●	●	●	●
Expanded Core	●	●	●	●	●	●			●	●	●	●
Stressed Skin	●	●	●	◒	◒	◒	●	●	●	●	●	●
Connections												
Universal	●	●	●	●	●	●			●			

Figure 11. Systems flexibility and interfacing of the enclosure system.

Chapter 5

CONCLUSIONS

Recent advances in building technologies and methods of construction have the potential to increase dwelling flexibility and user choice in the determination of living environments. The preceeding analysis has suggested that restrictions on user choice are more of an organizational than technological nature, since many of the decisions concerning dwelling flexibility must be coordinated with outside planning agencies and building trades personnel. Cooperation among neighbors is another related aspect necessary to facilitate the development of adjacent dwellings.

Future changes in dwelling configurations rely upon the flexibility of each sub-system composing the dwelling unit. An examination of these has shown that all have the potential to enhance user choice in subsequent planning decisions. There are, however, differing levels of flexibility pertaining to each sub-system studied. The enclosure, plumbing and structural components are much more restrictive than the electrical and space conditioning equipment.

Limitations on user choice become most appreciable when the various elements are put together in the form of a complete dwelling. For instance, a highly versatile heating and cooling system can only be exploited to its fullest if the electrical provisions and the wall into which it is placed are equally as flexible. These, in turn, depend upon the adaptability of the enclosure and structural systems. The range of available planning options is ultimately dictated by the structural system, the least flexible of all elements evaluated. In a similar manner, the decision making and implementation autonomy of the user is often contingent upon freedoms initially granted by the designer. This is especially true for the plumbing system, where designer selection of the single vent method is necessary in order to grant the user any role at all in subsequent planning decisions.

The potential of a direct participative role for the user in Western industrialized societies only exists within certain narrowly defined segments of the electrical, enclosure and space conditioning systems. These include: the location and implementation of electronic switching devices; the location and implementation of enclosure elements without services incorporated within them; and, the placement of portable heating and cooling units. There are no elements within the plumbing or structural systems that present the opportunity for user autonomy in the decision making and implementation process. Previously identified flexible components that are not referred to in the above summary will require outside assistance in their planning and implementation. User participation with regard to these elements is thus reduced to an advisory role at best.

From the outset of this thesis, it was recognized that the user would not have sovereignty in the decision making and implementation process. The approach that has been developed does not intend to represent a self-help housing program. Instead, the primary focus of this work was to optimize the potential for components flexibility so that the dwelling could respond to changing user needs over time. The objective in this case is to provide the means for the dwelling to complement the user's personal needs by accenting expectations and goals in life. Included within this framework are those aspects which generate an affordable and adaptable housing system. To reduce costs it was proposed that only the most essential functions be included within the initial unit provided. Later additions or modifications may then be implemented as the user accumulates sufficient funds. With this method, the user would have the opportunity to choose only what is necessary or desirable, as income allows.

For a flexible housing system to become a viable alternative to conventional methods, it is evident that a high degree of coordination between the user and designer will be needed over the life of the dwelling. A possible means of ensuring this is to establish a community-wide organizational framework to assist the user. Such an organization could stock essential parts or equipment, and provide technical and planning guidance. In this way, the user would not have to rely upon a fragmented building trades industry to effect changes in dwelling configurations.

There are many problems which must first be surmounted before a cooperative community planning body of this type is possible. Likely opposition from organized labor and the uncertainty of user motivation are but a few of the issues that require greater in-depth study before a truly flexible housing method can become a reality. Even considerable foresight on the part of the designer cannot effectively meet this challenge.

Perhaps the only way to develop an architecture that directly responds to individual human needs is to introduce the user at every stage of the decision making and implementation process. At the present time, this seems an oversimplified and unrealistic goal for middle income, high-density housing. There are too many forces that work against such a proposal. The multiplicity of decision makers who currently operate in isolation from one another reduce the potential of a direct role for the user at every step along the way. The entire range of current design and construction perceptions demands a complete re-evaluation if the user is to be granted an opportunity to make significant choices in the determination of living environments.

ENDNOTES

[1] N. J. Habraken et al., *Variations*, (Cambridge: M.I.T. Press, 1976), pp. 7-17.

[2] Barry J. Sullivan, *Industrialization in the Building Industry*, (New York: Van Nostrand Reinhold Co., 1980), p. 231.

[3] Habraken, *Variations*, p. 149-152.

[4] John F. C. Turner, *Housing by People*, (New York: Pantheon Books, Inc., 1977), p. 112.

[5] William Zuk and Roger H. Clark, *Kinetic Architecture*, (New York: Van Nostrand Reinhold Company, 1970), p. 95.

[6] Charles Darwin, *The Origin of Species and the Descent of Man*, (New York: The Modern Library, 1872), p. 512.

[7] Zuk and Clark, p. 9.

[8] Habraken, *Variations*, p. 8.

[9] Zuk and Clark, p. 83.

[10] N. J. Habraken, *Supports*, (New York: Praeger Publishers, Inc., 1972), p. 60.

[11] Sullivan, p. 117.

[12] Henry S. Harrison, *Houses*, (New York: Charles Scriber's Sons, Inc., 1973), p. 317.

[13] Available at Electrical Supply Shops.

[14] Available at Larger Retail Stores.

[15] William J. McGuinness and Benjamin Stein, *Mechanical and Electrical Equipment for Buildings*, (New York: John Wiley and Sons, Inc., 1971), p. 244.

[16] Ibid, p. 244.

[17] Produced by Major Appliance Manufacturers.

[18] Thomas W. Maver, *Building Services Design*, (London: RIBA Publications Ltd., 1971).

[19] Sullivan, p. 72.

[20] McGuinness and Stein, p. 45.

[21] Ibid, p. 45.

[22] Moshe Safdie, Beyond Habitat, (Cambridge: M.I.T. Press, 1970), p. 119. The U.S. Copper Pipe Manufacturing Institute bought the rights to the Sovent System to reduce competition from the plastic pipe industry.

[23] New Shelter Magazine, "Thanks But No Tanks," Vol. 2, March 1981, pp. 72-76.

[24] Ibid, pp. 72-76.

[25] McGuinness and Stein, p. 64.

[26] Ibid, p. 18.

[27] Sullivan, p. 220.

[28] McGuinness, p. 64.

[29] Ibid, p. 18.

[30] David A. Crane, Developing New Communities, (Washington, D.C., HUD Publication 11-RT, 1970), p. 27.

[31] R. M. E. Diamant, Industrialization in the Building Industry - Volume I, (London: LLiffe Books Ltd., 1964), p. 191.

[32] Crane, p. 27.

[33] Ibid, p. 29.

[34] Thomas Schmid, Systems Building, (New York: Frederick A. Praeger, Inc., 1969), p. 68.

[35] Laurence and Sherrie Cutler, Handbook of Housing Systems for Designers and Developers, (New York: Van Nostrand Reinhold Co., 1974), p. 104.

[36] Crane, p. 30.

[37] Cutler, p. 104.

[38] Sullivan, p. 53.

[39] Cutler, p. 2.

[40] Ibid, p. 4.

[41] Ibid, p. 4.

[42] Sullivan, p. 138.

[43] Ramsey and Sleeper, Architectural Graphic Standards, (New York: Wiley and Sons, Inc., 1981), p. 262.

[44] Ibid, p. 262.

[45] Sullivan, p. 138.

[46] Gyula Sebestyen, Lightweight Building Construction, (New York: John Wiley and Sons, 1977), p. 250.

[47] Ibid, p. 250.

[48] Cutler, p. 104.

[49] Ibid, p. 108.

[50] Ibid, p. 104.

[51] Schmid, p. 68.

[52] Konrad Wachsmann, The Turning Point of Building, (New York: Reinhold Publishing Corp., 1961), p. 140.

[53] Sebestyen, p. 252-261.

SELECTED BIBLIOGRAPHY

Adams, Thomas. The Design of Residential Areas. New York: ARNO Press, 1974.

Alexander, Christopher. A Pattern Language. New York: Oxford University Press, 1977.

Alexander, Christopher. Notes on the Synthesis of Form. Cambridge, Massachusetts: Harvard University Press, 1964.

Bender, Richard. A Crack in the Rear-View Mirror. New York: Van Nostrand Reinhold Co., 1973.

Bennett, Corwin. Spaces for People. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1977.

Broadbent, C. Design in Architecture: Architecture and the Human Sciences. New York: Wiley and Sons, Inc., 1973.

Chermayeff, Serge, and Alexander, Christopher. Community and Privacy. New York: Doubleday and Co., Inc., 1965.

Crane, David A. Developing New Communities. Washington, D.C.: HUD Publication 11-RT, 1970.

Cutler, Laurence and Sherrie. Handbook of Housing Systems for Designers and Developers. New York: Van Nostrand Reinhold Co., 1974.

Deasy, C. M. Design for Human Affairs. New York: Wiley and Sons, Inc., 1974.

Diamant, R. M. E. Industrialized Building - Volume I. London: LLiffe Books Ltd., 1964.

Fitch, James Marston. "Experiential Bases for Aesthetic Decision," Environmental Psychology. Edited by Harold Proshansky, William Ittelson, and Leanne Rivlin. New York: Holt, Rinehart, and Winston, Inc., 1970.

Gowans, Alan. Images of American Living. Philadelphia: J. B. Lippincott Co., 1964.

Griffen, C. W. Development Building: The Team Approach. New York: Wiley and Sons, Inc., 1972.

Habraken, N. J. Supports. London: The Architectural Press, 1972.

Habraken, N. J., et al. Variations. Cambridge, Massachusetts: The M.I.T. Press, 1976.

Harrison, Henry S. Houses. New York: Charles Scriber's Sons, 1973.

Heimsath, Clovis. Behavioral Architecture. New York: McGraw-Hill, Inc., 1977.

Hesselgren, Sven. The Language of Architecture. Essex, England: Applied Science Publishers, 1972.

Jencks, Charles, and Baird, George (editors). Meaning in Architecture. New York: George Braziller, Inc., 1969.

Macsai, Holland, Nachman, and Yacker. Housing. New York: Wiley and Sons, Inc., 1976.

Maver, Thomas W. Building Services Design. London: RIBA Publications Ltd., 1971.

McGuinness, William J. and Stein, Benjamin. Mechanical and Electrical Equipment for Buildings. New York: John Wiley and Sons, Inc., 1971.

Nagarajin, R. Standards in Building. New York: Pitman Publishing Corp., 1976.

Newman, Oscar. Defensible Space. New York: Collin Books, 1972.

Oakley, David. The Phenomenon of Architecture in Cultures in Change. New York: Pergamon Press, Inc., 1970.

Perin, Constance. "The Social Order of Environmental Design," Designing for Human Behavior. Edited by Jon Lang, Charles Burnette, Walter Moleski, and David Vachon. Stroudsburg, PA.: Dowden, Hutchinson and Ross, 1974.

Proshansky, Harold. "Freedom of Choice and Behavior in a Physical Setting," Environmental Psychology. Edited by Harold Proshansky, William Ittelson, and Leanne Rivlin. New York: Holt, Rinehart, and Winston, Inc., 1970.

Ramsey and Sleeper. Architectural Graphic Standards. New York: Wiley and Sons, Inc., 1981.

Rappoport, Amos. House Form and Culture. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1969.

Rasmussen, Steen Eiler. Experiencing Architecture. Cambridge, Massachusetts: The M.I.T. Press, 1962.

Raymond, Antonin and Hopie. "On Japanese Residences," Architectural Japan Old New. Tokyo: Japan Times and Mail, 1936.

Safdie, Moshe. Beyond Habitat. Cambridge, Massachusetts: The M.I.T. Press, 1970.

Schmid, Thomas and Testa, Carlo. Systems Building: An International Survey of Methods. New York: F. A. Praeger, Publishers, 1969.

Sebestyen, Gyula. Lightweight Building Construction. New York: Wiley and Sons, 1977.

Spyer, Geoffrey. Architect and Community. London: Peter Owen, 1971.

Sullivan, Barry J. Industrialization in the Building Industry. New York: Van Nostrand Reinhold Co., 1980.

Thompson, D'Arcy. On Growth and Form. 2nd ed. Cambridge, England: Cambridge University Press, 1959.

Turner, John F. C. Housing by People. New York: Pantheon Books, 1977.

Wachsmann, Konrad. The Turning Point of Building. New York: Reinhold Publishing Corp., 1961.

Wittkower, Rudolf. Architectural Principles in an Age of Humanism. London: Alec Tiranti Ltd., 1952.

Zuk, William, and Clark, Roger H. Kinetic Architecture. New York: Van Nostrand and Reinhold Co., 1970.

SYSTEMS FLEXIBILITY AND USER CHOICE IN THE HOUSING PROCESS

by

Stewart Anthony Skubel

(ABSTRACT)

The implementation of a flexible housing system relies upon a synthesis of many factors. Of these, the relationships between society, technology, and economics are fundamental. For a flexible housing concept to be successful, it must necessarily respond to the inevitability of social and technological change, while also being an affordable alternative to the escalating costs of conventional housing. This thesis explores the issues, components, and planning strategies essential to the development of an industrialized system which can, in turn, respond to changing user needs over time.