SUPPORTS FOR HIGH TECH
Permanence and Change in Building System Design

by

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August, 1987

Submitted to the Department of Architecture
in partial fulfillment of the degree of

MASTER OF SCIENCE IN ARCHITECTURE STUDIES
at the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
September, 1989.

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ABSTRACT

The current situation regarding the obsolescence of our constantly changing built environment is leading Architects, now more than ever, towards the process of designing for unknown future requirements. Providing for flexibility and adaptability, have become basic performance requirements for the design of current High Tech Buildings. This constraint will eventually force designers into providing more permanent and meaningful physical configurations which will also provide an adequate response to change. The failure of today's Architects and Engineers to respond in a systematic way to these constraints has produced a situation where High-Tech buildings are becoming obsolete faster due to their rigidity.

The purpose of this thesis is to explore and develop alternative design tools dealing with *rationalized building systems* applied to the process of *Support Design.* The term "Supports" refers to the permanent framework intended to give general order and meaning to a building. "Infill," in turn refers to the body of parts of the building which are more temporal in character. Their combination will allow the building to adapt in accordance to changing user requirements.The issues of designing for permanence as well as allowing for flexibility and variability of spaces are explored in light of the work of contemporary architects. Reference is also made to the relation between architecture and current advances in building technology, innovations in materials, building systems, structural design, intelligent environments and user participation and control.

The *Support-Infill approach* to building design has been hitherto considered as a design philosophy intended for the provision of change in built environments while giving the users some control over them. This approach is embraced as a base for the development of a systematic method of support design for specific building types which gives special consideration to the provision of both permanent and temporary configurations.

The research is presented in three parts. One of special studies and information gathering, the second, special references regarding permanence and change in the built environment and finally design considerations within a conceptual and methodological model for the design of support systems for HTBs.

Thesis Advisor: Eric Dluhosch
Associate Professor of Architecture and Building Technology.

To my partner, Sylvia,
for her love
and inspiration.

Acknowledgments

I would like to make use of this opportunity to express my gratitude not only to those that have contributed to making this document a reality but also to those to whom I am indebted for these years at MIT.

First my gratest dept to my teacher and advisor, Professor Eric Dluhosch. To whom I am greatful for willingly sharing his insights and time with me.Through his guidance he patiently brought to bear his erudition upon often unsustantiated hypotheses with his incisive and profound criticism.

I want to thank Professor Zalewski for his teachings and giving me the opportunity to work with him and Professor Dluhosch in their academic work.

Aso I am grateful to my parents for their continuous moral support and life long example and to the Fulbright Commission for funding my studies.

I am greatful to my class mates specially:

I particularly to Angel for his friendship and his scholarly contribution to this research. To Sebastian,Freddy, Enrique, Jyoti, Daniel, and Claire for contributing to make the most from these two years, and to those in the editorial staff of *Metamorphosis* for their unconditional contribution to the growth of knowledge of architecture in the department.

Nabeel Hamdi and Reinhard Goethert opened my way to MIT . For their friendship, and continuous commitment to developing better ways to housing the low income masses of the world, I am thankful.

Last but not least,

To Sylvia, my wife and partner, who has as supported me in all my endeavors; this work is dedicated. I am thankful for her sweetness, her tolerance and for her smile; my thanks and all my love.

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INTRODUCTION

Buildings are being constructed with materials and processes that make them potentially more *durable* than ever in the past, but at the same time the changing environment and user requirements are demanding ever more flexibility from them. HTBs such as laboratories, hospitals, or corporate office buildings are often submitted to change, modifications and growth. Accordingly they have been designed to be flexible and adaptable. This has had strong consequences in the "permanence" and "temporality" of the buildings being constructed.

In todays "Consumer Society", the way we value human-made objects has changed; buildings have acquired status of consumer goods and therefore are rapidly amortized, conveniently demolished and constantly replaced. Continuous change and demolition has also resulted from the constant loss of the buildings' capacity to be representative and meaningful to their users. This condition, has gradually changed the traditional role of "buildings" as generators of urban environments. The urban dweller feels lost and confused in an ever-changing built environment, and experiences the anguish of not being able to recognize a permanent place within it. On the other hand he also sees the possibilities of personal development being restricted by the rigid physical structures that shelter his or her's every day life. Hence in order to respond in an adequate way to this twofold condition, buildings have to be designed accordingly; to be simultaneously *permanent* while easily adaptable to *change*.

In this thesis a basic building design strategy is put forth so as to confront the problem of recurring obsolescence of HTBs and the building environment in general. As will be documented, this approach is based on the pursuit of the simultaneous accomplishment of two goals. One is to provide architectural solutions that will respond to the building's need to accommodate *change*. The other is the provision of a balanced response to the building's requirements of *utility and meaning*. The notion of structuring the built environment with the combination of generic *support* frameworks and ever changing adaptable *Infill*. Both possibilities seem in todays conditions to be impossible to meet. Capturing the ephemeral; the efficient response to changing user requirements and in the other hand, approaching the eternal and gaining the ideal conditions of the archetype.

However, this does not mean that feasible alternatives for flexibility and variability in "permanent" buildings can not be achieved. Thus, a "Support Infill" approach to building design is explored here specifically so as to respond to the simultaneous problems of change and permanence in High Tech Buildings.

*Within the notion of a building as a complex system of coordinated permanent and temporary changeable parts, the **Support** represents the permanent framework that will provide the basic means to sustain, to bear and to preserve the integrity and basic order of a building.*

***Infill** represents the body of flexible, adaptable and replaceable (physical) parts and systems that are needed to make the support suitable for human habitation.*

This notion differs slightly from the concept coined by Habraken (1960) and subsequently by S.A.R., which refers specifically to the problem of the design of housing.[1]

The Architect and High Tech

Architects have come under increasing criticism for their lack of technical knowledge and managerial skill in the field of building technology. The idea until recently with reference to advanced building technology was that to perform architectural design compared to the task of coordinating products. But architects have found it impossible to deal with a range of thousands of materials, components, products and building techniques now available.

Regrettably, new materials and methods of assembly are less and less the Architect's concern as questions about structure, heating, cooling, cladding, and construction are handed over to specialized Engineers and Technical consultants. The Architects creativity is then limited to the coordination of the various systems and in the worst cases, just to the "decoration" of their buildings with often superficial and frivolous motifs.

In an age when technology has never before so dominated architecture , why do architects appear to ignore it's implications? Reyner Banham (1960) addressed this question in the following way.

[1] The theory of "Supports" (Habraken 1960) as well as "Variations" have been developed initially for the design of housing. Therefore a reformulation of the methodological aspects of the system has been necessary for its employment in the design of HTBs. Refer to Chapter 8, "Support Infill."

"It may well be that what we have hither to understood as architecture, and what we are beginning to understand of technology are incompatible disciplines. The Architect who proposes to run with technology knows that he will be in fast company, and that, in order to keep up, he may have to emulate the futurists and discard his whole cultural load, including the professional garments by which he is recognized as an Architect."[2]

Gropius believed Architects were in danger of loosing control over the design of buildings to Engineers and contractors, because they were unaware of the impact of Industrialization. It could also be argued that the traditional values and organization of the profession do not seem appropriate for the highly specialized design services required today

But the lack of interest among Architects in technical issues threatens to impair their comprehensive understanding of the nature of building in our time. However this attitude seems not to have affected the development of the High Tech movement. On the contrary, since the second half of the 19th. century "High Tech Architecture" has been based in the incorporation of developments in building technology to the design and construction of buildings, as way of keeping up with "the spirit of the age."

The Research

When a specific framework does not exist, (as in this case) part of the process is to gather and organize all relevant theoretical work from whichever disciplines may relate to the problem, and synthesize this knowledge into a new theory or model. This has been the criteria that has guided the research here presented. A possibility for the final outcome could also have been a physical model that would embody the principles put forth in the conceptual research i.e. an architectural project consisting of a support building system including a set of rules and agreements. However in this thesis the design process was shifted from deriving design solutions to informing the process itself.

The exploration is based on the premise that the architectural design process cannot be completely rationalized. That its nature rests on the combination of *subjective* and *objective*

[2] Banham, Reyner. (1960) in *Theory and Design of the First Machine Age* . New York, Praeger.

criteria of intuitive and systematized knowledge. The research is then oriented more towards the development of knowledge and basic principles for good building design in response to change, rather than to the production of an aesthetically pleasing or practical architectural project. The bulk of the research work has been carried out in mainly two stages, one of special studies and information gathering and the other as an exploration of conceptual and methodological models for HTB building design.

Information was then gathered the current state of building design as well as pertinent historical backgrounds. Reference is also made to the relation between architecture and current advances in building technology; innovations in materials, building systems, *High Tech Buildings*, and user participation. Moreover, the relationships between social values and human creations are also discussed including the problem of *recurring obsolescence and* the expression of *tectonics*[3] as a form of understanding and creating a *permanent* and meaningful physical world.

Strategies regarding design for flexibility and variability in HTBs are then explored as well as the nature of the problems that originate them. Relevant concepts are extracted from past theories, and reformulated to the conditions of the *High Tech Building*. Conceptual formulations and theoretical assumptions are then made possible within this framework so as to inform specific strategies for achieving flexibility and variability in buildings as well as user participation/control. Also special reference is made to the importance of achieving permanence in the design of future HTBs. The use of tectonic expression and archetypical configurations when designing for permanence is also discussed. Consequently the *Support Infill Approach* is presented as an effective way of complementing the implementation of strategies for flexibility and variability with permanent frameworks of buildings.

It is intended to show how the notion of buildings as a combination of "permanent" frameworks (supports) and coordinated changeable or flexible building parts (Infill) has been present in the design of so called High Tech Buildings since the outset. This notion has been adopted in the premise that it is necessary for this approach to be made explicit and consciously applied to the design of systems for future HTBs. The work presented here is meant to put this case forth. However, by doing so, it by no means forgoes other aims prviously stated stated.

[3] *Tectonics* has been defined as the science and art of assembling, shaping or ornamenting materials in construction and in the constructive arts in general.

The thesis is structured in five parts.

First, general information is presented regarding the evolution of the notion of buildings as systems. This includes related conceptual developments as well as historical references leading to the systems approach to building.

The second part describes the nature and main characteristics of High Tech Buildings including the evolution of the concept and its relation to the problem of obsolescence.

Thirdly, the recent problem of change and growth in buildings is described. Design strategies for flexibility and variability pertinent to HTBs are then explained.

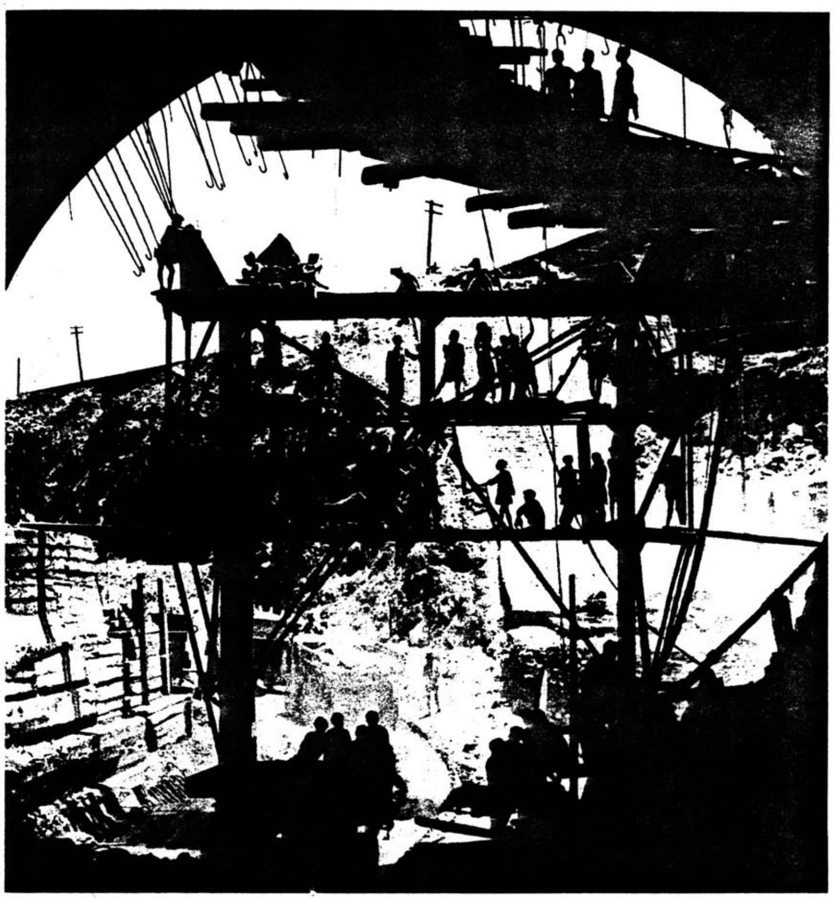
In Part Four the introduction of the importance of permanence in the built environment is attempted. Also design strategies for approaching permanent configurations in architectural design are presented in light of the work of Louis Kahn and Carlo Scarpa.

Finally the Support Infill approach is presented as a framework for the implementation of design strategies for achieving more permanence and flexible environments. In addition, an appendix which includes a reformulation of the S.A.R. methodology for Support design to the case of High Tech Buildings, is provided.

PART 1.

Chapter 1

1.BUILDINGS AND SYSTEMS



1. Building (from C. Sandburg, *The Family of Man*).

Chapter 1

1.BUILDINGS AND SYSTEMS

1.1 Introduction

The evolution of the characteristics of our built environment has come to the point where buildings are having to be considered as very complex machines. This complexity has consequently produced an increase in the number of factors to be considered in their design. The relationships between aesthetic and technical aspects, and their subsequent integration have specially increased in buildings with complex functions.

Likewise, the increasing need to meet user demands economically and efficiently, —turning out the highest standards of quality from limited resources available— has led architecture into taking advantage of industrialized products and processes.

With the advent of very sophisticated High Tech Buildings there has been a radical change from traditional building practices. User demands are now having to be served by a highly developed technology. The result is then that a truly High Tech building simply cannot be designed and built with conventional means.In the past buildings where *constructed*, today buildings are *assembled.* The building process has evolved from being a *manual* task to a *mechanized* and eventually *automated* process.

Even though systematic thinking has always been applied throughout history in construction and architecture to a certain degree, it was not until recently that the concept of *systems*[1] began to be applied to the building process. As will be explained

[1] See Chapter 2

subsequently, this concept has been a very useful response to the need for new approaches that would deal with complexity of analysis and of organization in buildings.

Technically, contemporary buildings can be seen as composed of a number of systems and subsystems that are interconnected in a coordinated and integrated way. Within this notion of building as systems, the subdivision of the whole into functionally and spatially differentiated parts and the relationship between the different spaces within the building, can also be understood as a hierarchical organization.

The totality with which architecture and the building process is concerned is not one undifferentiated whole: it can be grasped only by understanding its parts and their interrelationships; but, because these parts are numerous, they must be rationally and synthetically ordered in relation to each other and to the building as whole. [2]

The systems concept, as an accepted and historically successful way of approaching complex problems, accomplishes these requirements and establishes a conceptual framework for the design of complex built environments.

1.1.1 The Systems Concept

The Concept of System has been defined in numerous ways:

*A **system** is a coherent set of physical entities organized for a particular purpose. It works when its results correspond to the intentions and goals, based on identified needs, established for it.*[3]

.... an assemblage or combination of things or parts forming a complex or unitary whole.[4]

[2]Handler, A.B. 1970. *Systems Approach to Architecture*. New York: Elsevier. p.4

[3] Rush, Richard D. , Editor, 1986. *The Building Systems Integration Handbook*. The American Institute of Architects: John Wiley & Sons. p. 4

[4]*The Random House College Dictionary*. USA, 1988.

Thus this approach applies in many different ways to the building process.[5] What is basic is that there are elements or parts, specific relationships between them, that they all form an integrated whole, and that they unite for a purpose, or to perform a function. For example, Cities, or transportation networks constitute physical systems.

Since the advent of civilization, man has engaged in systematic research to discover means of controlling the environment. Since it may refer to products or processes, a"system", may act also as a "model" —they both consider basic aspects of a phenomena abstracted from reality for purposes of analysis.

Professions like "Systems Engineering," or "Systems Analysis" have been developed as a response to the necessity of applying "systems thinking" to the solution of complex problems in different fields. In the field of building design, architects have had to act as "system integrators", attempting to tie together the structural, spatial and aesthetics systems within a unified or holistic entity.

The idea of a system is simple in its fundamental definition of any whole as composed of interrelated parts. Since boundary definitions for systems, subsystems or elements are often blurred,its application, however, is very complex.[6]

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[5] See: Sittipunt, Prechaya. 1984, *The Systems Approach to Building: A Study of Systems Building Development*. MIT S.M.Arch.S. Thesis.

[6] Fergusson, F. 1975. *Architecture, Cities, and the Systems Approach.* New York: Brazilier. p. 14

The following is a list of essential characteristics of systems that may concern building systems design:[7]

1. The system constitutes a whole set of related things and events.
2. The whole is seeking to fulfill a set of goals.
3. The whole is composed of differentiable elements or subsystems, and the elements or subsystems are integrated in a patterned or structured form.
4. The elements or subsystems are in interaction, mutually affecting one another.
5. The whole system exists within an environment which is distinct and definable from the system itself.
6. A boundary differentiates the system from its environment.
7. The system is in constant interaction with its environment and producing outputs in exchange.
8. The system processes inputs into outputs through internal transaction in accordance with established needs.
9. The whole system seeks to maintain a state of dynamic equilibrium internally with its subsystems, and externally with its environment. Feedback is the process by which the system maintains equilibrium and steers towards the systems objectives.
10. To maintain dynamic equilibrium, the system is in a state of constant flux or change.
11. The system has some mechanisms for the control of its activities.

1.2 HISTORICAL BACKGROUND

As mentioned before the systems approach to building developed as a response to the growing complexity of the building process. Nevertheless the process of growing complexity had been triggered by developments that can be traced back to the industrial revolution of the 18th. century.

The "Industrial Revolution", especially in Europe, brought strong changes in the social, economical and political relationships of the time. Inventiveness was developed and important scientific and

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[7]Kraemer, K. L. 1973. *Policy Analysis in Local Government: A Systems Approach to Design Making*. Washington D.C.: International City Management Association. p. 31

technological developments were implemented. Manufacturing processes were developed and industrialization was born.

A new age was being born, many great discoveries were at once put to use, prompting a rapid succession of other discoveries, inventions and advances in knowledge. In design and construction, emphasis began to be given to the mechanics of building, mass production techniques, prefabrication, and the industrialization of the building industry.

For industrialization brings within our reach a level of technical accuracy, quality and precision never before attained in the history of building. Industry, not the individual and not craftsmanship determines what can be achieved and thus establishes the boundaries of the possible.[8]

1.2.1 The Nineteenth Century

The influence of industrialization on building became evident in the first half of the nineteenth century. The physical and conceptual changes in building construction at that time were greatly influenced by emerging technologies made possible by general industrialization and now available as a result of innovations and refinements to existing fabrication processes.

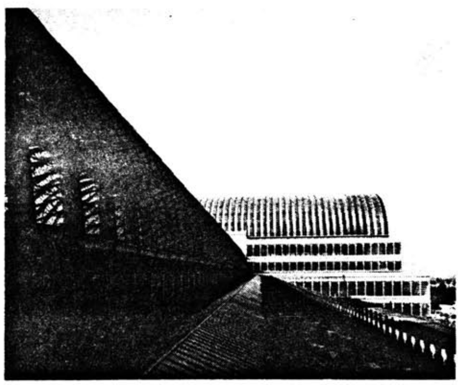
Iron, Steel, metal construction, bolts, rivets, reinforced concrete, monolithic construction, high tensile cables, continuous spans became the ingredients of the times "High Tech" architecture.(Fig.1.1)

From the architectural chaos of the general situation and the great formalistic contradictions of nineteenth century architecture, there did emerge a few examples of clarity and logical thinking to document the nature of the revolutionary change that was taking place. A few of these buildings, however, changed the way

[8] Wachsman, Konrad. 1961. THE TURNING POINT OF BUILDING: Reinhold Pub. Corp.,N.Y. 1961.p.49

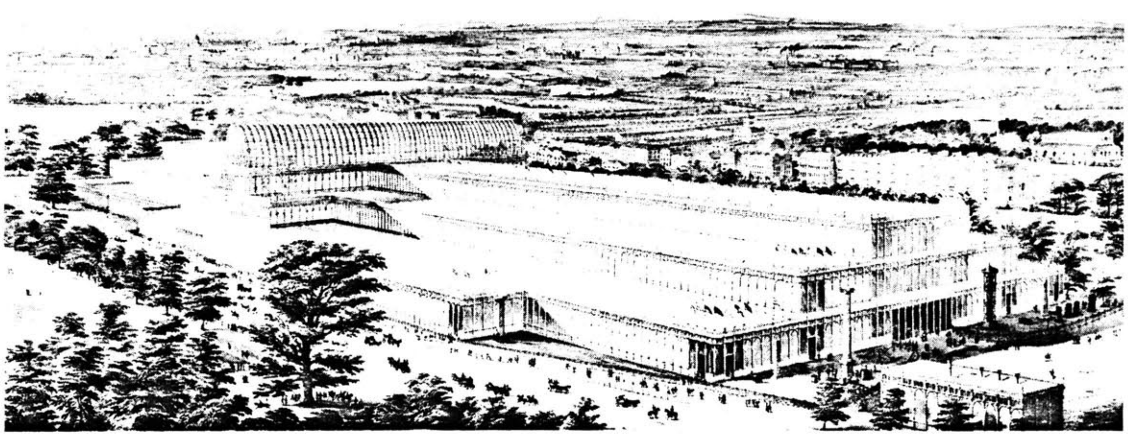
architects regarded the constructive aspects of their buildings. Among them, two buildings stand out as having greatly influenced the way buildings were going to be designed and built from then on. The Crystal Palace in London and the Steel frame Skyscraper developed in Chicago towards the end of the 19th. century.

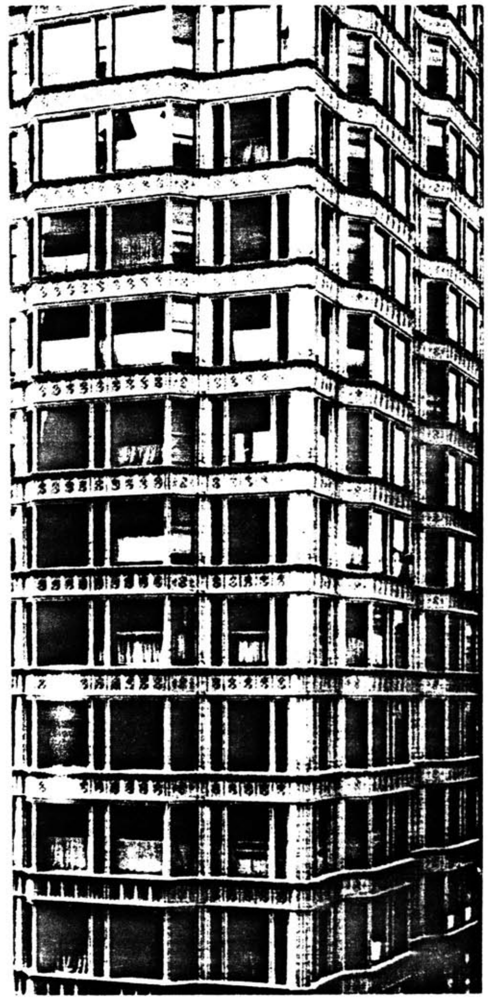
1.2.1.1 The Crystal Palace



The Crystal Palace was designed for the Great London Exhibition of 1851, by Sir J. Paxton (Fig.1.2). The building was to be of temporary nature, extremely flexible and capable of expansion. The building, covering an area of 19 acres, was completed in 9 months. The structure consisted basically of a series of hollow cast-iron columns joined by trussed girders that supported a glass roof.

Paxton submitted a proposal outside the 1850 competition which consisted mainly of an exact description of the building elements to be employed, the method of fabricating them and the manner of their assembly, and, above all, of a construction schedule. The proposal, having evolved from careful studies of production methods, research into materials and the development of details; was selected.





Since the building had to be of rapid erection, dismantling and expansion; no part could weigh more than one ton. Paxton and his team had to invent special production, testing and erection tools to handle both fabrication and assembly. The erection of the building, in less than four months, then became merely a question of assembling a set of finished, standardized, prefabricated elements.

These requirements resulted in a series of technical contributions to design and building practices of the time. Such contributions in the planning and design of the building, the fabrication of its components the assembly, dismantling and re-assembly of the structure etc. Also a system of modular planning which determined all the dimensions employedwas developed. The whole building was then planned on a modular grid, based on the distances between the center lines of the supports.

Not withstanding its temporary nature, the Crystal Palace visibly marks the break between two radically different eras in the history of building. Here, for the first time the design and construction of a habitable building had been systematized so as produce a simple solution to a complex problem.(Fig. 1.3)

... it was not only a demonstration of fresh insight but also a symbol of the new spirit of the times. From reason and logic intuitively embracing the thought of the new age of technology, their arose a beauty, such as had never before been known appraised or experienced
The Crystal Palace was a work of art.[9]

Konrad Wachsman.

[9] Ibid.p.19

1.2.1.2 The Chicago Skyscraper

Towards the end of the nineteenth century in Chicago. Here, cast-iron columns and beams where first used inside buildings to replace load-bearing masonry walls. Moreover, with the invention of the mechanical elevator, tall buildings really became a feasible proposition an the "skyscraper" was then invented.

This technological change would make the traditionally massive brick facades of the time dissolve into a free, non-load bearing structural framework supporting a thin masonry and glass skin.

The Takoma Building built in Chicago in 1888,(Fig.1.4) stands out as having greatly influenced the way buildings were going to be designed and built from then on. . It was designed by Holabird and Roche and it constituted the first tall building with a facade suspended from the structure, in some ways the first example of curtain-wall construction. It was one of the first "skyscrapers" which so clearly addressed the separation between the building's structural frame and the "skin".

The materials chosen for the building's skin; glass metal and brick, served no significant structural function, and were merely applied over a structural frame. The role of the brick in this building was closer to that of "decoration" than that of "structure."

It was at this point that the building's facade became an independent system separated from the rest of the structure. The effects produced by the new technological advances and the benefits of industrialization, gave birth to new ways of designing and building, which in turn made possible new building types.

1.2.2 Industrialization

The continued expansion of industrialization gave form to the concepts generated by the new possibilities. The hand tool developed into the machine and the machine became the tool of the time that would continuously repeat a predetermined cycle of activity producing a large number of identical parts.

But the industrialization of the Building process also required the **prefabrication** of building elements, which in turn demanded the **standardization** of the building components to be mass produced.

The concept of prefabrication in the construction industry of our time has been deeply influenced by the idea of incorporating industrialization in the building process.

Prefabrication is usually considered as a process that transfers to the factory the various work phases and work operations of construction and production of building components. In a broader sense it can also be understood as the application of production methods and techniques —based on organized and/or mechanized processes of repetitive character— to the integrated process of demand, design, manufacturing and construction.

Now since partial and full prefabrication on or of site, are widely implemented, the term has broadened it's meaning.

Prefabrication, in turn, implies the development of new techniques of joining individual elements on the site. "Building" becomes "assembly", a process which is essentially different from all previous methods of construction. In industrialized building, automatic fabrication takes care of everything, we find that there is few or no skilled building tradesmen needed on the factory floor.

On the site a building would simply be put together by an erection crew. (Fig.1.5.)

This goal is attainable thanks to the concept of mass production. In contrast to objects made by hand, the mass produced article must embody an abstract system of modular coordination and conform to previously defined *standards*. **Standards**, an abstract concept, however, is also an objective measure of the performance characteristics and quality of the product. Today with the emergence of CAD/CAM production methods the traditional meaning of "modular" has changed. i.e. the capacity of a robot to a combination of pre-programmed tasks. Control systems, one of the essentials of mechanical production, make it possible to maintain a standard of precision, rarely attained in the building industry.

As the concept of industrialization was incorporated into the the philosophy of the modern movement, it grew steadily in importance. At the beginning of the century not only was it being applied in building design but also in the field of large scale urban planning and mass housing. However with the growing complexity, previously described, the implementation of industrial processes in the design and production of buildings could only be accomplished through the a systematic approach to the problem.

The early stages of system building appeared in the form of industrialized building. It started in Europe after the second world war as a result of the urgent need to rebuild the devastated cities, and as a response to the large demand for housing.

Building systems where made possible by, and can be considered as industrialized building but not vice-versa. Early industrialized building lacked two of the characteristics of systems building; 1) in general they did not analyze user requirements 2) they did not define the functions of the various subsystems on the basis of open-ended design, and flexibility.

Until recently it was believed that since industrialization made available the best tools and the best methods; the forces at work on the scientific, technical, economic and sociological planes would be the only ones that would give shape to a building. Formal or stylistic problems became only a secondary consideration.

Nevertheless, industrialization should not be misapplied as an accessory to the realization of ideas independently conceived. It can only be understood as a direct cause, shaping the development of every product, which, as an element or component, co-determines the form of expression.

Today, it has been understood that the promises that industrialization will bring improvements in quantity, quality, speed and economy; are not always true. None-the-less when applied in a correct way the following technical advantages can be observed:

-Improvement of working conditions, to "back-breaking" tasks
-Better quality control, on a massive scale.
-Rationalization of the process, technically and economically
-More efficient planning, for "generic" solutions.
-Savings through repetitive operations
-Possibility of mechanization, of formerly manually performed tasks
-Higher productivity

1.2.3 The Current Situation

Translating this knowledge into concrete achievements, has allowed science to exert a direct and previously not fully expressed influence on the building process. In the last decades, two revolutionary forces have profoundly changed the context of building design:[10]

First, New methods, new materials and new skills have been made available as a result of technological development due to the effects of the industrialization of the building process. In this new context, buildings or their parts are produced by manufacturers, each with its own production technology.

Second, accelerating changes in human's needs and technology have influenced building design which has had to be able to harbor these and future changes. Therefore user needs and requirements have had to be carefully worked out through sophisticated analysis and programming techniques.

Both forces, have to be considered today in design, if the building is to survive obsolescence caused by unforeseen technological development or by the changing user needs.

Also, with the advent of new construction methods it has been realized that the fragmented organization of building processes hampered technological efficiency, interfered with the complete utilization of the building industries' potential, and frustrated the rationalization of available resources and technology. The systems approach is a attempt to coordinate the different parts and processes involved.

10 Parsons, D.J. 1972. *Performance : The New Language in design.* performance concept in Buildings. Joint RILEM-ASTM-CIB Symposium.

Konrad Wachsman, was to say in 1961:
Only an ideal, combined application of all the accumulated knowledge and resources of technology and of our understanding of modern man, his requirements and his developing critical faculties, will give our building its new form, simple, natural, anonymous, intelligible to all, because consistent with the thought of the times.[11]

1.3 THE GENERAL SYSTEMS THEORY

The General Systems Theory (GST) is a modern response for dealing with different problems that appeared similarly and simultaneously in several disciplines, which were evolving toward an ever-increasing specialization necessitated by the enormous amount of data, the complexity of the techniques involved and of theoretical structures within every field.[12]

As the number of specializations increased in science and technology, also the dependence between specialties also increased. In order to be able to understand complex phenomena in this context, it has become necessary to shift from an analytic to a synthetic way of thinking.

The GST assumes that there are models, principles and laws that apply to general systems, irrespective of their particular kind, the nature of their elements, and the relations between them. These models share certain common properties such as *wholeness*, *dynamic interactions*, and *organization*. Hence, when trying to comprehend situations which are characterized by interdependency and complexity, the observation of these principles may uncover the orders of a system.[13]

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[11] Wachsman, Konrad. 1961.Op. Cit p.11

[12] Bertalanffy, Ludwig von. 1968. The General systems Theory. NewYork: Brazilier. p.30

[13] See: Ackoff, R.L. 1959. "Games decisions and Organization" *General Systems.*

The consideration of the wholeness refers to the fact that systems should be studied as a complete entity rather than as an agglomeration of parts. Similarly, a system, as exemplified by the living organism, cannot be conceived now without taking into account *dynamic interactions* such as adaptiveness, purposiness, goal seeking and the like. Finally it is important to understand the characteristics of *organizations*, wether a living organism or a society. These include notions like those of, growth, differentiation, hierarchical order, dominance, control, or competition.[14]

1.3.1 Living Organisms and artificial systems

A consequence of the existence of these general systems properties is the appearance of structural similarities or isomorphisms in different fields.The state or property of being isomorphic means to be different in ancestry but to have the same form or appearance.

Systems can be classified as *Open or Closed*[15] and described in different levels; through *analogies, homologies and explanations,* —Natural or biological analogies are commonly used by architects and planners.

In the past living organisms have been understood as complicated clockworks, as engines and today as a cybernetic machines. When comparing natural and artificial systems through this machine model certain limitations appear still to be unsolved. Such are the problem of the origin of the machine, its regulation, and the lack of a metabolist response to the environment. Organisms are defined

14 See: Bertalanffy, Ludwig von. 1968. Op. Cit. p.45

15 The notion of Open and Closed building systems is explained in th subsequent Chapter . See the section: Building Systems and Systems Building.

in the General Systems Theory as open systems, since natural systems develop spontaneously in response to physical laws and achieve equilibrium of life through a dynamic process.[16]

While man-made machines work in such a way as to yield certain products and performances (air planes, railways, buildings..), the order of processes in living systems is such as to maintain the system itself. Wholeness and order, Adaptive self stabilization, Adaptive self-organization, and Systemic Hierarchies are some of the properties of natural systems that are still to be matched by artificial systems.[17]

In natural systems the whole is other than the simple sum of the properties and functions of its parts. They have the capacity of re-establishing to a previous steady state compensating for environmental disturbances. Organisms with these capacities develop hierarchically structured configuration.

Hierarchic order within systems is hence a fundamental concept in the General Systems Theory. Principles of hierarchic order can be stated in several ways ranging from verbal language to tree diagrams and abstract mathematical models.

Within these systemic hierarchies, every system is a subsystem of a larger system. In relation to a chosen level, systems belonging to a level below are called *subsystems*, and the systems belonging to the next higher level are called *suprasystems*.

Accordingly we could consider the universe as an enormous hierarchical system ranging in scale from the elementary particles

16 See: Bertalanffy, Ludwig von. 1968. Op. Cit. p.121

17 See:Lazlo, Erwin. 1972: *Introduction to Systems Philosophy. Harper Torchbooks. p.18*

and cells, to living organisms, organizations, environments etc. The process of invention of artificial systems requires not only achieving a similar structure but also a description of its inner organization and functioning, and the setting up of the interface between inner and outer environment.[18]

[18] See: Simon H.A. *The Sciences of the Artifitial*, The MIT Press

Chapter 2

2. THE SYSTEMS APPROACH TO BUILDING

2.2 The Systems Approach to Building

2.3. The Performance Concept
- 2.3.1 Performance Requirements
- 2.3.2. Performance Criteria
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2.4. BUILDING SYSTEMS AND SYSTEMS BUILDING
- 2.4.1. Building Systems and Performance Specifications
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  - Kit of Parts
  - Set of Rules
- 2.4.3. The SCSD System
- 2.4.4. The Implementation of the Systems approach to Building System Design.
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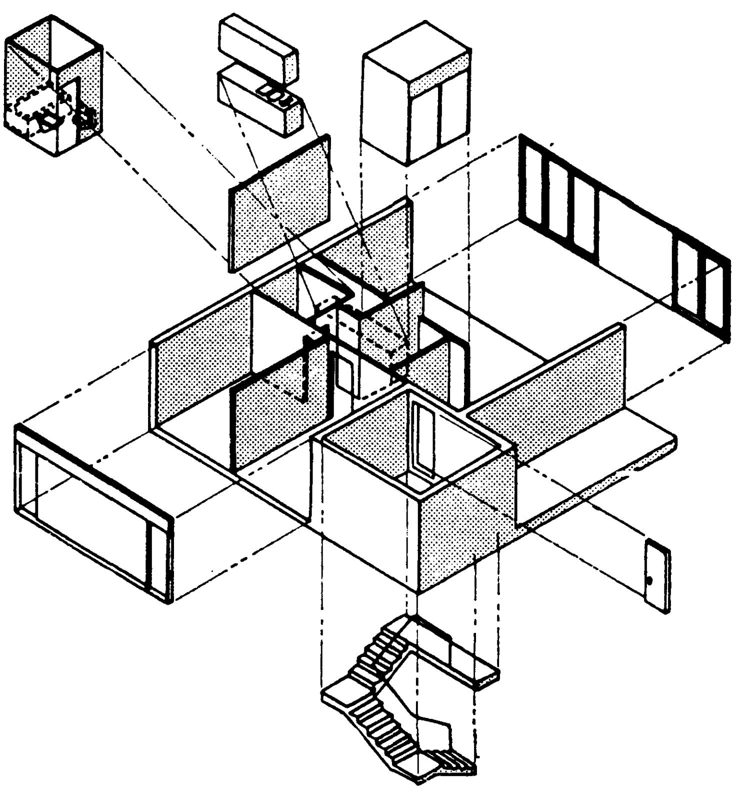
- 2.4.6. Modular Coordination
  - tolerances.
- 2.4.6.1. Modules

universal module
modular categories
2.4.6.2. The Grid



Chapter 2

2. THE SYSTEMS APPROACH TO BUILDING

2.1 Introduction

When the systems approach is applied to the solution of building problems, what results is a process whereby resources and user's requirements can be related effectively to performance, cost, and time. When it is used for designing a *building system*, then it aims at the integration of both the process and product of building. It converts scientific knowledge into applied technology by means of goal-oriented processes with clearly defined contexts and constraints on performance, cost and time.[1]

The Systems Approach fulfills the promise of a more efficient and rational use of resources, and better implementation of applied technology. It does so by providing the opportunity *to evaluate* more rationally as well as the means for *management changes.*

Ezra D. Erenkrantz (1970) defined the Systems Approach as *a process which is based on viewing a problem as a system, i.e. as set of interrelated, interdependent parts which "work together" for the overall objective of the whole.*[2]

In this context the concept of Building System was then understood as a set of interrelated building parts with a base of information

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[1] Dluhosch, E. 1986. *Building Systems*. Un-published class notes. Fall 1986. MIT.

[2] Ehrenkrantz, E. D. 1970. *The System to Systems.*"AIA Journal, May 1970, p. 56-59

which defines the relationships between them. The Systems Approach refers, thus, to a system as an *order of processes*; while, a Building System refers to a system as an *order of parts*. Since these two concepts are not the same, an important distinction can be made: building systems may or may not be developed through the systems approach, and the result of a systematic approach may or may not be a building system.

According to Marvin Adelson (1966), there are **five major characteristics of the Systems Approach:**[3]

1.Creativity. Properly used the Systems Approach provides a means for tapping the creativity and judgement of a broad assortment of relevant professionals and technical disciplines. This is accomplished by providing one or more frameworks into which inputs from the various groups of individuals may be channeled without getting lost or ignored.

2.Empiricism. The Systems Approach relies greatly on the utilization of information as data. This includes the gathering of information itself plus the use of techniques to ease its rapid use.

3.Organization. The basic concept of the system approach lies in the organized use of resources available. The design of systems is dependent upon the development of a process which assembles parts, both human and material, according to certain constraints, chosen to ensure the interaction of the parts in a way that will lead to the desired holistic behavior.

4.*Theoretical*. Empirical data is built up in a theoretical framework or model. When a framework does not exist, part of the systems process is to gather and organize all relevant theoretical work from whichever disciplines may relate to the problem, and synthesize this knowledge into a new theory or model.

5.Pragmatism. The systems approach is an action oriented problem-solving process. To be truly effective the organizations and individuals involved, or who are likely to become involved, must participate actively in the process of study, analysis, development and operation.

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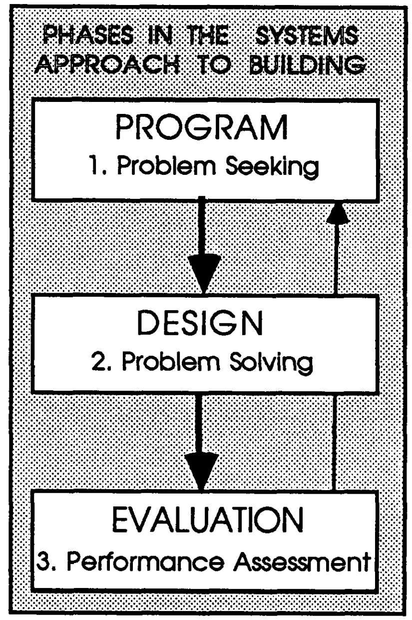
[3] Adelson, Marvin. 1966. *The Systems Approach —A Perspective* . SDC magazine. Vol. 9 No. 10, October 1966.

When studying a system, five aspects should be considered.[4]



1. *Objectives*, must be stated explicitly. Moreover some precise and specific measures of overall system *performance* are desirable so as to be informed as to how well the system is doing.

2. The *environment* influences and determines the systems' performance. The environment of the system is what lies "outside" of the system, and which the system cannot modify.

3.The factors that lie "inside" the system are the *resources* of the system which can be used for the own advantage of the system or for its functions.

4. A system is composed of *subsystems and components* which are related to the task the system must perform. The components of the system are organized as a hierarchy, including the specific action for each to take.

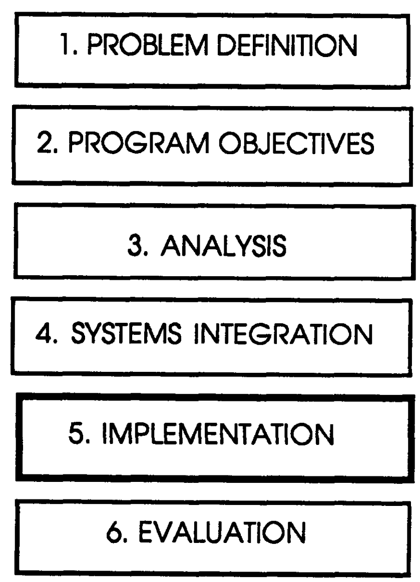
5. The *management* of the system deals with the generation and development of plans for a system, which involves considering all the parts, the environment, resources and their support to the activities of the whole.

2.2 The Systems Approach to Building

The Systems Approach, wether resulting or not in a building system, provides significant improvements in the building process.

1. *Complex demands placed on buildings can be solved* through the successful interplay of all the parts. involved in a integrated fashion.

2. *Better use of resources* in terms of efficiency and economy can be accomplished. Time and costs savings, both in construction and during the buildings life-cycle, can result from the use of performance specifications, standardized products, new methods of assembly, new procurement methods, new bidding procedures, and better response to alterations and maintenance.



Procedure for the Implementation of the Systems Approach to Building

4 Churchman, C. W. 1968. *The Systems Approach.* New York: Dell Publishing Co.

3. *Technological innovations* may also result from the use of performance specifications instead of conventional prescriptive specification documents.

4. *Quality.* the stimulation to seek and produce innovations, be it in terms of better performance, or savings in cost, lay out the conditions for its development.

Through the implementation of the systems approach, several means of shortening the design production process have been developed. *Fast-tracking* —a strategy for saving time in the overall building process— for example, has made possible to telescope design and construction as much as possible, i.e. to start construction as soon as the minimum required required design is completed.

Maximum benefits from fast-track processes emerge from very large projects and from building systems projects. applied to conventional construction fast-tracking can produce about 25% of time saving. In a project with a large number of coordinated subsystems and full fast-track programming, time savings may range up to 45%.

The following hierarchical organization of the built environment from a technical point of view; the **model of construction products** developed by M. S. Eldar[5] may be useful for a better understanding of the terms to be used here to depict a the systems approach to building.

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[5] Editors of Industrialization Forum. 1973. *Product Information: Sweet's Guidelines structures.* IF Vol. 4, No.4, p. 36

Products are classified into six types by structural and functional complexity: Basic material, Unit, assembly, System, module, and Facility.

Basic Materials. A simple product, pre-formed or formed in place, adaptable to a variety of uses, whether in the manufacture of construction products or applied directly into the fabric of conventional construction. Examples are sheet-glass; brick; resilient flooring; etc.

Unit. A built element complete in itself which can be used independently, or become a component of a larger whole (Assembly, System, etc.). No assembly occurs at site, only installation. Examples are pre-hung doors and frames.

Assembly. A pre-designed and pre-fitted whole, comprised of a number of components with a high degree of interchangeability. Three types are distinguished:
- Built Assembly— curtain wall, hung ceiling, etc.
- Network —electrical distribution network.
- Coordinated group —furniture, door hardware, etc.

System. Built element(s), comprise of a number of components which, when fitted together, integrate at least three of the basic building functions (structural, mechanical & envelope) and have a predictable performance as a whole. For example: integrated ceiling, structure-enclosure-environmental control system.

Module. A large built element which integrates at least three of the basic building functions, is self-supporting, and in addition encloses space. For example: dwelling modules; complete with kitchen and bathroom.

Facility. A built environment which satisfies all building functions to the extent required in order to serve one or more human needs. For example, single-family dwellings, or a greenhouse complete with environmental control.

2.3. The Performance Concept

The performance concept in buildings is the intermediary between user needs and physical solutions. It was pioneered in 1961 by the SCSD[6] program for guiding building processes to yield the best overall results, replacing conventional prescriptive approaches—

[6]See; The School Construction System Development, p.?

which relied on increasingly detailed drawings— by a new descriptive approach.

The ultimate goal of the performance concept is the assurance of a desired performance delivered to building users. It is, consequently, the measurement of the achievement of achievement against intention.

As defined by the National Bureau of Standards, the "Performance Concept",

is an organized procedure or framework within which it is possible to state the desired attributes of a material, component or system in order to fulfill the requirements of the intended use without regard to specific means to be employed in achieving the result.[7]

This concept presupposes that we can describe with scientific exactitude what a building or part of a building is to do, how we propose to measure that performance (i.e. evaluation techniques), and what are the rules necessary for the attainment of integration through compatibility of the parts. Nevertheless it has been noted that when dealing with rapid technological change; detailed performance requirements have proven to be less appropriate than stating the performance criteria of the desired environment.

When applied to buildings and structures the performance concept can be applied at the following different levels :

-Civil Engineering Works

-Building Complexes

-Building Types

-Building Elements

-Assemblies of Components

-General Products

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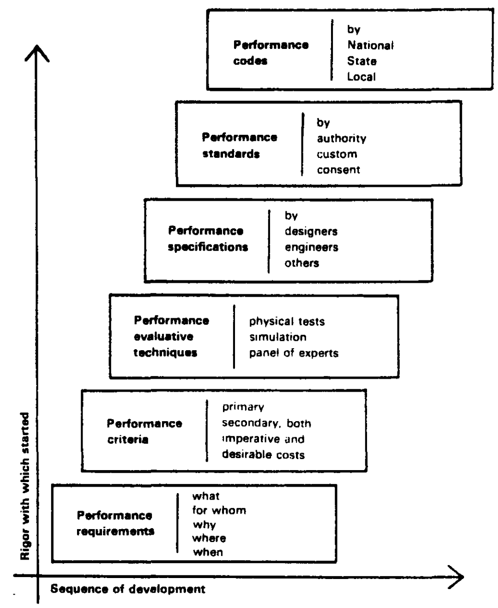
[7] Published in: *"The Performance Concept —a study of its Application to Housing."* building Research Division national Bureau of Standards.

-Materials



The mayor practical application of the performance concept in the building industry is the development of, and use of performance specifications. These state in precise terms the characteristics desired by the users of a product's or system's performance and the test of its evaluation. (Fig.2.3)

Performance specifications are derived from the analysis of user's needs, and they form the basis for procurement. Thus, there is an implicit guarantee that the user's demands will be satisfied. Moreover the use of performance specifications in building design can also increase cost-effectiveness, spur technological Innovation, draw better decisions in the procurement process, and facilitate formal evaluation and feedback.

A performance specification of any given building system usually includes three kinds of statements:

1.Performance Requirement

2.Performance criteria

3.Performance Evaluation Techniques

These three are essential elements of the performance specification for a physical system.

2.3.1 Performance Requirements

The importance of determining users' performance requirements as the first step in the statement of performance specifications, makes all the more important to identify the user and related users, needs during the total project cycle.

For example, in an office building the process of determining user requirements can be carried out;[8]

-*at the conceptual stage*: user acceptance of project size and location

-*at the development stage*: user self-identification through organizational analysis to establish block allocation of space for each functional unit.

-*at the acquisition (construction) stage*: user office planning program to define space planning layouts, furniture systems, telecommunications, special purpose areas.

-*at the operating stage*; user logistics program for occupancy.

According to life-cycle cost implications more emphasis should be given use-oriented costs rather than to fixing an initial user program.

There is mainly two approaches in *defining user requirements*:[9]
one is to analyze the daily activities of the users, while the other approach is to derive the functional requirements from existing buildings.

User activities are then the starting point to identify user' requirements since they may express the function of a building , and further express the user's reaction and adaptation to the building. User activities have then to be identified, analyzed and consequently, stated.

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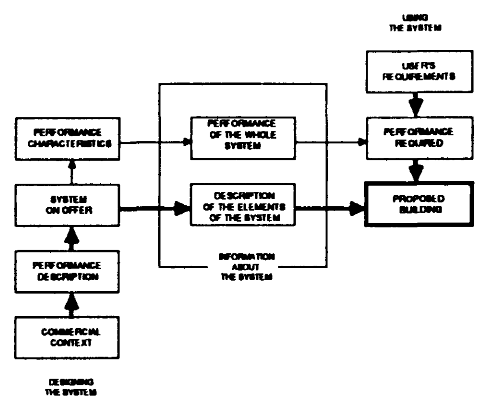
[8]Caufield, D. A., and V.K. Handa. 1974. *The User's Role in Programming and Project Management*."Industrialization forum. Vol.5 (1974), No.5, p. 58.

[9]Cronberg,T. 1972. *Human Requirements for Buildings*. Joint RILEM-ASTM-CIB Symposium pg.14.

However, it is not possible to study all activities, but only those which are important to the user, are affected by the design of a building or affect the design of a building. The process of identifying relevant user activities can be done through cooperation with the different user groups, through the analysis of theoretical studies (results of surveys and enquiries from other user groups), by directly observing the users' behavior or existing similar buildings.(Fig.2.4)



What matters is that performance requirements are stated in a clear and orderly fashion. For example, they could be stated according to the following parameters:

a. Requirements for accessibility/usability.
b. Requirements of safety/protection.
c. Requirements of perception/comfort
d. Requirements of social adjustability.

It must be noted that according to the users' characteristics many different ways can be followed so as to identify, analyze and structure the user requirements. It is also important to point out that not always all the user requirements that have been identified can be met in the final design solution. Therefore priorities between activities and user groups must be stated since requirements might be in conflict with each other or available resources may not be sufficient to apply a certain solution.

2.3.2. Performance Criteria

Performance criteria are quantified statements for building quality, or objective measures for guiding hardware solutions in compliance with the performance requirements.[10]

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[10]See Brandle, Kurt. 1976. *The Systems Approach to Building.* University of Utah. p.89

Since the choice of values is a reflection of a culture, performance criteria may be applied to different categories or contexts within a building. Nevertheless such design criteria are only delivered when the entire building performs as an integrated whole.

One classification of these categories includes the following contexts:[11]
-Functional
-Technological
-Perceptual-Aesthetic
-Sociological
-Economic

2.3.3. Performance Evaluation

In order to know whether or not a criteria is met by the design solution, *performance evaluation techniques* have been established. These indicate the method of assessing materials, components or systems and they can be physical tests, simulations and/or calculations, or judgements of experts. Satisfaction might be stated in terms of such goals as comfort, efficiency, and beauty, or in terms of their physiological, psychological, sociological, and economic desires.

In order to examine the impact of building systems integration on performance, it is necessary to begin with a manageable definition of the building performance criteria, to be met in the design, construction, and operation of a building. Richard Rush (1976) defines the following six discrete performance mandates:

- spatial performance
- acoustical performance

[11]Haider, S. G., and Kachaturian. 1972. *A Systems Approach for the Evaluation of Performance of Buildings in Design Process.* Joint RILEM-ASTM-CIB Symposium p.239.

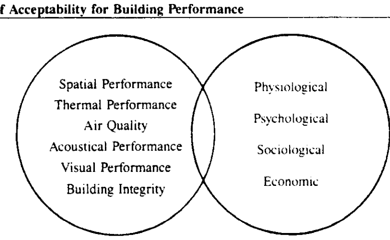
- thermal performance
- air quality
- visual performance
- building integrity

Responsibility for delivering these occupancy performance mandates has been divided largely along disciplinary lines. Architects have taken primary responsibility for spatial quality and delegated other responsibilities to mechanical, lighting, acoustical engineers.

The adjacent outline (table 2.5.) expands the definitions of these six performance mandates in terms of the sets of conditions that contribute to delivery in each performance area.[12]

	PHYSIOLOGICAL NEEDS	PSYCHOLOGICAL NEEDS	SOCIOLOGICAL NEEDS	ECONOMIC NEEDS
	Performance Criteria Specific to Certain Human Senses, in the Integrated System			
1 SPATIAL	Ergonomic Comfort Handicap Access Functional Servicing	Habitability Beauty, Calm, Excitement, View	Wayfinding, Functional Adjacencies	Space Conservation
2 THERMAL	No Numbness, Frost-bite; No Drowsiness, Heat Stroke	Healthy Plants, Sense of Warmth, Individual Control	Flexibility to Dress w the Custom . . .	Energy Conservation
3 AIR QUALITY	Air Purity; No Lung Problems, No Rashes, Cancers	Healthy Plants, Not Closed in, Stuffy No Synthetics	No Irritation From Neighbors Smoke, Smells	Energy Conservation
4 ACOUSTICAL	No Hearing Damage, Music Enjoyment Speech Clarity	Quiet, Soothing; Activity, Excitement "Alive"	Privacy, Communication	
5 VISUAL	No Glare, Good Task Illumination, Way-finding, No Fatigue	Orientation, Cheer-fulness, Calm, Inti-mate, Spacious, Alive	Status of Window, Daylit Office "Sense of Territory"	Energy Conservation
6 BUILDING INTEGRITY	Fire Safety; Struct. Strength + Stability; Weathertightness, No Outgassing	Durability, Sense of Stability Image	Status/Appearance Quality of Const. "Craftsmanship"	Material Labor Conservation
	Performance Criteria General to All Human Senses, in the Integrated System			
	Physical Comfort Health Safety Functional Appropriateness	Psych. Comfort Mental Health Psych. Safety Esthetics Delight	Privacy Security Community Image/Status	Space Conservation Material Conservation Time Conservation Energy Conservation Money/Investment Conservation

Limits of Acceptability for Building Performance



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[12] Rush, Richard D. , Editor, 1986. *The Building Systems Integration Handbook.*. The American Institute of Architects: John Wiley & Sons. p. 233

2.4. BUILDING SYSTEMS AND SYSTEMS BUILDING

As explained previously, in the design of todays complex built environments, architects are confronted with designing an *organization* of building elements and systems that will generate a coordinated whole: the building. This task can be accomplished efficiently through the use of the a systems approach to building.

The term *system* may be understood in two ways; as a process (software) or a product (hardware); a set of rules as well as a kit of parts. Coincidentally, the term *building* has exactly the same ambiguity. It may refer to the construction process or to an artifact that results from that process. Therefore when applied to the building process, a system may refer to an organization of activities or to an organization of physical elements.[13]

Systems building has been generally considered as a total process in the sense that it includes the rational and systematic organization and integration of all facets of the building development. In other words an integration from the design, to manufacture, transportation and assembly, into a finished structure that meets the users' needs most efficiently over the buildings' life cycle. By means of systems building, the building process is organized, analyzed and realized as a whole.

Accordingly, a *Building System* is understood as a kit of interrelated building parts, combined by a set of rules which determine how these parts interact to form a coordinated built

[13] Sittipunt, Prechaya. 1984. *The Systems Approach to Building: A Study of Systems Development*. MIT S.M.Arch.S. Thesis. p.25

whole. The fabrication of these parts, components, or wholes is considered as a separate process that could take place on or off site.

Therefore, Systems Building can be understood as a way of conceptualizing the overall building process in order to develop a *Building System*. Also as mentioned earlier, systems can be classified as *Open or Closed.* The latter when parts or components are peculiar to one system and are not interchangeable with others. The former when the components and parts can be arranged to form a reasonable number of alternative deign solutions and can be employed in a reasonable number of alternative systems.

In *Closed systems*, the compatibility of subsystems is to be achieved for one of a kind situations, that may be repeated. The subsystems are tailored to each other for performance only in this particular situation.

In *Open Systems,* compatibility can be achieved by choice of various subsystems of the same type which are flexible with regard to interfacing with their subsystems. These must possess flexibility to be combined with other subsystems of other functions within the value limits established in the performance specifications. It should be noted though that an open systems approach requires extremely complex measures of coordination, quality control and programming.

2.4.1. Building Systems and Performance Specifications

Performance specifications are needed to determine the form of a system most suitable for a given program. This will enable the designer to make a good choice in the selection of materials, and to establish a suitable process of production and assembly.

Performance specifications state the function each subsystem has to perform in the finished building as well as their their mutual compatibility.

Compatibility specifications between subsystems analyze where the parts of one system touch, pass through or influence the PPperformance of other subsystems within the building. Rigorous dimensional coordination is the critical consideration for subsystems integration and open systems compatibility.

2.4.2. Building System Design[14]

The development of an integrated and flexible building system has been approached mainly from two different stand points:
1. As a coordinated *Kit of Parts.*
2. As a performance-based *Set of Rules.*
Examples of the above are:
1. Kit-of-Parts: Marburg University (Laboratory) System.[15]
2. Set of Rules: School Construction System Development (SCSD).[16]

Kit of Parts:
Design consists basically in the development of actual hardware components and subsystems as a catalogue of coordinated elements. Usually, these are made compatible by modular and/or dimensional coordination. Prototype are often used to verify compatibility and correct mistakes. The actual buildings are assembled from catalogue in stages.

[14] Based on: Dluhosch, E. 1986. *Building Systems*. Un-published class notes. Fall 1987. MIT.

[15] See: Bausystem Marburg. Kempkes. Glädembach, 1956.

[16] SCSD: The Project and the Schools. A Report from Educational Faccilities Laboratories, 1967

The results of this approach is life-long flexibility, ability to upgrade and change within range of pre-designed catalogue elements. The expansion of buildings is made possible both horizontally and in height.

Set of Rules:

System design in this approach consists in developing a set of performance criteria for selected and compatible subsystems (in the case of SCSD: structure, ceiling, HVAC, partitions and furniture). Subsystem compatibility is responsibility of the manufacturer or system suppliers. The Compiled set of standards and rules for designers. Elements that are not contained in the catalogue are optional (in this case facade elements overhangs, etc.). Performance criteria are expressed in terms of performance standards in a rule system. Modular coordination is desirable, but not absolutely essential.

Many rationalized building systems have been developed in the last 50 years and it transcends the purpose of this thesis to list them. Nevertheless there are some systems that are worth referencing to so as to clarify these two different approaches.

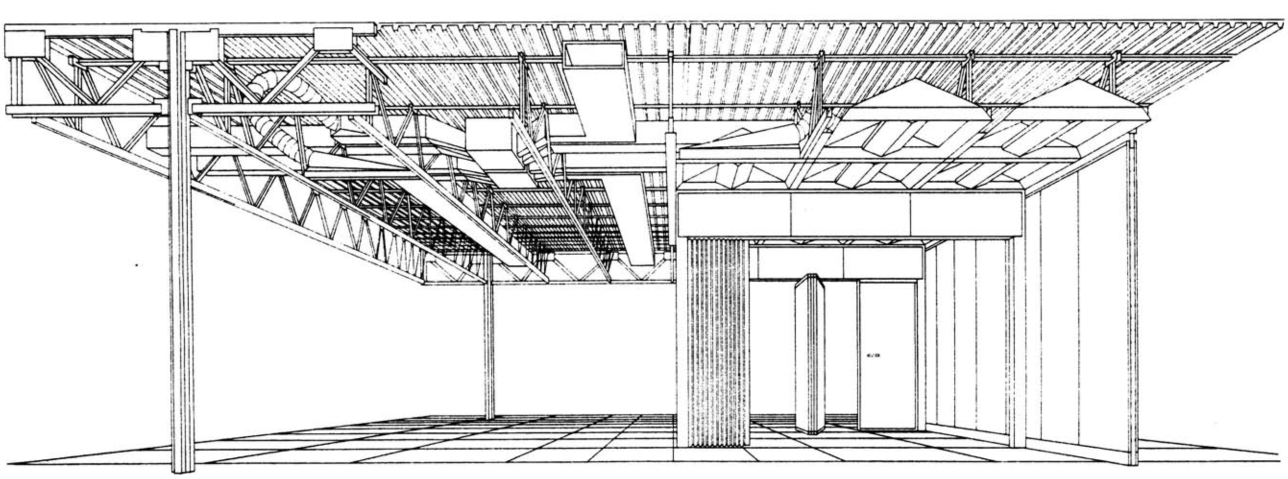
2.4.3. The SCSD System

The *"School Construction Systems Development"* (SCSD) developed for the state of California, U.S.A. in 1961, was basically conceived as a method for building better schools more rapidly and economically. Within the conceptual framework of the "systems approach" this experience could be to considered to lie halfway between open and closed systems, including both a performance base set of rules and a coordinated kit of parts.

In the SCSD system , manufacturers where asked to develop new building components to comply with a set of performance specifications developed by the SCSD staff. Instead of specifying the components in the usual way, SCSD specified the problem to be solved, and left the specific solution to the manufacturer. These products or subsystems where designed as a coordinated and integrated open building system.(Fig. 2.6)

Each School was to be designed by a different architect, but using the SCSD subsystems. Owing to the openness of the system, other subsystems not specified by SCSD, were also allowed to be designed and/or selected by each individual school architect. Thus each school could vary extensively, even though they were all built with the same systems.

The rapid changing needs of education required very flexible school buildings. One of the main performance requirements addressed by the system was flexibility of the school buildings. The final solution consisted mainly of a kit of parts coordinated on a modular grid. It included a steel structure, an integrated lighting-ceiling and mechanical subsystem, movable interior partitions, cabinets and lockers.



2.4.4. The Implementation of the Systems approach to Building System Design.[17]

Three main phases have to be considered when applying the systems approach to the building process.

- Problem Seeking. (program)
- Problem Solving (design).
- Evaluation of the Design (Analysis).

Within this framework the following sequence of six steps can be followed for the design and production of building systems.

1.Problem definition (program). This step addresses three questions :

Who establishes the program?

Where is the program implemented?

What are the needs and the problems?

The context and constraints of the design problem must be defined and analyzed in order for them to be understood and solved. By context we understand social, political, economic environments, geographic and climatic conditions, available resources and technology, manufacturer capability, and program organization (bureaucratic and administrative procedures).

2. Program objectives.

Once problems are posed, they can be divided into **general objectives and goals.**

General objectives refer to quality, cost and time reduction.

[17] Based on Garcia Alvarez, Angel, 1989. According to Brandle. K. 1976 and Sittipunt P., 1984. See: *Interstitial Space in Health Care Facilities: Planning for Change and Evolution.* MIT Thesis June 1989. p.57

The step-by-step approach is based on the notion that the whole problem solving process can be facilitated if the problem can be formulated in terms of sub problems, which may be investigated within their domain independently from the total.

3. Analysis

This step includes the generation of optimal amount of information necessary to generate a set of performance requirements. Performance specifications can then be generated according to the process described earlier:

First, user needs are analyzed so that related user requirements can be generated. Main guidelines are then obtained so as to generate performance requirements for systems and subsystems. performance requirements are translated into performance criteria from which performance specifications for subsystems can be drawn. These can include, for example, the establishment of a dimensional system, a modular planning grid, coordinated subsystems, and other technical aspects such as lighting, acoustics, and space flexibility.

4- Synthesis or systems integration.

At this stage the complete building system development is considered. Alternative ways of achieving systems objectives are generated —the use of building systems and subsystems already available in the market can be encouraged. If this is not possible, one must look at the total context of the task and analyze ways of developing acceptable solutions.

5. Implementation.

The design and construction of individual building projects. This includes the generation and testing of full scale mock-ups and simulation models.

6. Evaluation.

The final outcome of the approach is tested and evaluated against the goals, and corrective feedback is introduced into the process, including also improvements in predictive conceptual models or plans.

2.4.5.Building Systems Integration[18]

Within the notion of "Building System" that has been put forth we could consider the notion of "Building System Integration" as the act of creating a whole functioning building containing and including building systems in various combinations.

As the task of designing a building has increased in complexity, the interaction of diverse professionals, performance standards, or whole pre-designed systems enter into the design process. To understand completely all the systems necessary to operate and construct all buildings is a difficult if not impossible task. It is less likely then, that the building designer alone, would be able to manage the enormous numbers of combinations of systems that a building represents.

Therefore in order for building systems to achieve the intentions they were designed for as part of a larger whole; the relationships between them have to be made clear in a creative manner. It is in the coordination or integration of the different parts of a building

[18]Based on ; Rush, Richard D. , Editor, 1986. *The Building Systems Integration Handbook*.. A.I.A.: John Wiley & Sons. Chapter 1

that its overall functional, morphological and meaningful purpose will be met. Building systems integration is a vehicle the designer can use for translating human needs to physical reality.

Therefore in complex buildings —where a large number of systems and subsystems interact in a coordinated fashion— building systems integration becomes essential. The demands for perfect environmental control can only be met by simultaneously integrating all the complex mechanical and electrical services and other equipment with the structure. Efficiency and high levels of integration has become difficult to accomplish in modern buildings. Part of the reason is the added complexity; part is the speed of design; and part is the materials and machinery needed for their construction.

Systems by their nature are rational. However building systems integration is not a purely rational process, it inevitably involves an informed choice; that is, a consideration of all the relevant facts and a judgement of all the best answers. Vision, intuition, and experience always accompany the logic.

The integration of the whole building is complete when all of the links between all of the systems have been established. The more unified a building is, the more difficult it is to distinguish its various systems.

Nevertheless each mayor system can have its own integrity. Once the individual requirements of the program have been isolated, an individual system can be independently designed to respond to these requirements from the beginning. The designer then identifies the appropriate system for the program needs and selects the exact materials products and machines that satisfy the design criteria.

Because it is a creative process, building systems integration has to be accomplished by the architect. Uniquely suited for this task, he usually has total responsibility for the integration of the systems in a building. In this context, the architect's role remains crucial in building design and practice. Nevertheless, his traditional role as leader of the team can only be earned by his possession of an informed overview.

Theoretically, we can then consider two situations; a building whose parts are completely independent but coordinated; and a building whose components perform multiple tasks that are inseparable.

When maximum integration occurs, parts cannot be interchanged or repaired and spaces become too specific. Hence, flexibility is minimized, and the building cannot respond adequately to growth and change. It is a judgement of the architect, therefore, to consciously seek a level of integration that is appropriate, both to the immediate intended function of the building and to its possible future use.[19]

Accordingly, building integration can also affect the capacity of a building to respond to permanence and change either by providing a unified level of integration to enhance the permanence of the structure, or easily disassembled connections for temporary configurations.

[19] strategies for this category of integration will be described subsequently in Chapter ?. Designing for Growth and Change.

2.4.5.1. Method for Building Systems Integration

Whenever a problem of taste, judgement or experimentation enters the process of system design, there is a potential for disagreement. Therefore, the process of design and selection of the systems and components of a building requires a vocabulary simple and universal enough to be used effectively for describing and analyzing building systems integration.

Richard Rush, in his *Systems Integration Theory* (1986),[20] developed a logical methodology for translating an existing condition of systems coordination into a universal language. Since on the subject of integration words eventually fail the task, in order to discuss integration, what is being integrated must be defined and the way integration takes place must be defined.

Hence the mayor subsystems in a building are reduced to a set of four overall distinctive entities:[21]

- *Structure:* The structure creates the equilibrium necessary to allow the building to stand. It includes frames, shells, slabs, bearing walls, and so on. By definition, a structural member supports load other than its own.

- *Envelope:* The envelope is what is visible on the exterior of the building, its function is to protect the building from penetration and physical degradation by natural forces.

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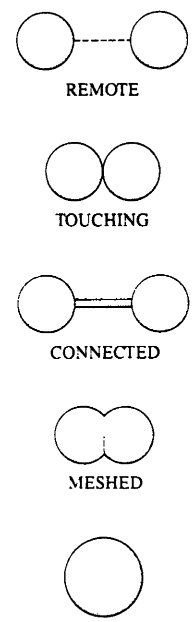
20 See,Rush, Richard D. , Editor, 1986. *The Building Systems Integration Handbook..* A.I.A.: John Wiley & Sons.p.317

21 Rush, Richard D. , Editor, 1986. *The Building Systems Integration Handbook..* A.I.A.: John Wiley & Sons. p. 318.

- *Mechanical:* Mechanical systems provide services to the building and its occupants. They control heat transfer, power supply, water supply and waste disposal. Therefore they include, HVAC, electrical subsystems, plumbing subsystems, elevators, security equipment, and fire safety subsystems. Output is delivered through ducts, conduits, and pipes.

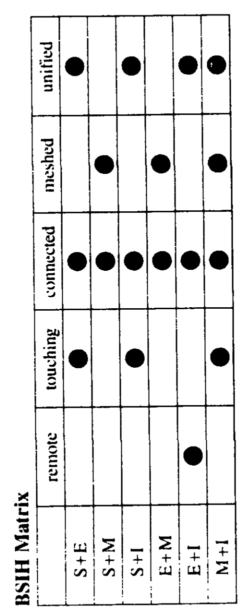
- *Interior:* Interior systems are simply that what is visible from inside a habitable building. They consist of ceilings, walls, finishes, furniture, and equipment.



Five Levels of Integration

Building systems may combine in many ways, the possible combinations of these systems are exactly eleven and can be combined in basically five levels of integration: [22]
- remote
- touching
- connected
- meshed
- unified

These five levels of integration establish a range of system interaction and serve as a conceptual model for understanding the way integration takes place.(Fig. 2.7)



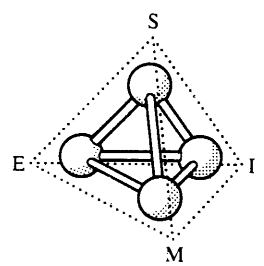
Conventional buildings can be designed in pieces, or in other words, by separate systems. Each system can be created independently of the others, with integration occurring when all of them are assembled for the first time. However the problem of deciding between different integration possibilities has to be considered in advance.

To reduce, therefore, the total number of possible combinations of systems to a reasonable number, the probable occurrence of all the

22 Rush, Richard D. , Editor, 1986. *The Building Systems Integration Handbook.* A.I.A.: John Wiley & Sons. pp. 318-320

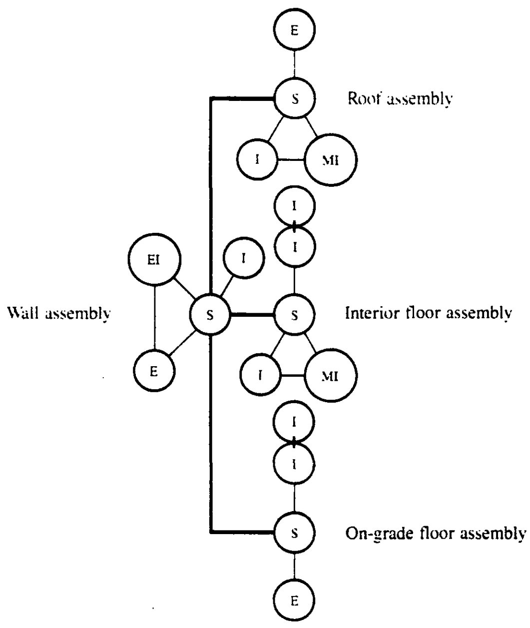
combination levels for each two-system combination, is evaluated, through the use of the *BSIH Matrix.* (Fig.2.8)This is an analytical tool for discussing system relationships in general and it can also be used as a tool in the design process.

When the integration task becomes confused, the definitions become extremely valuable ways of identifying barriers and opportunities. The way integration takes place must be defined. However in the context of integration, it is common to get entangled on a semantic game.



A *tetrahedron* is then used as a key so as to make the combinations simpler to isolate, analyze, and discuss. Each of the four systems is placed at a point of a tetrahedron, making possible a geometrical representation their theoretical potential to influence one another.(Fig.2.9)

Combining the system definitions with the notions of combination levels, produce a series of *integration diagrams* .(Fig. 2.10)

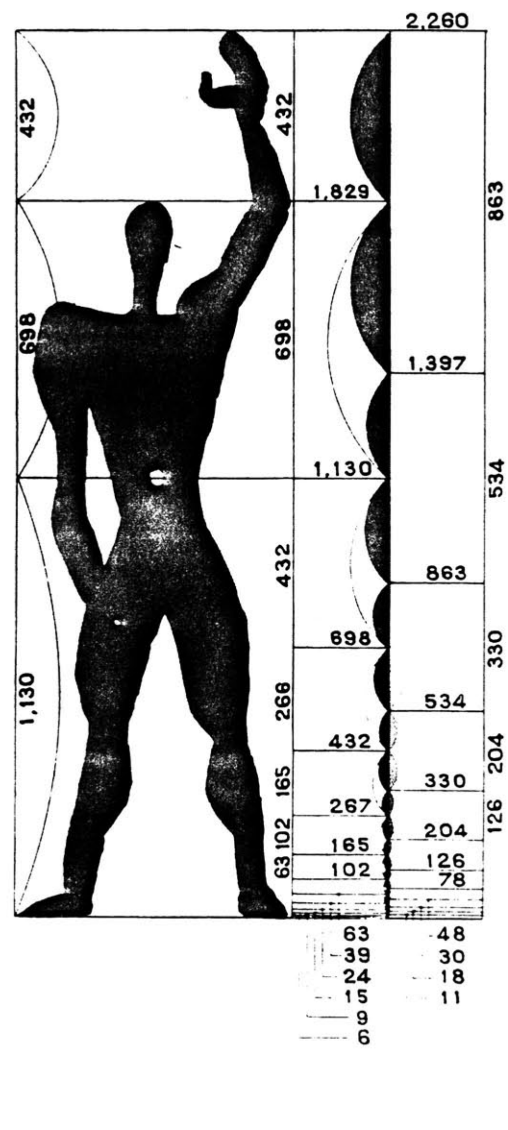


Before systems are actually chosen, diagrams are helpful to a discussion of possibilities. This is based on the belief that if the right object is dissected, the creative act of re-assembly is contained in the dissection itself. By cutting the frame of the building in half, an "E" shape was developed. The diagram described a roof, an interior floor, side walls, and a foundation floor.

There are two main ways that this system can be used, One is in the preliminary design process, and the other is after some design choices have been made. In either case, by using the matrix and the ball diagrams the designer allows a symbol to represent the kind of integration desired among the systems.

Regardless of where it comes from, the result of the decision-making process can be described in a universal way; in the appearance of the building. This is called here, *visible integration.* It has to do with the visible consequences of an aesthetic decision and how building systems integration can also be used as a means for visual expression i.e. the choice whether to expose the mechanical systems and structure to the interior space is major from the point of view of integration.

2.4.6. Modular Coordination



In the design of coordinated building systems the dimensions of surfaces, objects and spaces should be organically related both to each other and to additional subsystems. These conditions give rise to the idea of **modular coordination**, which embraces the results of investigations into measurements, measuring methods, the determination of proportions and the dimensioning of everything from the smallest component to the building as a whole, not only of plane surfaces, but also space and volume. (Fig. 2.11)

Through the use of modular coordination, the systems approach is also used then to establish a common knowledge base that will allow all the participants of the building process to communicate more efficiently. This will be seen to be crucial further on in this thesis as the Support Infill concept is described and the importance of system integration is once more referred to.

There are three criteria especially important important for the coordination of components.[23]

-The distances between "fixed" constraints, such as elements of the structure
-the relationships of the components to each other at joints and to grid lines
-the components' thickness.

23 Brandle, Kurt. 1976. Op. Cit. pg.106

An important aspect of modular coordination is the determination of **tolerances**. As advances in technology make possible ever greater precision, the control of tolerances has become one of the critical problems of contemporary building system design.

When large numbers of identical finished parts are fitted together, there is an accumulation of very small dimensional discrepancies, due to the production inaccuracies, changes in the dimensions of materials, installation procedures, etc. Modular coordination systems therefore assume a scale of tolerances, which, in developing modules, can be used for determining dimensional extremes.

2.4.6.1. Modules

The module is the abstract fundamental unit of measurement which, by means of multiplication, subtraction, or division numerically determines the geometrical system of a given modular order.[24]

The ideal is to have a fundamental module in which all the requirements are fulfilled in consistent three-dimensional measurements. The determination of the single *basic module*, forms the foundation for the modular system constructed upon it. It may also prove necessary so as to enable the selection of a number of different measurements or modules within a given modular order.

Integration between different systems is to be achieved through the use of coordination modules. Konrad Wachsmann (1961) believed that, depending on the problem, the **universal module**

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24 Wachsman, Konrad. 1961. THE TURNING POINT OF BUILDING: Reinhold Pub. Corp.,N.Y. 1961.Pg.54

should develop from the reciprocal relationships linking several or all of the following **modular categories:**

- material module
- performance module
- geometry module
- handling module
- structural module
- element module
- joint module
- component module
- tolerance module
- installation module
- fixture module
- planning module

All the planning possibilities should refer to combinations of various modules however it is the **geometry module** which defines the proportional system governing the structure, the individual element and the overall planning.

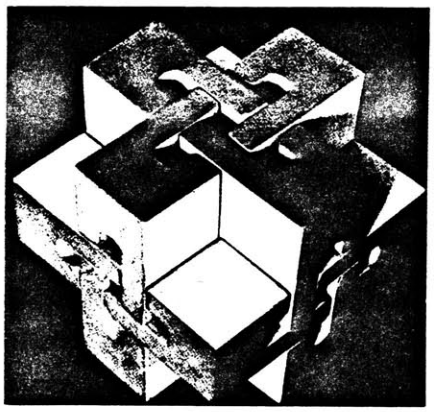
The **handling module** is governed by factors of a physical nature, originating in transportation, storage and erection procedures. The capacity of the loading equipment and the available transportation will have an important influence in determining the maximum dimensions of the finished product.

The handling module will then establish certain limitations on the dimensions of building elements for the sake of easy handling during erection.

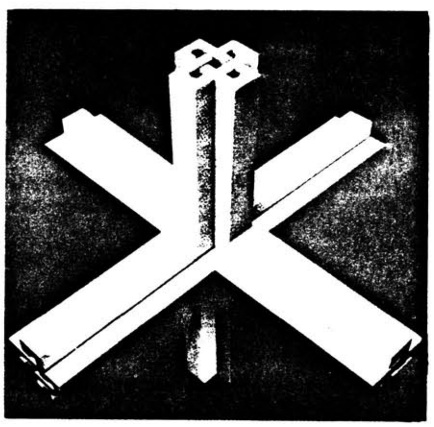
The **structural module** determines the relationships and position of all structural elements, it will derive essentially from the conditions imposed by desirable spans or cantilevers, the structural depths available and the modules of the building elements and components.

The **element module** defines the dimensional relationships among all the objects with surface-defining characteristics.

The development of such a module of universal surfaces is mainly determined by two opposite conditions. While the dimensions of a building element should be made as large as possible, in order to reduce to a minimum the number of joints, which, in fact, are always points of weakness, the element should at the same time be made as small as possible, for its usefulness is determined by its flexibility with respect to possible combinations in planning and in service.

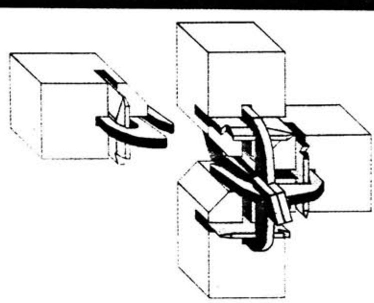


To develop this element module can prove to be crucial in relation to the coordination surface defining components with the structural module in such a way that the two can be joined by in organic combination whenever required.



The **installation module** determines the relationships and the position of cables, pipes, ducts and outlets within the building system as a whole. The incorporation of the so called mechanical functions in an ordered system of general modular coordination becomes extremely important in the design of flexible buildings.

The **planning module** is the sum of the results to which investigations of all the other module categories have led. The planning module is defined by balancing and drawing together different, often dimensionally divergent modules which actually do not lie very far apart, because they are built up on a common basic module, that is the module of the smallest unit.

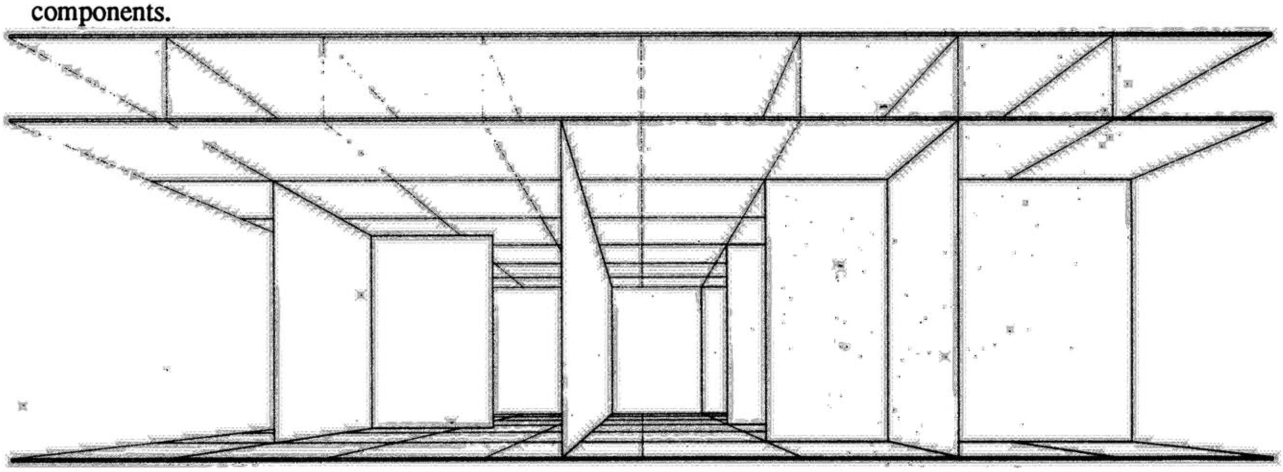


Wachsman developed a series of building systems including, the building panel system, the Mobilar system, and a space structure. In all of these the joint was the key element. (Fig.2.12)He also developed an universal connector to be used in a prefabricated, demountable assembly system which could be combined into buildings of any size or shape with a minimum number of joints. The development of these systems was made possible by strict modular coordination.

2.4.6.2. The Grid

Relationships between systems can only be described if there is a method to place the systems within a shared spatial framework.(Fig. 2.13) A modular grid is such a framework. In the development of building systems, the location of the structural components must be clearly defined.Locations must be capable of being clearly described so that the dimensions of the elements and the spaces that they form are unambiguous. To aid this process the utilization of a "modular grid" is suggested in which the distances between the grid lines represent an agreed basic module.

Grids are composed of bands, with a width of one or two basic modules (1M or 2M). Modules can be combined in different ways as to form special coordination grids such as the "tartan grid."[25] The existence of a grid will also allow a series of other conventions to be stated regarding the position or dimension of building components.



[25] The characteristics of the Tartan Grid developed for the design of building supports will be explained extensively later on in this thesis in The Support Infill Approach.

PART 2.

Chapter 3

3. THE HIGH TECH BUILDING

3.1. "High Tech Architecture"

The High Tech Shed
The Living Machine
The Facility for Advanced Technology Equipment

3.2. MAIN CHARACTERISTICS OF HTBs

3.2.1. The Glorification of the Machine Technology.
3.2.2. High Tech and Mass Production
3.2.3. Symbolic Power and Tectonic Expression
3.2.3. The Plug-in Service Pod
3.2.4. Exposed Systems and the Provision of Flexibility

Chapter 3

3. THE HIGH TECH BUILDING

3.1. "HIGH TECH ARCHITECTURE" A Tentative Definition

"High tech Architecture", is a recent and therefore, difficult term to define. Both in the academic and professional environments there seems to be certain ambiguity in relation to what Architects, Engineers, and Builders mean when referring to High Tech Architecture. The following is then an attempt to establish certain concepts so as to clarify a possible definition from an Architects' point of view.

High Tech Architecture could be said to refer to the result of a building design process which responds to specific and changing requirements through the utilization of "state of the art" building technology —mainly in terms of the materials and systems used for the construction, function or image of a building.

However since the term could be said to have its roots in industrialization and prefabrication, it has also been used to describe buildings that incorporate prefabricated, or "off-the-rack" building components or just buildings with a "technological look".

The term is sometimes also associated with a techno-functional architecture characterized by a response to change through flexibility as well as by having a short life span. Most of the time HTBs resemble a kit of parts assembled in such a way so as to produce specialized and flexible environments. The advent of High Tech Architecture has been made possible by the developments in the notion of buildings as systems, with relativity, mobility and a more ample understanding of the universe of new building materials made available through technological development.

Even though these descriptions could seem to be fairly adequate, they are still far from including the whole range of buildings refered to as "High-Tech". In industry it means electronics, computers, silicon chips, robots and the like. High Tech in architecture has a different meaning from High Tech in industry. In architecture it also refers to a particular *style* of building refering to a series of specific building types.

3.1.1. Three Typological Modes

In an attempt to set a base for this understanding we could then identify the "High Tech Building" (HTB) as variations, or combination of the following three different typological modes:

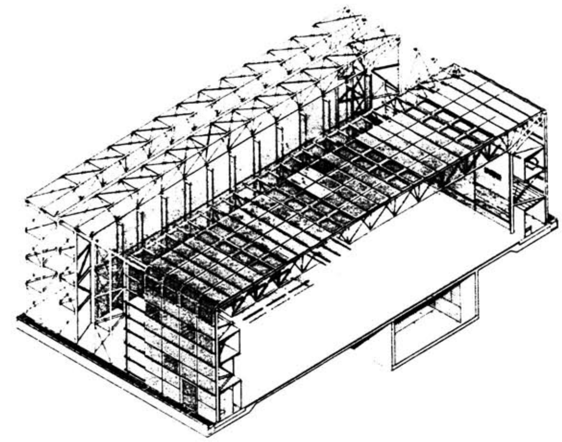
1. In terms of it's process of design and construction:
The High Tech Shed
A building that has been constructed with state of the art, rationalized industrial construction technology.[1]

2. In terms of it's image:
The Living Machine
A building in which mechanized state of the art construction technology inspires it's overall imagery.

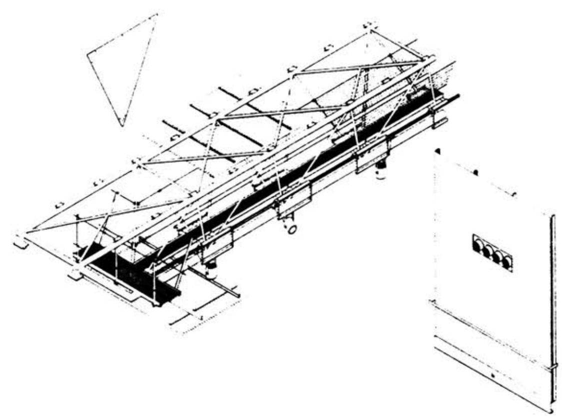
3. In terms of it's function:
The Facility for Advanced Technology Equipment
A shell that houses state of the art, highly specialized, or sophisticated equipment.

[1] These different views will be comented further subsequently as aframework for the analysis of obsolescence in HTBs. See: ?

The HTB of our time will fit into one or a combination of these categories. However, an isolated prototype, for the purpose of this research, should include all three of them. In other words it should be built with state of the art construction technology and materials, reflect this process in it's overall image and function in the most efficient way current technology will allow. This insight of how a prototypical HTB should be, suggests the importance that should be given to the coordination of these aspects in it's design.

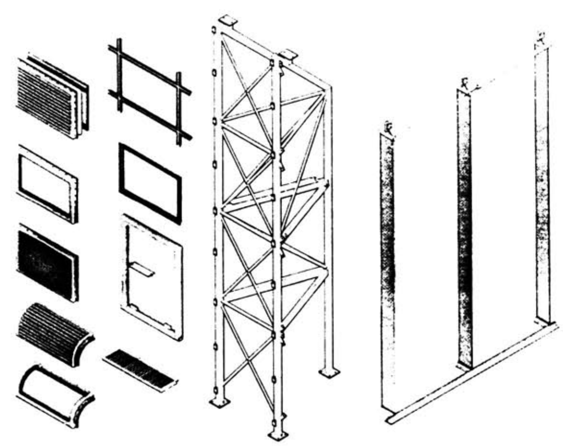


However, with the observation of current examples, mainly the work of the so called "British High-Tech Movement" —including N. Foster and R. Rogers— we realize that the results haven't changed much from the theoretical projects of the Russian "Constructivists" of the twenties . However, as will be shown subsequently,the underlying conditions have ceratainly changed.



3.2. HISTORICAL BACKGROUND

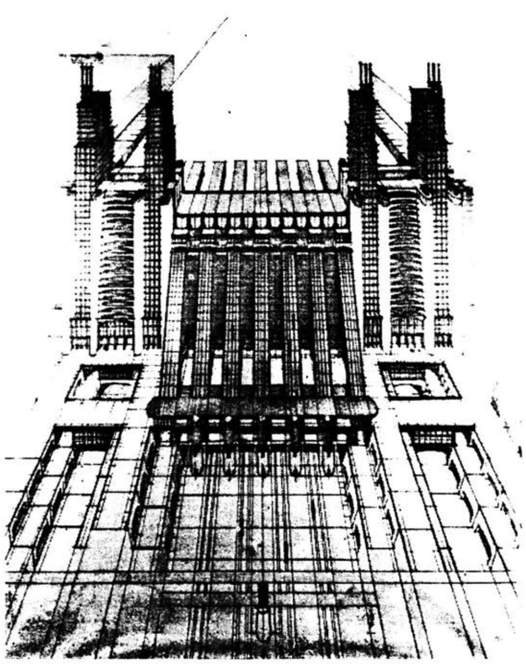
In spite of the fact that early examples of the development of this movement include buldings such as the Crystal Palace and the Eiffel Tower, both buit for world fairs, historically the typical high tech building has been a factory. *The factory building type* , defined as a long span structure with a simple skin enclosing an undifferentiated space, has evolved in recent years to house other functions.



As modern industry has become cleaner and quieter, the distinction between office and factory has become increasingly blurred. A good example of this adaptation can be seen in the Sainsbury Center for the Visual Arts at the University of East Anglia (Fig. 3.1) designed by Norman Foster.

Nevertheless buildings such as the Crystal Palace, are enduring influences on today's High Tech architects. They represent a different way of building, based on industrial technology instead of architectural tradition. Additional origins to this movement or style can be traced to the recent past where it evolved from a series of influences that represented the consequence of the development of industrial technology and its importance in the formation of our built environment.

As explained earlier these influences range from the cast iron bridges of the late 18th century to an outgrowth of the modern movement (represented by the work of Mies van der Rohe), passing through Paxton's Crystal Palace and the work of Russian Constructivists as well as Italian Futurists.



The design philosophy was kept alive mainly in theoretical projects, most notably those of the Italian futurists and the Russian constructivists. It initially developed as an architecture that glorified the technology of concrete, steel, and glass, and which gave dramatic external expression of lift towers, girder bridges, and elevated walkways.(Fig.3.2)

"We no longer believe in the monumental, the heavy and the static, and have enriched our sensibilities with a taste for lightness, transience and practicality,"

wrote Sant' Elia in the catalogue of the Cita Nuova exhibition...

"We must invent and rebuild ex novo our modern city like an immense and tumultuous shipyard, active mobile and everywhere dynamic, and the modern building like a gigantic machine. Lifts will no longer hide away like solitary wells in the stairwells ... but most swarm up the facades like serpents of glass and iron.[2]

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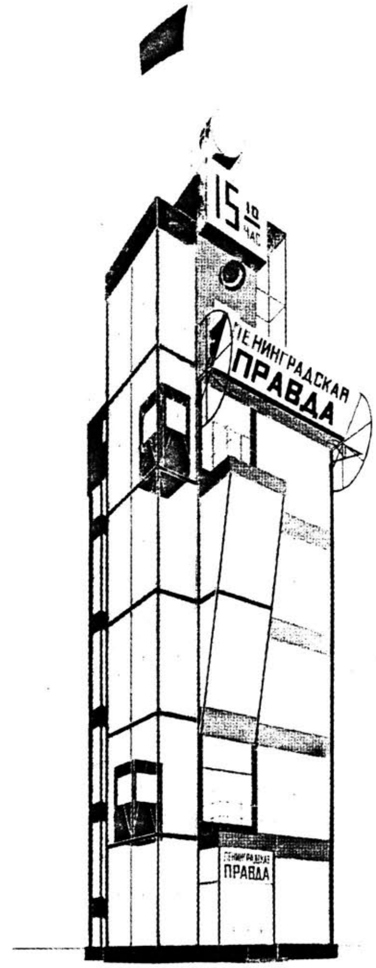
[2] Text established by Bernasconi in *Rivista Tecnica* (Lugano, 1956, No. 7) and quoted in: Banham, Reyner, *Theory and Design of the First Machine Age*, pp.128-130, The architectural Press, 1960.

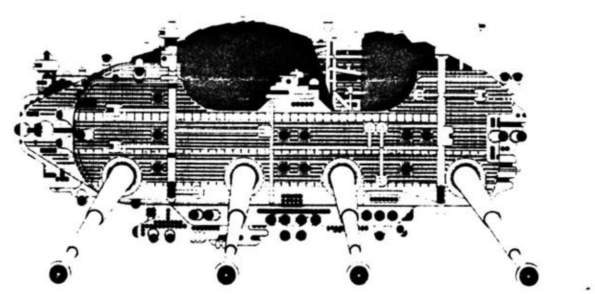
With the work of the Russian Constructivists —such as Chernikov or Vesnin—(Fig.3.3) we come even closer to the underlying principles High Tech. The Russians did not have the technology, but certainly the phantasy. Materials and mechanical forms where then elevated to the level of symbols of a new social and cultural order. Later this approach was to merge with a series of other objectives such as expression of structural principles, flexible frameworks or the construction process.



Past the mid-twentieth century the movement was fueled by the influences of projects by "Architects-Engineers" such as *Jean Prouve, Buckminster Fuller* and *Konrad Wachsman..* Their comprehensive and knowledgeable use of materials and technology borrowed from other industries, and their refusal to have anything to do with the conventions of traditional, academic architecture greatly contributed to building the ideological structure of todays High Tech movement.

High Tech Architecture of the 1970's and 80's displayed many of the features of the spectacular theoretical projects designed by "Archigram" group: *Peter Cook, Warren chalk, David Greene, Denis Crompton, Ron Herron and Mike Webb.*(Fig. 3.4)

Other influences by architects such as *James Stirling* (before his change to the British post modernist movement) *Louis Kahn*, and *Charles Eames* have to be distinguished.



Kahn's concept of *Served and Servant Spaces* [3]is extremely important to the development of the High Tech concept. It was this approach to the design of flexible and adaptable buildings that set the basis for future strategies for the integration of permanent and

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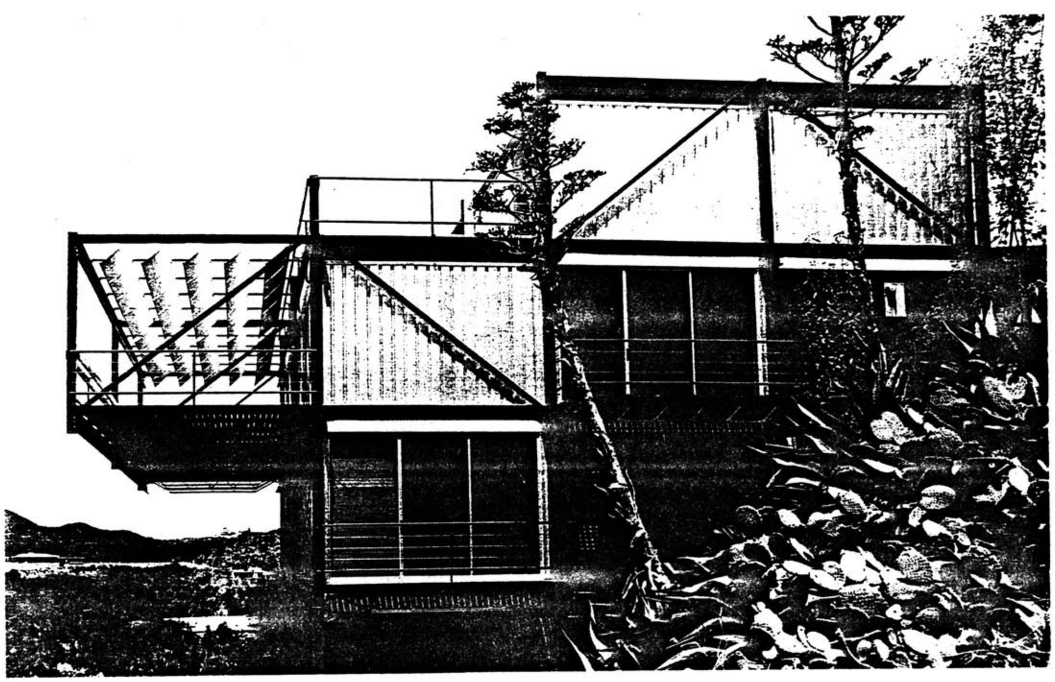
[3] This concept will be explained in further detail in Chapter ? on Growth and Change in HTBs, Part 3.

changing configurations within the same building. Even though Kahn continued to develop this concept in his projects was first exemplified in the Richards Memorial Laboratories in Philadelphia.

Also the flexible, light-weight houses of steel and glass designed by *Charles Eames, Helmut Schulitz* and others in California,(Fig. 3.5) not only form part of the development of High Tech but also had great influence in the architecture of others such as Foster and Rogers.

In 1977, with the construction of the *Centre National d'Art et de Culture Georges Pompidou,* more commonly known as the "Beaubourg" (By Piano+Rogers), High Tech came of age. Pompidou had everything: flexible plan, exposed structure, plug-in services, and the glorification of the machine technology. When it was completed the image of high tech suddenly became consolidated, entered the public consciousness, and became an internationally recognizable style.



3.2. MAIN CHARACTERISTICS OF HTBs

3.2.1. The Glorification of the Machine Technology.

.. its characteristics materials are metal and glass, that it purports to adhere to a strict code of honesty of expression, that it usually embodies ideas about industrial production, that it uses industries other than the building industry as sources of both technology and of imagery, and that it puts a high priority on flexibility of use.[4]

The style derived from a design philosophy that demanded

"that there should be no features about a building which are not necessary for convenience, construction and propriety" and *"that all ornament should consist of the essential construction of the building."*[5]

For High Tech architecture, the "spirit of the age", resides in advanced technology. Architecture then has the moral duty to express that spirit, therefore participating in and making use of that technology —the technology of industry transport, communication, flight, and space travel. This is part of the nature of high tech environments, intentionally pursuing new technological "matches". Some fail, as do traditional solutions, some suceed. Those which succed provide us with innovation and "surprise".

High Tech presupposes that architecture has fallen behind this development and therefore should be committed to the idea that building must catch up with technology. In this endeavor, *symbolism and representation*, of new materials, processess, etc.,

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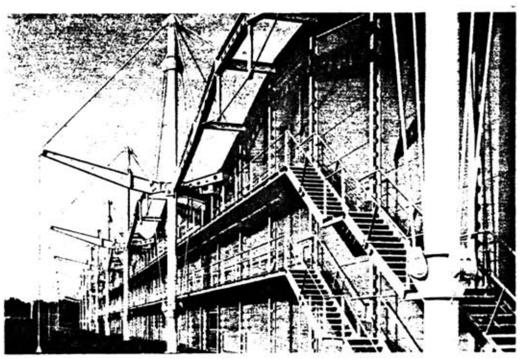
[4] Davies, Colin, 1988. HIGH TECH ARCHITECTURE . Rizzoly International Publications. New York, USA, 1988.Pg. 6

[5] see Pugin, A.W.N. *The True Principles of Pointed or Christian Architecture*, London, 1841, p.1; quoted in:Davies, Colin, 1988. HIGH TECH ARCHITECTURE, p. 6.
See also the works of the "French Rationalists" (Le Duc, Choisy, and others)

have an important part to play. The building is not only to use and express state of the art technology, by creating an architecture that looks mass-produced and machine-like, but should also do it honestly.

Building technology has been changing considerably, but architecture itself has not. High Tech architecture wants then, to bring buildings to the level of the latest technological advances. As will be explained further on, this has become difficult to accomplish in a efficient manner. The typical HTB then *symbolizes and represents technology* rather than simply use it in the most efficient and honest way possible. The way High Tech chooses to do so is through the *glorification of mechanized technology*. The buildings may not be mass produced, or even assembled with mass produced components, but they could look mass produced.



The motifs of High Tech —exposed steel structure, exposed ducts, plug-in service pods, and so on— are almost never the most economical solutions for the functional requirements of the building. However design solutions are made according to the symbolic and representational ends mentioned above. A good example of this dichotomy is the tension structures recently used in some HTBs. Here the structure is real and there is functional justification for it, however, it was chosen not for its economy but for its symbolic power. (Fig 3.6)

What seems to be important is the congruence between the means used so as to achieve these representational and functional ends. Hence this suggests that by understanding the process of "High Tech" one may be able to use it instead of having to "fake" it.

3.2.2. High Tech and Mass Production

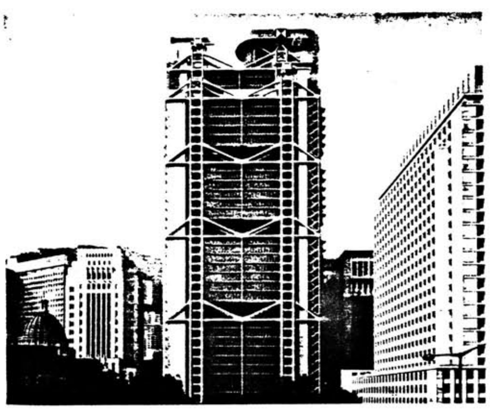
As explained earlier, there are several ways in which building design can benefit from the industrialization of the building process. One of these is by taking advantage of the benefits of mass production. Even though High Tech has experimented in the mass production of complete buildings, except for examples as the mobile-home industry, no attempt has yet been seen to succeed.

However High Tech is not necesarrily equal to mass production, but to the maximum utilization of scientific and technological advances. If a building is to use the same technology, and achieve the same level of sophistication of mass produced products such as automobiles, a similar level of investment has to be made for its design development. This of course is out of the question unless identical buildings where to be mass produced by the thousands.

However, the *mass production of building components* in factories such as: windows, doors, curtain wall mullions, raised floors, and suspended ceilings has continued to expand. It is common today for buildings to incorporate to their design, complete integrated building systems.

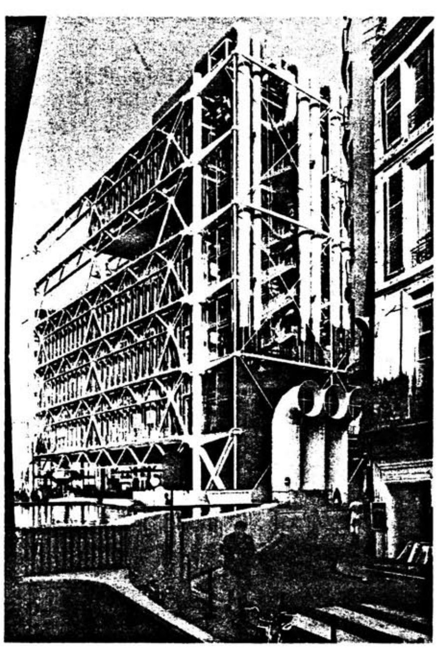
Colin Davies (High Tech, 1988) suggests two answers to the problem of mass production and architecture. The first is to design, develop, manufacture, and market a standard building and the second is to make buildings entirely out of catalogue components. Both strategies, in the form of closed and open systems respectively, have been tried with diverse results. One good example of the second is the "Eams house" in Pacific Pallisades.

Nevertheless there is to a resistance to use mass-produced un-modified building components. High Tech architects prefer to develop their own components and systems and to have them custom made. Through this process they explore the frontiers of technological capabilities beyond mere mass production. This includes using new materials, new ways of connecting them, and new concepts of structure and "tectonic" performance.



The architect participates with product manufacturers in the design and development of building systems. The best example of this collaboration can be seen in the project development of Foster's HongkongBank Headquarters, (Figs. 3.7) in which all the main elements of the building were designed, developed and tested by both architect and manufacturers working together.

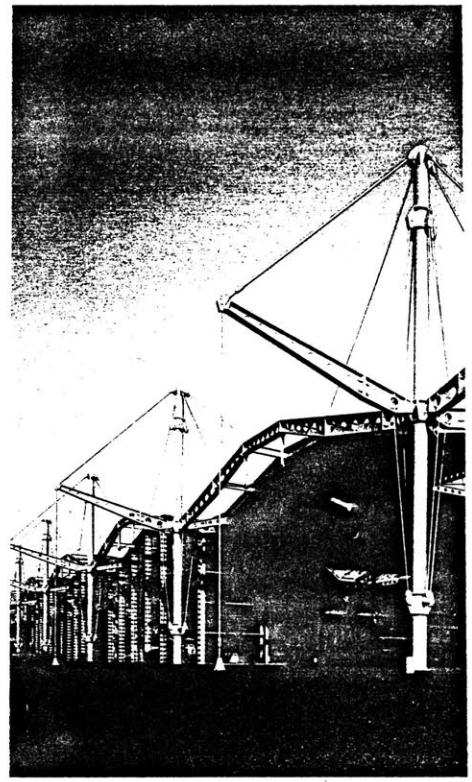
This attitude has opened the way to the *internationalization* of the building industry. Design development was done at a global scale. Products and components where developed and tested in different parts pof the globe. They were then shipped to Hong Kong in a coordinated way so as to be assembled at the construction site. This not only included the main structural components but also the curtain wall, the structural cladding, service modules and interior systems such as the raised floor, hanged ceilings, partitions and furniture.



3.2.3. Symbolic Power and Tectonic Expression

Exposed structure and exposed services are the most distinguishing visual features of the "living machine" High Tech building type. These traits can be clearly seen in the works of architects such as Foster and Rogers.(Figs. 3.8 & 3.9)

High Tech architecture is tempted by the bold expressive power of the building skeletons. Steel tension members are given prominence as a tendency to dramatize the technical functions of building elements. This tendency is well exemplified mainly in the work of *British High tech Architects* such as Rogers' Immos factory, Foster's Renault warehouse, and other works by Grimshaw and Hopkins.

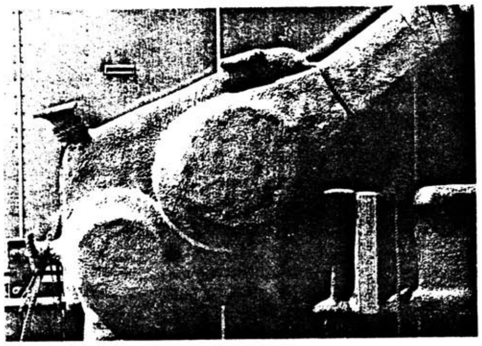


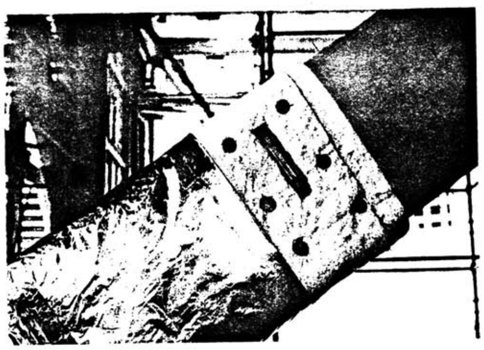
Notwithstanding the technical disadvantages of using exposed steel structures, this has become very popular in this context in an effort to convert ordinary factory sheds into colorful works of architecture. Nevertheless, in multi-story buildings, the frame must be *fireproofed.* Traditionally that means either using reinforced concrete or , in the case of a steel frame, encasing it in concrete or spraying the members with a fire-retardant mix. This has posed a problem to High Tech architects mainly in how they can accomplish the honest expression of the building's tectonic characteristics.

At the Center Pompidou, the problem was solved by a combination of water-cooling for the columns, dry insulation for the trusses, and spray-on fireproofing for the joints.

In Foster's HongkongBank, the structure could hardly be more prominent. The floors are not supported on columns, but hang from structures that resemble giant coat hangers, which in turn are supported by eight massive masts. Here the opportunity for using the tensile strength steel was fully expressed both in the outside and inside of the building. Because the steel had to be fireproofed , by means of wrapping it with an insulating blanket, it was then necessary to encase every structural component in aluminum cladding in order to preserve the "High Tech" smooth metallic finish.

Since the whole skeleton had to be cladded, this led to certain contradictions —such as in the the hanger joints with the tensile members— where the final formal expression of the cladded result partially contradicts the structural principle underlying the solution. This attitude could be considered as breaking one of the un-written





laws of high tech: *that materials should always be used with complete honesty.*[6] (Figs. 3.10 & 3.11)

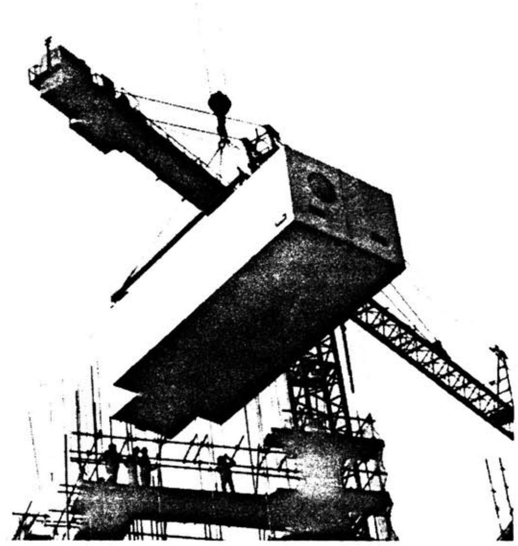
It is at this point where High Tech touches one of the most discussed themes of current architectural discourse; what is, and what is not honest in architecture. In a more sophisticated sense "honesty" can be either "nakedness" (top of the "Venus de Milo") or "draping" (bottom). Which is less honest? It seems to be the way a material is articulated, especially at the joint, which makes it a matter of "honesty". "Dis-honest" means *intentional* disregard for any continuety between primary and secondary elements (viz. Post-modern or Stone Veneers), i.e., not letting one system inform the next by making them compatible both technically and formally-visual. Failures such as the one described above are more to be considered as failed attempts, but not in-herent intentional models of dis-honesty.

3.2.3. The Plug-in Service Pod

The various preoccupations with flexibility, demountability, renewability, and mass production that can be found in the different systems and subsystems of HTBs are all combined in the concept of *the plug-in service pod.*

The sources for this idea refer back to architecture movements, such as the Japanese *Metabolism* and the British *Archigram*. The initial concept was first developed by Buckminster Fuller in his design of the completely prefabricated *Dymaxion house*. More developed examples can be found in the work of Japanese metabolists, such as Kisho Kurokawa's *Nagakin Tower* of 1972.(Fig. 3.12)

[6] Davies, Colin, 1988. Op. Cit. p.9



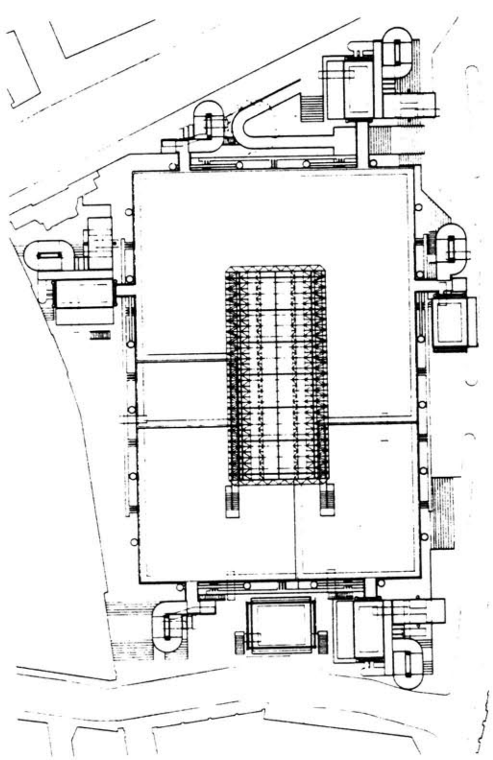
However, recently two excellent examples of this concept have been built in the *Lloyd's* building and the *HongkongBank.* The idea gets its clearest expression in the Lloyd's building, where 33 stainless steel clad boxes containing toilets are stacked up on concrete towers. (Fig.3.13) The equivalent pods on the HongkongBank are slightly different. They do not only contain the toilets but also the air handling plants.

In both examples it seems that as usual with high tech architecture, the *visual expression* of the idea is as important as practicality. In both cases it is extremely difficult to separate the pods from the structure that supports them. They are permanently fixed in place and in the HongkongBank they have been clad with a continuous aluminum skin.

Renewability is one of the reasons for these pods but the main reason is that it enables highly finished parts of the building to be manufactured on a production line and shipped to the site complete. This of course brings to the building process the advantages of industrial production such as long term economy based mainly in speeding up the on-site work, better quality of the finished product, and the compactness or space saving that the process allows.

3.2.4. Exposed Systems and the Provision of Flexibility

The various components of a High Tech building, specially the exposed structural and mechanical systems, are usually very expressive of their technical function, but the form of the whole building does not always relate to the buildings program. The Lloyds building by R. Rogers and Partners exemplifies this distinction perfectly. Here, as in other similar buildings, the



purpose of keeping the interior as simple as possible contributes to the resulting complex exterior. (Fig 3.14 & 3.15)

The issue of space has been replaced in High Tech architecture by the more technical issue of flexibility. ... What we are providing, say the High Tech architects, is not an enclosure —a room or a hall or a spatial sequence— but a serviced zone. It might be internal or external. The possible uses of this zone are maximized by providing facilities of various kinds —air, heat, light, power, and something to fix partitions to— on a regular grid.[7]

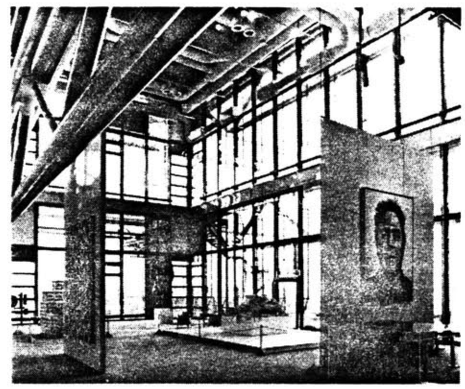
The more technical issue of flexibility in High Tech architecture has then allowed the provision of specialized space. What seems to be provided is a *flexible plan* that resembles more a service zone than a space enclosure. The possible uses of these zones, internal or external, are maximized by the efficient provision of services. If really flexible, a zone presumably could could be made into a "space".

The best example of this can be seen in the Center Pompidou. This is the building that, more than any other, has given the High Tech Style its image. The structure resembled more a flexible framework than a traditional building.High Tech though introduces the idea that also the more permanent elements of the building, such as walls, roofs or the skeleton should be also demountable. The plan, becomes an *abstract grid* that can accommodate a number of different functions, while the elevation expresses this same condition in a more literal way. Hence, the building becomes an explicit collection of artifacts of different types and different life-cyles instead of a single artifact that would give out to obsolescence much sooner. (Figs. 3.16 & 3.17)

This is one of the reasons that High Tech buildings expose equipment and services outside of the building. The reinforced

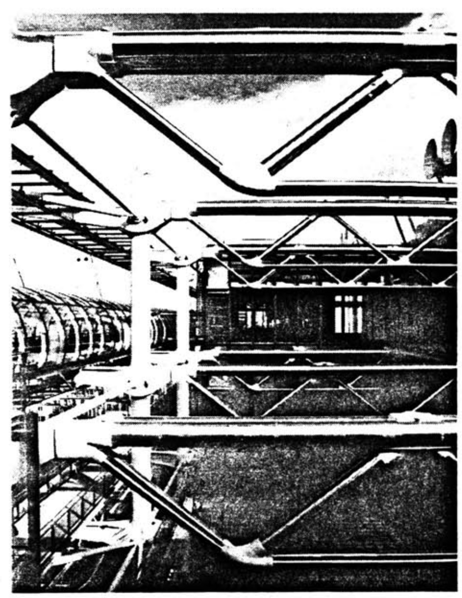
[7] Davies, Colin, 1988. Op. Cit. p.9

concrete skeleton of one of these buildings will virtually last forever. the mechanical systems, plants, ducts or motors might be expected to last for 20 years. To place these outside of the building is a response to the need for alteration and replacement without having to disturb the functioning of the internal spaces.



Providing for Permanence and change is thus a matter of materials more than a grid, since one could separate the services even in a conventional building. Basically, it is more a matter of "Support and Infill" where both act as part of a light skeletal geometry capable of interprenetration in all directions.

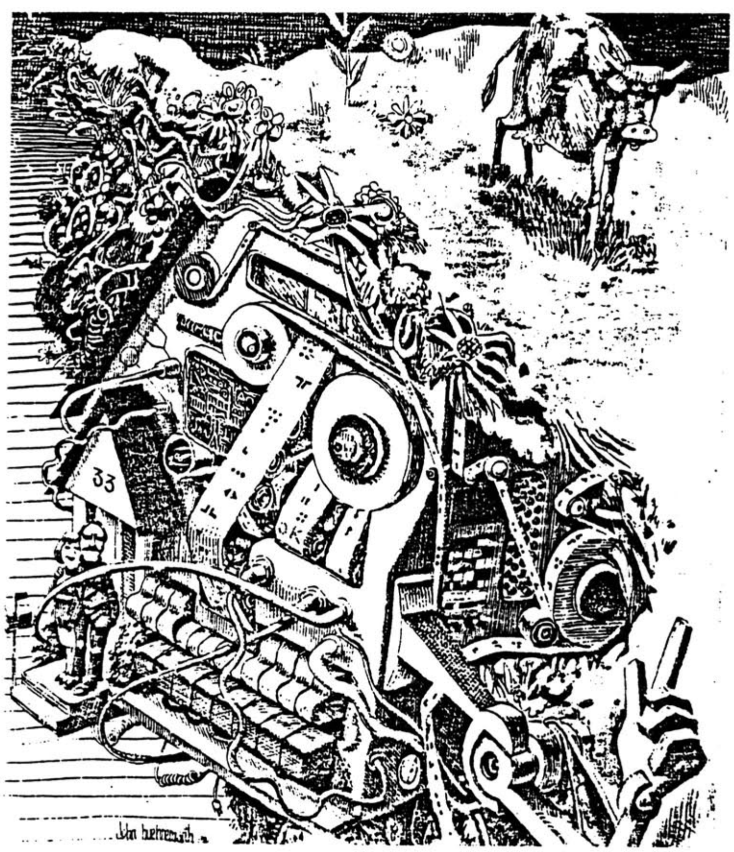
The idea of *growth and flexibility* is often implied in the overall form of High Tech buildings. The Center Pompidou, the Lloyd's and the HongkongBank are all "incomplete" forms. They are all potentially open ended, so that floors and other elements of the structure could be added and taken away without destroying the overall integrity and order of the composition.



This idea, of course, is not exclusive of high tech buildings. Most of the traditionally built contemporary office buildings also allow a degree of flexibility mainly through the use of the open plan with movable partitions within it. This attitude towards growth and change is common also to the support-infill approach for the design of housing configurations developed by S.A.R. in the sixties. Different strategies that have been developed to deal with this problem will be explained in a detailed way in the next chapter.

Chapter 4

HIGH TECH AND OBSOLESCENCE



Chapter 4

4. HIGH TECH AND OBSOLESCENCE

4.1. Recurring Obsolescence

Designing highly specialized environments, extremely expensive to build, that become obsolete by the time they are completed, is absurd. Traditionally we have responded to obsolescence through the provision of more flexible and adaptable solutions for these buildings, resulting in higher initial costs. Also new materials and systems have been implemented so as to allow for this approach at a lower cost, however HTBs are becoming more expensive to build and falling sooner into obsolescence.

Accordingly, several strategies, have been developed and implemented so as to deal with the problem of obsolescence in the building design stages. The persistence of obsolescence therefore suggests the possibility that this contradiction is a cause of still hidden issues.

This problem, of course is not exclusive of HTBs but can be found many different building types. Nevertheless it becomes necessary to address both the problems of *constant change* and *obsolescence* not only for their implications in the process of building design but also because of their influence on the future survival of a meaningful built environment.

4.2. Building Obsolescence

The notion of *obsolescence* is intrinsically connected to the different aspects of building performance. Once a building is handed over for use it is considered to be at it's highest level of performance. it should be noted though that this is not always the ideal level since in the case of very complex HTBs, once the building construction is completed, the most sophisticated equipment installed within it, will already be outdated by new technological advances. As time passes in the life of the building, it's performance will fall smoothly from it's maximum level to nothing.

At some point in this process the building will reach the minimum satisfactory level of structural performance. At this point if the structure is rebuilt the building will achieve again a higher level of performance. But if the building is only repaired and maintained above minimum performance levels, it will never achieve its original performance level.

In the process of ageing of a building two types of obsolescence can be distinguished:[1]

a. "Physical Obsolescence" (need for replacements) and

b. "Functional Obsolescence" (need of modifications)

Problems arise in buildings when there is a disparity between physical and functional obsolescence. In general buildings could remain physically sound long after they become functionally obsolete.

Inefficiencies result when functional requirements can not be met within the building. This condition is what we have called

[1] Cowan, P. 1963. *"Studies in the Growth, Change and Ageing of Buildings."* Transactions of the Bartlett Society, London University College. Vol. 1, p.68

functional obsolescence. Operational performance is affected when changes cannot be implemented in the following circumstances.

- When there is a need for additions of organizational units (i.e. departments) or services.
- When there is a need for institutional re-organization.
- When there is a need to make major functional changes.

Physical obsolescence or structural degeneration has been observed to be a gradual process. However the increasing rate of technological change will cause the building to become obsolete faster.

Functional obsolescence also increases gradually during the buildings life. However, building performance does not fall as smoothly as in the case of physical obsolescence, instead, it follows a pattern of steps indicating the introduction of a new procedure, technique, or equipment which suddenly lowers the functional effectiveness of the building.

Heating, cooling, and electrical systems in highly serviced buildings can come to account for more than 75% of the energy consumption in the building. Cost effective technology can therefore provide a great opportunity for energy conservation. Active energy considerations such as solar collection, high efficiency equipment, and computerized control systems as advertised by the recent concept of "Intelligent" or "Smart" buildings, can contribute significantly to reducing the possibility of functional obsolescence. As will be comented later on, these advances can produce the contrary effect if given excessive priority within the building's systems'.

However the constant process of updating through minor change can be a powerful inhibitor to progressive obsolescence, and it can postpone the need for mayor changes.When needed changes are not implemented, the building becomes obsolete, having to either live with obsolescence or be demolished.

4.3 Obsolescence and the Design of HTBs

As shown, the longer a building physically lasts and functionally performs adequately for it's users; the least amount of resources will be demanded for it's operation, maintenance and replacement. Apart from the obvious economic benefits that a longer life of the building can offer , there is a further advantage; buildings and places that last for a long time (out-living it's creators) will achieve a certain *poetic charge* created by time and use, that will add to their overall value as a necessary and meaningful component of a culture.

The obsolescence problem starts when the main functional requirements of a building change drastically and constantly making it's rehabilitation extremely expensive. According to a representative from Symmes Maini & Mckee only in the U.S. alone, 70% of the operating clean-room facilities (considered very sophisticated High Tech environments) are already obsolete and at an extremely high cost in equipment and construction

The main problem Architects are confronting today when designing "High-Tech" buildings (HTBs) is how to provide for their highly specialized conditions, creating at the same time meaningful built environments in an economic way. To do this he must overcome a series of related obstacles. One of these is, *planned obsolescence*; the growing tendency to the design of highly specialized and very sophisticated environments that not only are very expensive to build but become obsolete by the time they are completed.

The problem does not originate as one may be led to think, only from current *technical issues* related to the design and construction of these buildings, but instead from the concepts behind the design approach. New design methods, construction methods, materials, building systems etc. for the provision of more flexible and adaptable environments have been made available to the designer. However recurring obsolescence has continued.

HTBs tend to be very expensive to build mainly because of the sophisticated technological conditions needed to accomplish their specialized environments. New materials as well as further exploration in new building systems and construction methods promise better and more efficient alternatives for the future. However user requirements are changing rapidly and becoming increasingly specialized. HTBs are resulting to be more expensive to build and falling into obsolescence sooner.(Construction costs of todays HTBs in the U.S. can range from $185 to $950 sq.ft. and is presently going up.)

4.4. Temporary Buildings vs. Permanent Buildings

Today we can observe that HTBs are being designed for change that seldom happen before the building becomes obsolete (at a very high cost). However we could argue that these changes need not to be expensive or impossible when confronted with a design solution that allows for *flexibility*. For example, considering the problem of sheltering today's "Research and Development" facilities , it could seem to be preferable to use very inexpensive *made-to-fit, temporary shells* (i.e. Silicon Valley),that would become obsolete fairly fast and could be easily replaced or adapted. Pursuing this alternative is one of the main problems having to do with the design of todays obsolete HTBs. We are therefore confronted with the alternative of designing either temporary (short-life) buildings or more permanent (long-life) buildings.

4.4.1. Short Life Buildings

In short-life buildings the facility is designed to be temporary and closely tailored to the needs of the activity. As it is narrowly adapted, it becomes immediately obsolete when change is necessary, and thus it is replaced.

Since systems and parts of temporary buildings are required to last only for a short period of time, reductions in cost can be accomplished partially through a reduction in the quality, when this is sociably acceptable. In practice it leads to higher maintenance costs which rise rapidly with time, therefore leading to rapid obsolescence.

However Stone, 1964 writes that shortening the life of buildings tends to reduce their value, not their costs.

Until methods of construction are found that will provide short-life buildings, with a life of perhaps ten or fifteen years, at perhaps half the cost of a building with a long-life, few people or communities will be able to afford a rapid turnover of their buildings. This is difficult to achieve because usually half the initial costs arise for (conventional) fittings, furnishings, equipment and site works which are necessary in much the same form whether the building is permanent or temporary.[2]

So the cheaper the conventional building, the greater the costs in use and the shorter the useful life. Although high in cost, complete factory finished units which can be easily linked together, are considered here since savings can also be accomplished savings due to industrialized production and assembly.

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[2] Stone,P.A. 1980. Building design Evaluation: Costs-in-Use. London:E.&F.N. Spon pg.13

We are also confronted with the high cost of producing these buildings with adaptable and flexible building systems. The more flexible; the more expensive the building becomes. In the short run producing a series of **disposable specialized shells** can prove to lower the cost of short term adaptations, however, in the long run, when systems have to be changed, the cost of repair will exceed the cost of a new building. The cost of flexibility becomes then directly compared to the opportunity cost of replacing the whole building.

4.4.2. Long-life Buildings

Most buildings can be considered in this category. Any system that accounts for permanence, can also be considered as very durable. The notion is that if properly maintained these buildings can virtually last forever. We can then make a distinction between material quality and the process of providing continuous maintenance as strategies for long-life.

Most buildings could have quite a long physical life even if their maintenance was indifferent and, in fact generally even the most inexpensive forms of construction have a physical life of 50-60 years.[3]

The physical life of a building is usually reduced by either functional or financial obsolescence, i.e. either because it is found to be less expensive to clear and rebuild rather than to adapt the building to meet a change in the requirements (functional obsolescence), or because it is found a more profitable use for the site (financial obsolescence).[4]

3 Ibid.p.198

4 Ibid.p.59

4.5. The High Tech Building Type

The HTBs meager acknowledgement of the surrounding built environment is characterized by their *lack of relationship with the past*. High Tech is a forward-looking optimistic architecture that believes in progress through industrial technology. It believes in invention rather than tradition, in temporary arrangements rather than permanent institutions, and the ability to control the environment rather than adapting to it. If the city is the embodiment of tradition, permanence, continuity, and history then High Tech has been in most cases an anti-urban style. High Tech buildings imply a revolutionary, rather than a traditional, view of the city.

These principles reflect in a way those developed in the Megastructure Movement in the sixties including Yona Friedman's "Ville Spatiale", the cities of "Archigram" and the Japanese "Metabolists". In these theoretical projects, as in their built High Tech counterparts, structure, access, services, and equipment are more important than space and place, whether internal or external, private or public. However, today High Tech architects seem to be reconsidering their position.

4.6. High Tech Buildings and Obsolescence

The following is an analysis of how in a greater or lesser degree, HTBs are prone to fall into obsolescence, in light of the different "High Tech Types" defined earlier.

4.6.1. "The Decorated High-Tech Shed"

In this category we could include buildings that through one way or another have been considered High-Tech mainly because of the fact

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4.6.3. "Facilities for Advanced Technology Equipment."

In this case to HTB design, the problem of obsolescence as a consequence of High Tech design becomes critical. **Facilities for Advanced Technology Equipment** is the type of building that seem to be produced as standard-issues and resemble a big box. Here the building has turned into a custom made shell for a set of machines, the basic attributes that make it a "building" for the use and enjoyment of human beings, has disappeared, not only because of its precarious aesthetic qualities but also because here, the capacity to accommodate human activities is of secondary importance due to the priority status given to it's equipment.

In these facilities there is a dominance of the service aspects of the building in the overall hierarchy of the system (which can account to more than the 60% of the total construction cost). When this equipment fails or becomes obsolete, the value of the building as a whole is seriously affected. Since a "building" is not necessarily a sheltered machine less likely is a mere shell to be considered a building. Therefore these structures instead of resembling "Buildings for human beings", would more likely resemble mere *Facilities for Advanced Technology Equipment.*

In this case the most common examples available are modern-day factory-offices or facilities for the rationalized production and research of very sophisticated and expensive goods. In these facilities (such as clean room environments) very sophisticated equipment is needed for their operation. The tasks performed within them will sometimes require the constant presence of human beings working under in inadequate and restrictive environmental conditions. (Fig. 4.9)

This emphasis given to the engineering aspects of the building (that in clean room facilities can go from 20 to 60% of the available space) suggests that the building will probably have a very short life span since these are the systems that will have the shortest life cycle an will become obsolete before the "shell". Obsolescence in these facilities is even more critical considering that the price per-sq.ft. of construction is extremely high, ranging from $185 to $950.[7]

Since these "human filled machines" are usually located in our cities. Their designers in their effort to elevate them to the status of buildings, framed within the concept of *the decorated shed* attempt to "embellish" their shells. The Architect is then driven to the exterior of the building where he is only responsible for it's packaging. Unfortunately due to the high investment needed for the building's "equipment", few resources are left for enhancing the spatial and formal qualities of the building. This often results in either the simplest possible weather protection or a completely independent response to the context.

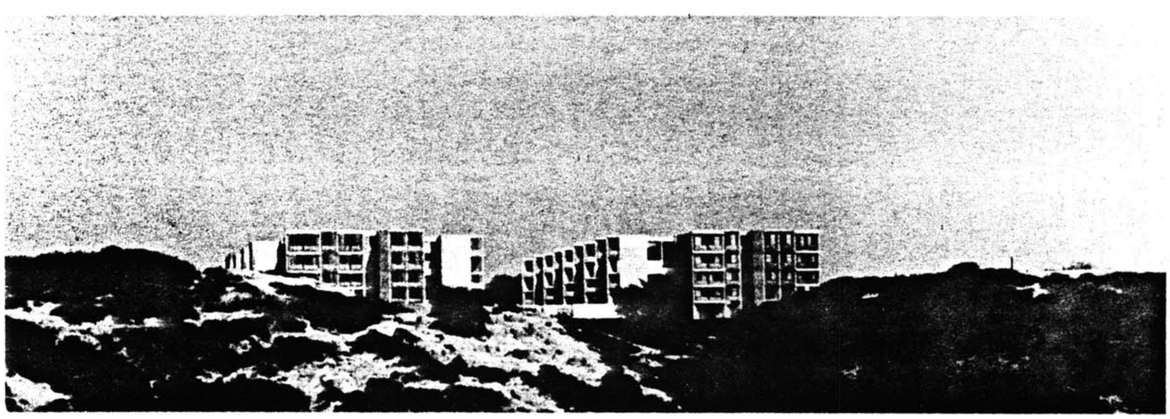
In the following Chapter the the underlying issues here discussed will be addressed in how they relate to the necessary change and evolution of HTBs. Design strategies for flexibility and permanence that result from this needs and that explain the preceding observations will be commented.

[7]Figures given at a HTB seminar lecture at MIT, fall 1988.

PART 3.

Chapter 5

GROWTH AND CHANGE IN HIGH TECH BUILDINGS 113



Chapter 5

5. Growth and Change in High Tech Buildings

5.1 INTRODUCTION

Although designers are aware of the need to accommodate change in buildings, current practice in building design takes little account of these conditions. Traditional office buildings at the most, will be designed with free plan configurations in order to allow flexible space layouts with the use of movable partitions. However complex HTBs require a much broader response to the problems of growth and change. We have already mentioned a few of the strategies that heve been incorporated into the High Tech concept. In order to understand these phenomena and consequently establish design parameters that will include additional considerations for growth and change, we must first learn about the general properties of change in buildings,

Regrettably, unlike other fields there is a lack of proper data concerning the building process in the architecture field. Nevertheless some valid observations can still be made by the way of analogies or the observation of existing buildings.

It helps to observe that "all things change" or that "change is normal." These principles seem to govern the universe but they are not easily palpable in our world. There is of course different types of change/growth processes. Growth, change, and ageing are closely bound up with size, shape, and function, it is virtually impossible to separate one aspect of change from another. Natural changes in buildings are a consequence of the processes of ageing and growth.

5.2 CHANGE:

Change in buildings depends on the qualities of change in human matters. Therefore it is in the understanding of the growth and changing patterns of human organizations that we may understand the present characteristics and future consequences of change in HTBs. However it must be made clear that the growth of buildings is not in any case equivalent to that of organisms or populations.

One of the most representative characteristics of current western civilizations is the constant change of their organizations. With the growth of knowledge and information; the rate of change in human affairs has been accelerating very quickly. Organizations have had to become rapidly adaptable to new patterns of work.

The main change has been from one of rationalizing the production process (labor) to one of mechanizing and automatizing white collar work. i.e. management and administration. This has had two consequences:

1) Less "man" power in offices, meaning more equipment and machines.

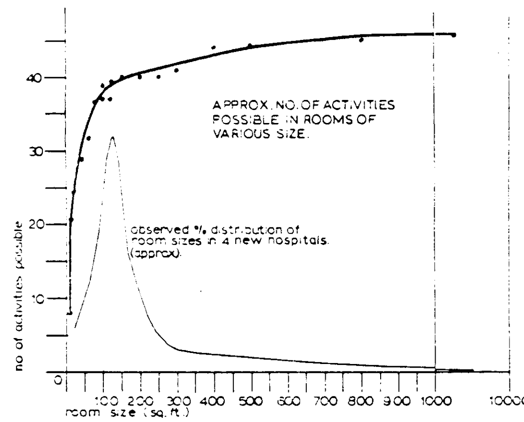
2) More demand for linking (integrating) electronic devices and communication networks.

Studies have showed that human organizations such as companies grow very rapidly in their beginnings, however we cannot be precise about the actual rate of growth and change of buildings. We know for example that the staff of hospitals has become infinitely more complex in the past decades.

As organizations grow , mayor changes occur in their internal structures, such changes in the internal organization of a company must affect the design of the structures that harbor them. One of the most demanding problems is that of sheltering an organization which has a rate of change so great that it makes its buildings obsolete before they naturally decay.

In the other hand we know that human activities are adjustable to a wide range of spatial situations. Therefore, if we are to construct our buildings so as to accommodate these organizational changes: How far is it worth while going in responding to these changes? Where do we draw the line?

P. Cowan (1963)[1]determined that it may well be that the majority of human activities occur in spaces of under 200 sq. ft. In addition, it is quite reasonable to suppose that rooms of 150 sq. ft. will serve a very large proportion of human needs. (Fig. 5.1)



Alterations to the insides of buildings are very expensive, and it is necessary to discover the frequency of change within a building before we are sure it is worth making special provision.

High Tech buildings, being hospitals ,universities, airports, research institutes or other types of buildings, need to have in built potential for the different kinds of changes which have to be matched to the change patterns of the organizations that these buildings house. Otherwise, the buildings would be rigid shells that would outlast the activities for which they were designed and, unless destroyed, impede the activities of tomorrow. A medical center is a dynamic, growing system, which can achieve permanence only by adapting to change.[2]

[1] Cowan, P. 1963. *"Studies in the Growth, Change and Ageing of Buildings."* Transactions of the Bartlett Society, London University College. Vol. 1, p.60

[2] Weeks, J. 1964. *Indeterminate Architecture.* Transactions of the Bartlett Society. Vol. 2, 1963-64. London University College. pg. 90

Changes in buildings are the consequence of the processes of ageing and growth. Changes include Alterations and Replacements as well as growth.

Alterations are those actions that physically alter the original configuration of the building as designed; they may be the result of minor or major modifications (modernizations) undertaken in the interior, or the result of the growth and expansion of the facility.

Replacements refer to the substitution of worn out elements as result of their irreversible decay, and they are made in order to keep the building in usable conditions. Replacement can happen at the level of the whole building or at the level of building components.

It is necessary to understand the conditions that have led to change in the past in order to understand its nature. It is also helpful to attempt to forecast future factors which may nurse further change.[3]

5.2.1. Forces that Generate Change in Buildings

Changes in buildings may be required due to one or a combination of the following conditions:

A) Technical Change
- — new procedure or equipment

B) Social/organizational change:
- — change in work load
- — change in layout efficiency
- — change in new operational policy
- — change in insufficient area for an activity

C) Political and administrative change:
- — change in codes
- — change in professional standards
- — change in administrative policy

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[3]From Garcia Alvarez, Angel, 1989. Based on: Bobrow and Thomas (1978) and Mathers and Haldemby (1979). See: *Interstitial space in health care Facilities: Planning for Change and Evolution.* MIT Thesis. June 1989. p.57

D) Other sources of change

Depending on the building type these forces will ... different emphasis in the need for change. Nevertheless, advances in technology seem to be the main force producing modifications and replacements in buildings —information technology is without doubt the single most potent generator of change in modern organizations.[4] This explains why today, more than ever before, HTBs are constantly being required to change.(Fig. 5.2)

Structural frame, exterior skin		100	years
Floor finishes	- resilient	40-50	years
Wall finishes	- paint	5	years
	- plastic fabric	15-20	years
	- tile, masonry	50-100	years
Ceiling Finishes	- acoustic	25-50	years
	- hard-surfaced	50-100	years
Roofing		25-35	years
Windows	- wood	40-50	years
	- metal	100	years
Mechanical	- storm drainage	100	years
	- sanitary drain	40-50	years
	- pressure piping	40-50	years
	- small motors and controls	15-20	years
	- large motors	30-50	years
	- duct work	50-100	years
Air condit. syst.	- large (>20 tons)	20	years
	- medium	15	years
	- small (<5 tons)	10	years
Heating systems	- boilers & furnaces	20	years
	- gas burner equipm.	15	years
	- oil burner equipm.	10	years
Electrical	- buried wiring	50-100	years
	- switchgear, etc.	25-50	years
	- standby generat.	30-50	years
Fire protection	- pressure piping	100	years
	- stanby pumps and controls	30-50	years
	- alarm and communicat.	15-20	years
Conveying systs.	- elevators freight	25	years
	- elevators passenger	20	years

Table VIII. Life expectancy of different components in Health Care Facilities. Based on: Mathers & Haldenby. 1979. *Op. Cit.* p.6.8

In HTBs such as Hospitals and laboratories change is stimulated by the requirements of having to maintain state-of-the-art physical plant technology. Therefore during the HTBs life cycle, different kinds of changes will constantly take place within the building.

In the period 1977-1984, 37% of the Hospitals listed by the American hospital association undertook expansion programs, and least 50% of all existing hospitals undertook and completed a construction program to accommodate changes.[5]

5.2.2 When Changes Occur:

Changes can take place at any time in the buildings life; during the design, construction and/or occupancy of buildings.

Changes that are produced due to external factors are called *"Steady State" changes.* These have been seen to become necessary after two to five years of normal operations.

4 The Architect's Journal, June 1988.

5 Hardy,O.B. and L.P. Lammers. 1986. *Hospitals, The Planning and Design Process.* Rockville Maryland: Aspen.

"Break-in " changes respond to modifications that are usually needed during the operational "break-in" period of 6 to 12 months. These are a a particular cause of minor changes in High Tech buildings.

A successful design should be able to incorporate them with corrective measures if obsolescence is to be avoided.

A good example to illustrate the nature of changes in HTBs can be given by the following notes on the evolution of the *Nottingham Teaching Hospital* (Queens Medical Center), UK: 1500 beds over from a report made by 'The Building Design Partnership" of the a Hospital equipped with interstitial space service floors.[6]

A) *Changes made during the design period.*
Minor changes made to the internal arrangements, and a new department added immediately before tenders were incorporated. The service floor facilitated changes without interruptions to the design of services and structure. Also, the structural flexibility to increase user floor heights within the composite heights of the user and service floors enabled these changes.

B) *Changes made due to phased construction.*
Some areas were planned as temporary accommodation, to be converted later to other permanent use. The ease of removal of partitions and revision to service installations provide for in the design, facilitated these planned changes of use.

C) *Changes made during construction.*
Where it was possible without the interruption of the construction process, changes required by the client were incorporated. Revisions

[6] Building Design Partnership. 1978. *Nottinghams & Leeds Teaching Hospitals: Interstitial Space Research Study*. Preston, Lancasshire, England. pg.41

made necessary were: reduction, re planning, amendments or inclusion of new requirements; changes in the specifications of equipment, or changes in the method.

Where it was not possible due to difficulties, either in determining the revised brief or in the effect on construction programs, planned areas were frozen at the particular staged reached.

D) *Changes made after hand over*
The re-establishment of temporary accommodation into its permanent form. Changes of minor nature resulting from the development of the equipment and from changes in the working methods of the users.

5.2.3 The Incidence of change

The rate of occurrence of change at the different levels of a building (whole facility, floor, room..), depends upon the type of change under consideration: Modifications, Replacements, and Growth. These changes affect any highly serviced building designed to last, specially in hospitals where medical science advances and changes very rapidly.

5.3 GROWTH

Growth must be taken into account when planning a buildings today. requests for extra space and, and the task of fitting additional buildings into an existing complex, are now frequently presented to the designer.When planning High Tech facilities, consideration should be given to allowance of extra space, and the task of fitting additional future buildings into an existing complex.

5.3.1 Characteristics of Building Growth

The growth of buildings occurs suddenly and starts at varying intervals of time, usually dictated by a balance between social pressures and economic circumstances. Social forces operate differently upon each type of accommodation.[7]

Buildings grow by *accretion* like hair or nails. They do not grow by multiplicative compound interests like tissue. The growth of buildings is perhaps more similar to that of crystals. But the most important difference between building growth and other forms, is that it occurs only as a result of human action.

Building growth is therefore subject to the whims of a balance between human social and economic pressures and circumstances.

We may distinguish several classes of building growth:[8]

a) Growth by large functional Units.or by using space more intensively.

b) Growth by small additions to floor space.

c) Growth by large structural Units.

d) Growth by using space more intensively.

matters of social organization also play their part in limiting building growth.

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[7] Cowan, P. 1963. *"Studies in the Growth, Change and Ageing of Buildings."* Transactions of the Bartlett Society, London University College. Vol. 1, p.62

[8] Cowan, P. 1963. Op. Cit., p.62

5.3.2 Limits to Building Growth

Cowan points out that the limits of growth have to be considered when building expansion is planned. There can be external or internal limits.

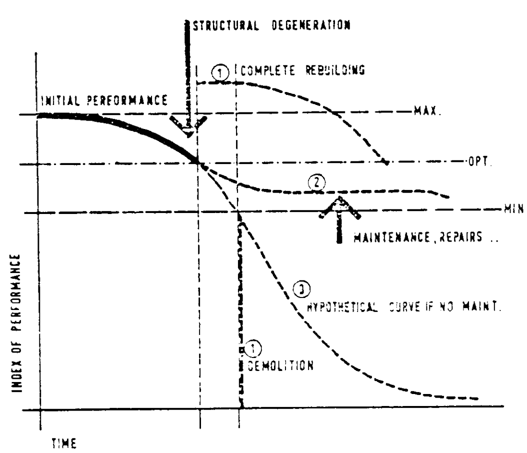
External limits derive from matters of social organization and they are:
- *dimensional limits*; set by the size or shape of the site.
- *economic limits*; imposed when the funds for new construction become restricted
- *political and legislative limits*; enforced by plot ratio, zoning requirements and daylight factors.

Internal Limits can be:
- Social Limits described by the type of organization which the building houses.
—Physical limits imposed by a building that set definite boundaries for grow, which can include for example; structural limits, limits on the loads of services.

5.3.3 Growth Patterns

Much can be learned about this by observing growth patterns in existing buildings.

As Cowan demonstrated, the curve of total building growth, plotting total floor space against time, takes very roughly an "S" shape, irrespective of the date of construction of the building involved, or the actual size of the original structure. (See Fig. 5.3)The growth of any object can be described by a growth curve.



STRUCTURAL DEGENERATION : HYPOTHETICAL CURVES

5.3.3.1. Organic Growth

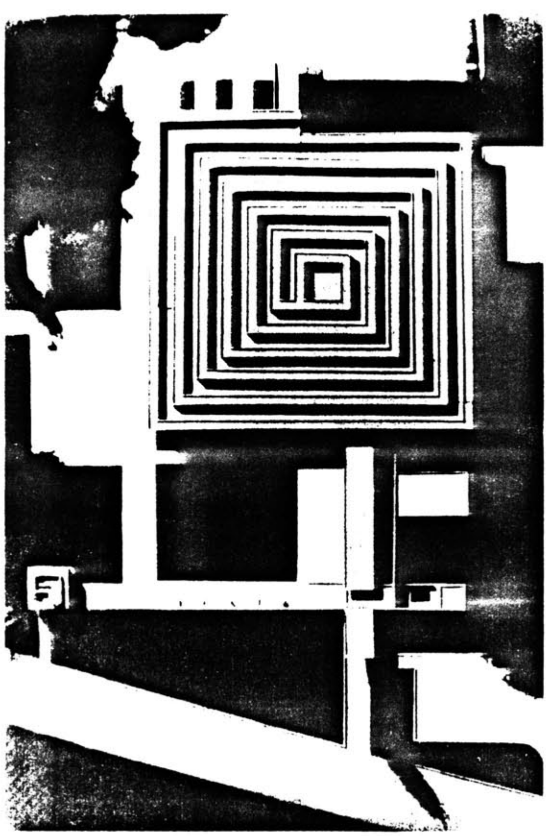
It is interesting to note the shape of these curves and to observe that the growth of animals; plants and humans; certain populations of humans and animals; and of organizations; is also thus described. However buildings do not, like living organisms, grow by proportional enlargement of all their parts. Rather, different growth rates and characteristics can be visible.

5.3.3.2. Differential Growth

HTBs do not present, however regular patterns of differential growth. Studies show that in buildings as hospitals, different parts have grown at different speeds over the years.
We can then conclude that the various parts of a particular complex building do not show much consistency in their patterns of growth.

5.3.4. Predicting Growth

This suggests that growth may be predictable within same building types under similar external circumstances. Observing the evolution of different forces that have affected change in the building's organization enables us to discover something from the nature of what generates growth and change in the building type. We could then be able to assess the possible effect of future organizational strategies on the size and shape of a particular building.



5.3.5. Controlling Growth

.. there have been many diagrammatic proposals for ideal systems of control ranging from the linear systems of early times to the spiral schemes by Le Corbusier.(Fig. 5.4)

"These have all been based more or less upon naive ideas and imagery borrowed from organic growth and are all to this extent false. As I have

tried to suggest, to impose patterns of natural growth upon buildings is not only irrelevant but wrong."[9]

Communication systems are of particular importance in directing and controlling building growth. Unless a new piece can be serviced and connected to the rest it will not work properly. In many cases the layouts of ducts and corridors will dictate the pattern of growth.

The form of a building evolves usually becoming more complex with time.
Such increasing complexity form brings with it radical change in the appearance of buildings, and makes even more difficult the task of fitting in new growth.

5.4 EVOLUTION

Maybe building types exhibit the general characteristics of evolving systems. This is not evolution in the Darwinian sense of a process by which functional variations are tested against there performance in life, leading to selection of those variations which confer advantage on the species.

In certain cases it is possible that some selective pressures do operate on buildings of a particular class. Building growth has been compared to relationship between the "endosomatic"evolution, of normal biological type, and the "exosomatic" evolution," which concerns the development of tools and artifacts as extensions of human organs.

[9] Cowan, P. 1963. Op. Cit. p.66

While normal biological evolution goes on rather slowly, exosomatic is proceeding very quickly. It relies upon the collective memory of the race, which is embodied in tools, artifacts, books and the like.

5.4.1 Shape Size and Function

Size, shape and function are interrelated and are closely linked with these topics. There is an appropriate size for most of the things. The upper size limit of organisms is bounded because the volume of the body grows as the cube of its linear dimension, whereas the surface grows as the square.

Through the observation of living organisms we find that in every case the size of the successful organism is matched by a appropriate degree of complexity. The limits of size in nature are structural, metabolic and nervous, and have their equivalent in social organizations, which in turn pose limits on building size. Human affairs thus settle out according to certain size criteria, and these in turn are reflected in the size of buildings and cities.

Buildings are part of the general system of human affairs which is constantly changing, and they affect and are affected by the larger systems of human development. The key lies in recognizing the changing balance of such systems. *Homeostasis* which describes the shifting balance between the organism and its environment, is a condition which we should seek to achieve in our buildings.

Chapter 6

DESIGN FOR GROWTH AND CHANGE

Chapter 6

DESIGN FOR GROWTH AND CHANGE

6.1. INTRODUCTION

Now that we have become acquainted with the characteristics of growth, change and evolution in High Tech buildings, it is possible to explore a series of design strategies intended to overcome the problem of building obsolescence. As explained before, science and technology have induced new attitudes in every area of activity . Consequently, the circumstances of modern life have changed constantly and demand new and flexible responses from the built environment.

In general academic buildings have not been able economically to meet new demands, thus planning major physical constraints on the changing activities of the building's users. traditional design and construction methods are in large measure responsible for the lack of adaptability of these buildings, principally because the need for change has only recently been recognized. Partitions are built as virtually immovable walls, plumbing and services are fixed. When physical changes are needed, mayor remodeling work is necessary. This in itself is costly, an inevitably involves disruption to the normal activities of the user. Not only is the space being remodeled disrupted but also the adjacent spaces. the rooms below, providing access to drains and plumbing for the remodeled space, cannot be used while the workmen are active.[1]

Architects are facing the challenge of designing buildings that will be capable of accommodating the changes that technology will bring well into the next century. One way they have chosen to approach this challenge is trying to predict the technological changes likely to happen. Since predicting the future has proven to

[1] Building Systems Development. 1971. *Academic Building Systems (ABS)*. Volume 2

be an impossible task, a different approach, has been to re-examine the basic principles we inherently use in the design process.

Nevertheless, if possible, future advances in technology must be anticipated and accommodated in both the design process and the built result. As shown in the previous chapter; with regard to the High Tech building, solutions must also provide for changes brought about by organizational changes, as well as by new technologies. In the traditional design process, architects in both cases have reacted to these requirements according to past or to present conditions and demands, failing to carefully consider the consequences of unforeseen technological development or changing user needs. This has culminated in designs that where outdated before the buildings where completed.

The rate of change of social, economic, organizational and technological systems will most probably increase and, as a consequence, the engineering demands placed on buildings will also increase. Provisions for maintenance, change, alterations, and/or growth in response to future program changes require consideration in a coordinated and integrated design of systems.

If we are continually conscious of the unknown future and design accordingly, it should be possible to introduce new technology without causing major disruption to the buildings and its occupants. Therefore we need to create flexible buildings into which new facilities can be introduced with minimal disruption. This approach to design flexibility will enable buildings to adapt to the environmental changes that cannot foreseen today.

However, often the emphasis given to the original design configuration of a system as a tailored made response to the original requirements, has contributed to the future obsolescence of a building.

6.2. DESIGN STRATEGIES FOR CHANGE IN BUILDINGS

6.2.1. Flexibility and Variability

Flexibility in a building is the *in-built ability to accommodate change over time.* It ensures that future modifications, growth, and replacements can be accomplished readily at a reasonable cost, without major modifications to the building structure and without disruptions to the normal operations of the building.

In the building's response to change it is not only the capacity of the built environment to accommodate change that is important but also the possibility of changing the built environment itself to achieve changes in the conditions of use of a building. Therefore design for change should not only consider flexibility and adaptability but also the possibility for variability.

It is important for the designer to be conscious of the distinction between them as well as what these terms stand for.
Therefore, Flexibility and Variability could also be defined as follows[2]

> - *Flexibility* may be defined as the ability to achieve a change of conditions, without changing the basic system as such;
> -*Variability* may be defined as the ability to achieve a change of conditions by changing the system.

Thus flexibility refers primarily to adaptations to change , while variability refers more to change as such.

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[2] Dluhosch, Eric. 1974; *Flexibility/Variability and Programming*. in Industrialization Forum.,p. 40

Flexibility itself can be approached in two ways:
Flexibility can be Generic and Universal[3]. The first entails adapting the physical environment to changing technologies, while the second means developing a prototypical environment to accommodate a range of technologies.

Even though considerable benefits can be attained from the use of movable partitions, integrated ceilings, and cellular floors; the real limits of flexibility are found in the size of the air handling units, in cooling capacity, or in power distribution. Thus flexibility involves space and service networks, and affects two variables, costs and disruptions.

Unless building systems can be designed to meet the future demands of the changing mechanical subsystems, architectural flexibility means very little. Therefore in a flexible building it should be easy too find additional mechanical and electrical capacity.

Even though contemporary buildings can be designed as *relatively permanent* or temporary environments, the existence of change within them cannot be denied.

Today we can closely determine, the needs for space and equipment, and other facilities for a building. We also count with the ability to calculate accurately the materials and service equipment needed for the building so as provide the users with a required performance.

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[3] Cardona and Vazzano, 1986 See :Stubbs, Stephanie, and Senewald, Bea: *Flexibility by Design, It is more than a matter of engineering or "widgets."* in ARCHITECTURE, AIA Journal. April 1987

Buildings are being designed to higher standards of service provision than in the past. Mechanical equipment is constantly improved and new installations are likely to force alterations to the building. However buildings that are tightly designed according to these requirements are not able to easily absorb larger demands or change in their spaces. Therefore design strategies for coping with change aim at trying to reduce or ultimately eliminate the problem of buildings which virtually dictate what standards and kind of services they can offer or functions they can serve.

6.2.1.1. The Flexibility Paradox.

If we observe our built environment in order to learn from past experiences how to deal better with the problem of flexibility, two experiences are paradoxically enlightening.

The Speculative Office Building

The speculative office building which is designed with the sole purpose to generate profits for its owner can be found to be quite flexible. Actually, "spec" buildings can accommodate a extremely wide variety of tenants whose only requirement is to use standard interior components such as desks, telephones, type writers or computers. These buildings base their universal flexibility in how little is put into them.

Research Laboratories

If "spec" buildings are flexible because of how little is built into them, research laboratories represent the opposite end of the spectrum. they are usually designed for very specific uses and have to deal with gases, special plumbing, and exhausts. In spite of their rigidity, they accommodate constant change in the research programs they house. Modular walls and ceilings are almost never used in these buildings. Metal stud and gypsum board partitions are the norm.

Highly complex HTBs such as laboratories, represent a *flexibility paradox* in that they are designed for very specific uses, yet must be able to accommodate constant change in research programs. The key is often accessibility of the mechanical systems, allowing modification of the systems without disruption of ongoing research. The most common techniques used in the design of these buildings such as "deep plan" and "interstitial service floors" will be explained in the subsequent chapter.

The Nineteenth Century Building

Many "Old" buildings, mainly from the 19th. century, have been rendered flexible enough to convert to modern uses. This is a direct cause of a generosity of design in space and structure. In a way these buildings are a paradox, since they certainly where not designed to be flexible . Yet they adapt beautifully to their new uses.

As noted by Weeks,(1964); the same factors that help old buildings survive to the uncertainties of our times, are the very factors that work against the survival of modern buildings. The relatively *large amount of space* for a given number of people provided in 19th.. century buildings and the relative *absence of mechanical equipment* contrast with the reduced amount of space allocated in today's buildings as well as the considerable provision of service equipment.

Generosity of Space

The technical reasons for this versatility are simple: old buildings have tall floor-to-floor heights which make it easy to add mechanical, lighting, or wiring systems, lighting and duct-work and still leave room for spacious ceilings. They also tend to be very solid structures with that little bit of extra capacity that permits cutting out a bay or adding new loads. It is *generosity of design* that makes these buildings flexible.

A good example of this is the 19th.. century railway stations. Here the intensification of use and the adaptation to new functions have been easily accommodated thanks to the availability of extra space.

Thus we can conclude that *generous space* allows "elbow room" for adding equipment or new functions. Besides the difference in space standards this was possible to provide in the nineteenth century since the relationship between first cost and operation/management costs was different as to what it is today. also, since structure (support elements) is relatively less costly than equipment, one could provide *larger* structural spans as a first move. If we check the cost of this strategy against land/site cost and availability we can begin to understand why most High Tech buildings in U.S. cities are localized in the suburbs. Since land is cheaper so is the provision of generous space.

6.2.1.2. Designing for Flexibility

Without the provision for Flexibility and Variability, programming and designing for future generations of anonymous "users" will lead to closed systems, —which are inherently impervious to change and which tend to serve only a limited number of user groups. Emphasis on the potential for flexibility and variability becomes then a necessary design objective that will eventually lead to more "Open" systems of variable plans for buildings. Flexibility and variability have become a criteria for the evaluation of HTBs. Consequently the building is then looked upon as an object of change as well as of continuous transformations in order to meet the users' expectations and needs throughout the buildings existence.

The most critical decisions made in the planning of HTBs occur in the initial design phases of the project. At that stage of the process it becomes very important to choose an appropriate approach to flexibility in terms of planning configurations, distribution of utilities, space adjacencies, building systems, and initial and life-cycle costs.

6.3. STRATEGIES FOR FLEXIBLE DESIGN

Before defining the basic strategies a building must follow in order to cope with growth and change, the life-cycle requirements of the project should be made clear. Strategies for flexibility will greatly differ for similar programs when dealing with buildings that are to have a short life(temporary) or those that are to have a "long-life."

There are two levels of action for the provision of overall building flexibility .[4]

The first has to do with the *nature of the material*, its fabrication, connections, and dimensional coordination.

The second refers to the organization *(hierarchy)* in which elements or space qualities are concentrated in an area or system; in other words, the specialization into zones of different functions or activities. Within each of these levels certain design strategies can be identified.

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[4] See: Alvarez, Angel G. 1989. *Interstitial Space in Health Care Facilities: Planning for Change and Evolution.* MIT Thesis. (Based on Aylward, G., & K. Lapthorne. 1974.)

6.3.1. The Nature of the Material

1.Modular Coordination

Modular planning and a well chosen planning module allows more freedom in the positioning of the elements within the space. A system of *dimensional coordination* is essential.

2. Joints and Connections

The dimensional coordination is complemented with *connections* which ease of inter-changeability, demountability, and relocatability of components, either partitions, furnishings, or equipment.

3. Structural Configurations

The structural bays have a particular effect in the flexibility of a layout. Long spans achieve maximum flexibility.

6.3.2. Hierarchy

The organization or hierarchy of the system is the key to the problem of flexibility.

According to N. J. Habraken, in examining the composition of complex artifacts, we are likely to find a hierarchical structure, and that depending on the criteria we apply for the decomposition, different hierarchical structures will come out. [5]

"Control hierarchies" are parts that make the whole and lend themselves to be controlled by a third party.

[5] Habraken, N.J. 1987. *"Control Hierarchies in Complex artifacts."* Proceedings of the 1987 Conference on Planning and Design in Architecture, pg.75.

"Assembly Hierarchy" is commonly known and predominantly technical in nature. It tells us that a unit on a higher level of the hierarchy is composed of parts we find on the lower level.

In *Dependency and Territorial Hierarchies*, the entities found on a lower level do not assemble to form a higher level unit, their relation is not one of assembly but of "dominance," where the transformations on the lower level are constrained by the higher level. Of these two, Dependency Hierarchy is the one that has to do with the control of physical elements. Territorial Hierarchy has to do with the control of spaces in which we distribute our physical parts.

6.3.3.The Dissolution of the Building's Systems

By separating and zoning different functions, systems or parts of the building, in the design stages, the overall flexibility of a building is enhanced. This process has been called the "*dissolution of the building.*"

The term dissolution has been defined as:
The act, process, or an instance of separating or of being separated ... the breaking-up of an assembly or organization.[6]

In this context dissolution has two meanings; It means *separation* when referring to the subsystems and the parts which build up the whole building —for example the separation of main structure from the facade; and it means also *zoning* in the spaces —for example the zoning of mechanical and use spaces. The idea of dissolution or braking up of the building components affects, thus, both the physical elements and the spaces that house the systems.

[6] Definition from The Random House College Dictionary, 1988.

The main criteria behind the dissolution of the building is the *life cycle approach*, which in this case refers to physical, functional, and financial obsolescence.

There are long life-cycle elements and short life-cycle elements. Alterations and replacements are accomplished more effectively when different subsystems are physically separated or zoned according to their life-spans. In the case of HTBs this becomes critical in how the permanent structural system and the changing, specialized mechanical subsystems, are coordinated and integrated. This has to be considered at the design stages.

The ability of a building to react to changing requirements relates directly to the recognition in its design of the *distinction between the different life spans of the parts*, and to the provision of facilities for change suitable for each.[7]

Steps for the dissolution of the building include the following:[8]
1. Predict the rates of change of the different components
2. Group elements according to change-rates. For example short-life elements can be specified in areas that may undergo future alteration cycles.
3. allow the greatest accessibility for ease of modifications and replacement.
4.Create an organization capable of managing the process.

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[7] Weeks, J. 1973. *"Hospitals Briefing."* Architectural Design. July 1973. pg. 442

[8] Turner, J. 1967. *"Designing for Obsolescence".*'The Architects Journal. oct. 1967. pg.940-1

6.3.4. The Support Infill Approach

The general theory of *Supports* has been around since 1961 when N.J. Habraken published his book; "Supports , An Alternative to Mass Housing." (Architectural Press,1972) here he suggested the idea of forming housing infrastructures, or "Supports," constructed for maximum longevity into which framework prefabricated elements are placed to form houses tailored to individual needs.

The idea of *supports* and *detachable units* is based on the principle of *user participation and user control.* Therefore the basic principle of the support concept was that the building is always the result of two or more spheres of responsibility in the decision making, taking into account the role of the user.

In the "Support- Infill" concept, part of the built environment is clearly within the realm of the user (the infill) which he can change and adapt as he wishes, while the other belongs to an infrastructure (the support) about which the individual cannot decide upon, but must abide by the rules and conventions established in the design. The building is then divided into frame components or "supports" with long life characteristics and function objects or "infill" which are short-lived and easily replaceable.

In 1965 the Stichting Architecten Research (SAR) in Holland, proposed a method for the design of adaptable dwellings by means of "Supports" and "Detachable Units". The method (which will be explained in more detail further on), is designed to provide maximum flexibility and variability giving the occupants the maximum choice. In the case of supports, the final floor plan is not predetermined and has the potential for varying over time.

Schulitz in 1971 proposed system for residential construction in a similar approach.[9] Here he organizes the elements into open, interchangeable, long-life *"indeterminate"* elements and closed, replaceable, short-life *"determinate"* elements consisting mainly of services, the whole to be assembled into a long-life structural grid. The residual activity space is further zoned into "specified" and "unspecified" areas.

6.3.5. The Indeterminate architecture.

Initially intended for hospital design, Llewelyn-Davies and J. Weeks developed the Theory of Indeterminancy, an architectural principle enabling buildings *"to grow with the order and change with calm"*[10]

The Theory of Indeterminacy is an elaborate proposition for framing the zoning concept in HTBs and has been applied in Hospital design very successfully as a response to problems of change and flexibility.

It consists on a framework that provides in-built potential for change to be matched to the change pattern of the organization the buildings house. Essential to this concept is the notion of *organization*, of how to provide order in a situation in which closed design rules cannot be applied. The ordering principle is the communication pattern. It is this network which ties the whole together,.

Instead of designing for exact programs and single strategies (which guarantee rapid obsolescence), the concept of indeterminate

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[9] Schulitz, H. 1971. *"Structure for Change and Growth."* Architectural Forum. March 1971, pg. 60-3.

[10] From: Alvarez, Angel G. 1989. Op. Cit. p. 194

architecture is based on the uncertainty principle, or in the *"robustness,"* which is the complementary principle which measures the ability to survive through multiple futures.

Thus the principle of uncertainty pertains to *the use of spaces, the relationships between spaces, and the size of the building*, which leads to indeterminate internal plan arrangements and indeterminate size of the building. [11]

The concept of indeterminate architecture is based on three principles:

1) The duffle coat analogy.
2) The three dimensional lattice.
3) Provision for Growth

6.3.5.1. The Duffle Coat Analogy

This principle is based on the notion that buildings should provide space which is as non-specific as possible. At the level of the individual space the concept means that the modular planning element chosen must be suitable for a wide range of functions.

Studies regarding the sizes of rooms showed that, with exception of certain specialized, almost mechanical operations, it is possible to carry on a large number of different activities in a few given room sizes. Taking advantage of this fact, Weeks proposed the "duffle coat" analogy for planning, in analogy to the coat provided by the Navy to its officers, in which a few sizes suit all men.

Change of use can be made by *adaptation* (no physical alteration) or by *adjustments* (physical alteration). The adaptation of a space

[11] Weeks, J. 1973. Op. Cit. pg. 442

without physical alteration to multiple patterns of use has also been called "*Polivalency.*" An important aspect of polivalency is the ability of the design to stimulate multiple use.

The adjustment to new activities within a room imply physical alteration and usually has implications for the provision of services. It includes the change by subdivision of space, in which case the proportion or shape of the room play an important role. Since adjustments usually demand new services, a wide range of services should be available to a standard, wide-use range module of space.

At the level of a cluster of rooms, a flexible plan relies on a clearly defined circulation system, and also on the degree of variety of room sizes, since it increases the ability of a set of rooms to adapt to an even wider range of use patterns. In large scale aggregation spaces according to basic space type , the link by a simple circulation system permits a multiple pattern of use.

When expansions or reorganizations become necessary, another principle is set forth: the *three dimensional lattice*. Here the communication pattern becomes the basis for the plan. The adjustments are made to take place within a clear and fairly fixed framework of communications.

6.3.5.2 Provisions for growth:

Growth is controlled by the communication pattern that sets out the characteristics of elements to be added in principle, but does not dictate in detail, size or form. A long-range master plan which permits major additions to the existing circulation routes is essential.

Before actual external growth occurs, growth may happen internally, (internal growth) either within the space, or by acquiring surrounding *"soft" space* or less highly serviced areas and upgrading it. In the first instance, intentional "over designing" by providing an initial over-capacity is an expensive but uncomplicated and effective way to accommodate growth. In the second instance a viable strategy is to create an expansion buffer for expansion around those areas likely to grow.[12]

Week's strategies for actual growth comprise:
1) Provision of an open end for future extension.
2) Extendible mechanical system
3) Extendible structural system. (It should allow the incremental addition of space by direct extension of the existing structure.)
4) Extendible circulation network, (by direct continuation of the existing pattern to accommodate additional space.)

6.3.6. The Consideration of the User

The consideration of the users' ability to control his built environment is very important in designing environments that are receptive to the changing requirements and aspirations of human beings. As HTBs evolve as large complex interrelated machines, maintenance and operational personnel need to work with the buildings equipment without fully understanding all the elements. Systems should be designed and integrated in order to allow the people who work in these places to feel that they can use and operate the facilities of the building.

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[12] Weeks, J. 1969. *"Multi-Strategy Building."*. Architectural Design. October, 1969. Pg.540

Therefore, as the complexity of the design increases we must remember that the possibility of user control and the human scale of the design are important to consider. Where ever user requirements have been traded off for economical considerations this has led to the eventual obsolescence of the structures.

6.3.7. Other Strategies for Flexibility

While designing for flexibility, one should keep in mind from the beginning that growth and change of HTBs is an inevitable process and therefore the building will never be considered complete. Nevertheless, *defining different stages of growth* or phasing of changes in the building's life-cycle as part of the initial design can prove to be very helpful for an ordered evolution of the building.

Efficient structural, mechanical and electrical systems when designed to respond to modifications in user demands, facilitate a substantially longer effective life of basic structures. Even though this strategy may suggest that custom designed mechanical systems can prove to be more efficient if replaceable, we also have to consider that the more closely a design is tailored to a particular function, the more quickly it becomes out of date and obsolete. Requirements for the adequate integration of systems as well as more specific strategies for the design of flexible environments will be described subsequently.

6.4. SERVANT AND SERVED SPACES, Interstitial Space and Deep Plan.

6.4.1. The Concept of Servant and Served Spaces

Louis Kahn's vision of a building similar to a living organism, expressed in his theory of *Servant and Served Spaces*, contributed to the notion of buildings as a construction of permanent and changing configurations. He believed that a building should also have separate spaces for the mechanical systems serving the habitable rooms. Kahn reintroduced the renaissance principle according to which space is built up out of cells of space articulated by a "strong" structure.

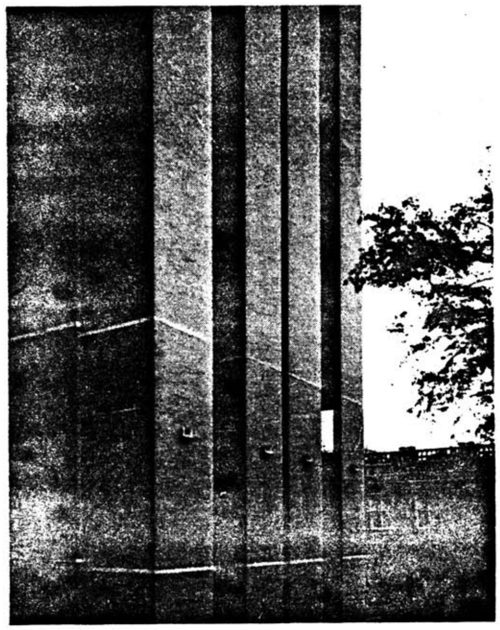
This notion responded both to the problem of flexibility as well as to the new requirements of contemporary buildings. It basically consisted on a arrangement in which certain parts of a building would explicitly provide the (servant) space necessary for the efficient servicing of the habitable (served) space. Kahn not only meant this in a functional sense, but this loose-fit, as well as architecturally ordered scheme, should also be made explicit in the overall conception of the building.

"The nature of space is further characterized by the minor spaces that serve it. Storage rooms, service rooms and cubicles must not be partitioned areas of a single space structure, they must be given their own structure."

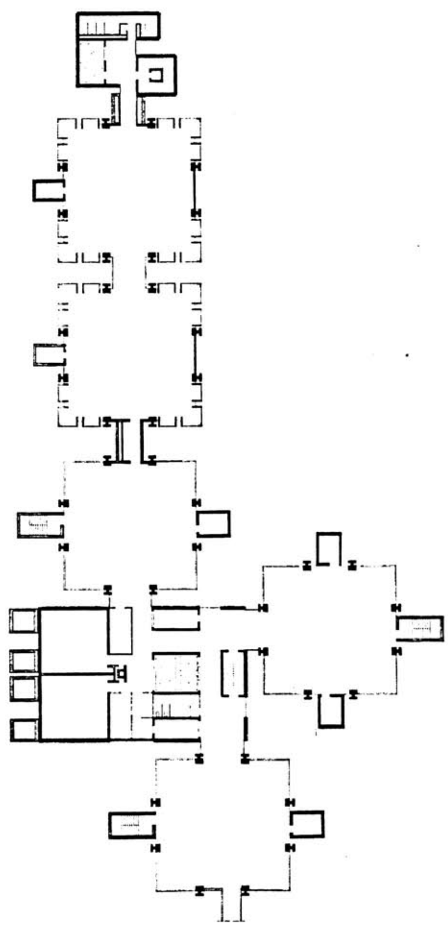
Kahn considered the use of voids an acknowledgement to an order inherent in character of spaces created with modern building materials.

" Today we must build with hollow stones" once said Kahn referring to his project for the **Trenton Community Center** (1955-56). Vincent Scully in his book "Louis I. Kahn" (1962) stated his belief that this was to be Kahn's germinal project. Here he incorporates the servant/served notion to the design of the bath house. (Fig. 6.1)

Nevertheless his "Servant and Served" concept, even though not fully integrated, is first suggested in his project for **The Richards Medical Laboratories** in Philadelphia, Pennsylvania (1957-61) (Fig.6.2).



The research complex is organized into three laboratory towers clustered around a central fully enclosed service building. Each laboratory within them is surrounded by a cluster of hollow vertical service columns that provide the laboratory modules with clean air and other mechanical services as well as the removal of the exhaust fumes. Utilities are then directly channeled through the structure fully integrated with "served" and "servant" spaces. Here the vertical service shafts are treated as a principal part of the permanent composition of the building. The mechanical support elements are not hidden nor fully exposed; a special space is provided for them.



Within the laboratory buildings incorporated into the floor-ceiling structure as separate interstitial space is a crawl space high enough for a seated worker. These voids carry the air ducts from pipes and electrical lines that connect the labs with the utility shafts. These laboratories were considered unique in those days as the only laboratory buildings in which each type of space had been given a special treatment.

Even though Kahn's notion of a building as construction of servant and served spaces was already being suggested here it was only until he designed **The SALK Institute** (1959-65) that he really came to grips with this spatial relationship. In this laboratory research complex in La Jolla California, the study spaces are clearly distinguished and separated from the experimental labs. Also the vertical ducts of the Richards laboratory buildings seem to have been placed horizontally and turned into *interstitial space service floors* housed in the hollows of spanning box girders.

In the laboratories the distinction between served and servant spaces has been made clear. The incorporation of 9 ft. high spaces for mechanical equipment between floors that he called "Pipe Laboratories", acknowledged the concept of the interstitial service floor. These "servant" spaces allow the "serviced" space (the labs) above and bellow them, to function in a specialized way as well as being very flexible.

After the Salk institute all of Kahn's buildings responded in way or another to the servant-served relationship between spaces. It is an understanding of the connections between different types of spaces, each serving and being served by another in different ways.

6.4.2.Deep Plan and Service Floors

6.4.2.1. Interstitial Space.

The concept of servant and served spaces can be successfully applied to the design of flexible HTBs through the combination of service floors and deep plan configurations. Both concepts are a response to the strategies for flexible design previously explained. However, in order to fully understand how these design strategies respond to the previous notion, we must first come to grips with the the concept of *interstitial space.*

Modern technology and architectural ingenuity, as a response to complex and changing user requirements as well mare efficient and economical construction principles, have introduced a clear separation between the structural, functional and visual attributes of building components. This has permitted the development of hollow sandwich systems for ceilings, floors, walls, shafts, escalators, etc. As will be explained further on this has had a mix effect on the condition of permanence of the built environment.

The dictionary definition of "Interstitial" refers to the condition of

... pertaining to, situated in, or forming interstices ..... a small or narrow space or interval between things or parts[13]

Interstitial space in architecture could then be defined as the space that is situated between the structural parts of a building. The in-between space in buildings that can be used as servant spaces. This is the meaning here embraced in spite of the fact that in the field of hospital planning this term has been mostly used to allude only to service floors.

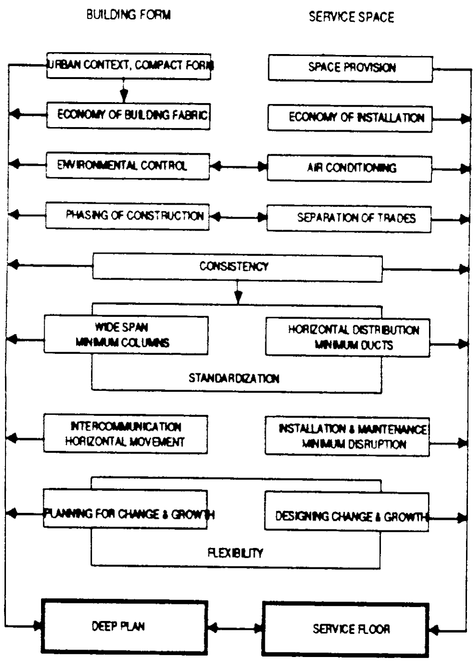
The use of interstitial space for horizontal service floors or vertical shafts has to do with the acceptance of the previously described notion of *generous space* as a way of making possible a flexible "serviced" space. Moreover, the ability of a given building to accommodate vertical or horizontal growth within a coherent and logical system has come to be substantially influenced by the presence or absence of interstitial design in the support configuration.

The provision of generous service space is in turn based on the acceptance of *space-redundancy* (over abundance or excessive provision of space) as a "necessary evil" for the adequate separation of systems and components within interstitial spaces. As mentioned before *the planning of serviced spaces with in-built flexibility for change and growth* represents a shift of emphasis away from the design that is carefully planned to suit specific functions towards an approach which recognizes the need to accept flexibility as a functional parameter.

6.4.2.2. Deep Plan and Service Floors

[13] The Random House College Dictionary, revised edition 1988. The random House Inc. New York.

Two design strategies that combine the concept of served and servant spaces with the notion of generous space for flexibility through function separation, are the use of *deep plan* configurations (served space) and *interstitial service floors* (servant space).



The "Building Design Partnership"(1978) has argued that the need for flexibility is best met by the *Deep Plan* concept. It is able to accommodate probable changes during the design, construction period, and occupancy, and also to allow future growth. The Deep Plan building form combined with the interstitial Service floor is an integrated solution that has been successfully used in the design of HTBs, especially complex hospitals.[14](See Fig.6.3)

The interstitial space concept is then most suitable for large complex buildings, which are highly serviced, have a great incidence of change and need access to services without disturbing their basic functions. The building types most frequently encountered is research laboratories and hospitals and specially those in which access for maintenance might upset experiments or be hazardous for service staff.[15]

The form of a HTB is greatly affected by the need for a variety of services to be provided at many different points in the building. Consequently , a full and early consideration in the design stage has to be made of the space to be provided for these functions. Spaces for the distribution of services may be provided horizontally, vertically, or by a combination of both.

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[14] See: Alvarez, Angel G. 1989.Op. Cit..Chapter 7.p 211.

[15]Building Design Partnership. 1978. Op. Cit. Pg.41

There are four alternatives for relating horizontal service to horizontal structure:[16]

- Services moving horizontally under the structure.
- Services moving around the perimeter of the building.
- Services moving between structural members.
- Services within a structure permitting freedom of movement in two horizontal directions. (If enlarged to full clearance height, it becomes the service floor concept.)

The use of Interstitial Spaces allows the application of two needed planning concepts to the design of HTBs.

First, a building methodology (*fast-track*) which allows the construction of the basic building shell and the mechanical spine system without finalizing user's requirements.

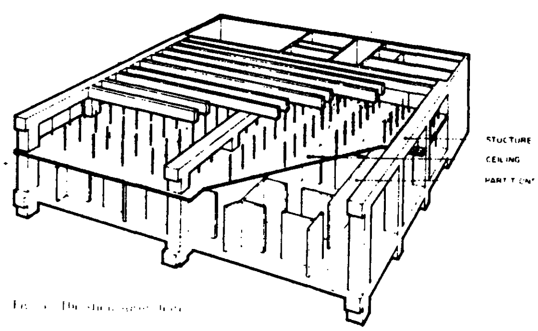
Second, a building technology (*flexibility and variability*) that makes it possible to adjust the environment created to needs that can not be anticipated at the time of planning.

[16] Building Systems Development. 1971. *Academic Building Systems (ABS).* Volume 3: Information Manual. University of California and Indiana: U.S. Department of Health, Education and Welfare. Pg.265

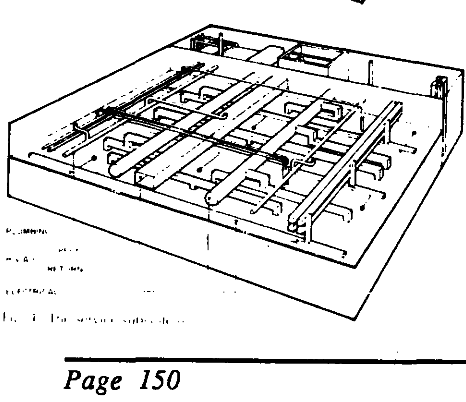
6.4.2.3. Historical Background.

The rationalized concept of interstitial service floor design, was first applied to hospitals in the U.K. during the early sixties. It was born in response to the need to accommodate complex service installations, and also to the perception that an effective building life depended on the ability to ease and respond to the continuous need for change. Nevertheless the use of a complete floor to house mechanical and electrical plant has been quite common since very tall buildings appeared on the scene.

The earliest built example is at the Welcome *Foundation Pharmaceutical Laboratories* at Beckenhan, Kent, built in 1956 [17]. The interstitial space is walking height only over the spine corridors. However the first building that provided complete floors entirely dedicated to the maintenance and distribution of engineering services was the *Greenwich Hospital* (1966-69-71 &74) This building was to be a real breakthrough in hospital design, representative of the first generation of interstitial floor planning.



Developed at the same time, the *Salk Institute* in La Jolla California, included two laboratory wings each with a 60 foot clear span and services very well organized in generous interstitial spaces. (Fig. 6.4) Services are carried horizontally up to 245' before they are taken into vertical shaft.



The second generation of these buildings was developed in the US for the Veterans Administration in 1972. This initiative resulted in the *VA Hospital Building System.* (Fig. 6.5) The modular VA system sets forth strict disciplines to the horizontal and vertical

[17]Devereux R. 1962. "The Design of a Pharmaceutical Laboratory." IHBE Journal. May 1962. Pg.45

zoning of services as far as practicable. Later developments in a fully coordinated approach to the design of engineering services and their spatial enclosure by means of service floors appears in the *Good Samaritan Hospital* in Dayton Ohio by Richard Levin associates. (Fig.6.6)

As of 1986, some 70 hospitals have been designed world wide on the engineering floor sandwich principle.[18]

6.4.3. DEEP PLAN[19]

6.4.3.1.Description

The concept of Deep plan consists on the provision of large horizontal open areas of accommodation which will allow rooms to be organized and re-organized for a wide range of activities and functions in easier and less expensive fashion.

The idea of deep plan has its origins on the concept of "free plan" developed by Le Corbusier at the beginning of the century. Nevertheless this concept is conditioned here by a series of other factors that relate more to economical and technical considerations. In other words emphasis is made on the "deepness" rather than the accepted notion of the free uninterrupted plan. Thus the objective is to produce internal space that is consistent in terms of structure, form and services, and is uninterrupted as far as possible so that changes of use both in the long and short-term can be accommodated. Interestingly one could also say that the flexible

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[18] Alvarez, Angel G. 1989. Op. Cit..Chapter 7.p 213.

[19] For a more in depth description see: Building Design Partnership. 1978. *Nottinghams & Leeds Teaching Hospitals: Interstitial Space Research Study*. Preston, Lancashire, England. p.11

"Deep" space can constitute "Infill" while the "unique" elements correspond to the "Support."

6.4.3.2. Characteristics

The predictable but indeterminate growth and change of organizations is more easily accommodated in the deep\plan layout, particularly if it is associated with a *wide structural span* and minimum interference from columns.

The relatively low but deeply planned building form has evident economy of structure and fabric which will arise chiefly from the lower proportion of its external envelope to its total internal floor area. Since this ratio is lower than other less compact building forms, deep plan is also the most economic shape for an air-conditioned building.

Benefits derived from the low-rise condition of deep-plan buildings stem mostly from the avoidance of the problems that are typical of high-rises and by the easier to achieve *phasing of construction* Also horizontal movement of people and supplies has been shown to be more economical in time and cost than the alternative method of reliance on lifts in high-rises.

In attempting to provide a building which is structurally consistent throughout, and capable of housing a variety of different uses and accepting changes, *the structure* should be considered carefully. Economic considerations will usually require the structure to maximize its efficiency by using wide spans, minimum columns and regular structural bay sizes on a large scale.

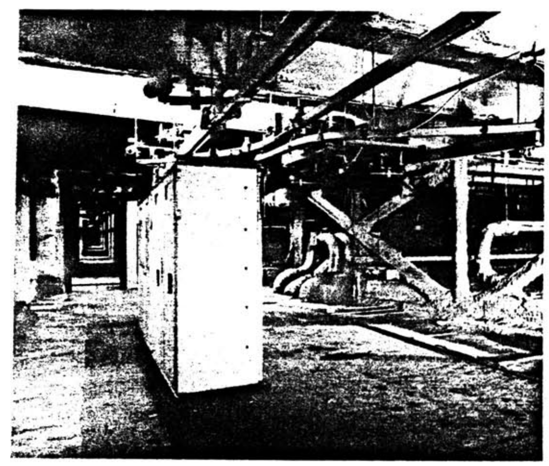
"Long-Span" structural frames add to the flexibility of a building. Since it is not the room size that determines the column spacing, but the rooms' relationships; thus, the flexibility of the room layout increases as the span increases.

One of the main characteristics of deep plan configurations is the *consistency of structure*. This condition refers to the following:

- *the structural grid* within the building is related to the planning module and planning grid.
- *the floor-to-floor ceiling height* is uniform throughout the building
- *a uniform floor loading* and allowance for services and partitions.

6.4.4. THE SERVICE FLOOR

As stated before, the implementation of interstitial service floors in HTBs responds mainly to the need for served spaces that are planned with in built flexibility for change and growth and servant spaces providing ease for alteration. (Fig. 6.7)



The use of interstitial service floors responds to the increased need to make spatial provision for the accommodation of services within the building, and the need to do it in such a way as to make the least obstruction to access to installation and maintenance personnel as well as the least disruption to users during changes or extensions to services.

The Interstitial Space concept is a recognition of the building fact that in Hospitals the services installation occupies more than 40% of the total building volume, that the cost of these services reach 50% of the building cost, and that they are to increase in quantity, complexity and cost with the new technologies. the total building volume given over to services in an interstitial space solution is 49% as compared to 43% in a conventional alternative.[20]

[20] Building Design Partnership. 1978. Op. Cit. pg.2 and 14.

As can be seen, the largest single cost is the mechanical system, the next is the electrical system, the third the structural system, the fourth the partitions and other interior items, and the fifth the exterior windows and walls.[21] The volume and nature of air-conditioning duct work is generally regarded as a justification for an interstitial floor solution. Since it is the most space consuming element, when adequate depth of the service floor is not available, it can impose severe restrictions on the distribution of other services.

Moreover, advancing technology and the client's requirements for the upgrading of environmental standards may involve the re-organization, replacement or installation of completely new service equipment. Due to the high costs involved in designing mechanical and electrical services, the ability to physically adjust to future changes is increased by increasing the degree to which the original mechanical and electrical systems and the structural frame can be retained during changes.

However the following restrictions have to be considered when designing a service floor configuration:
- Redundancy (waste of needed space)
- Height restrictions to required density.
- Difficulty to manage and control.
- Extra labor required construction and maintenance.

6.4.4.1. Description

Interstitial Serviced Floors is defined as ha *fully accessible, walk-through space at least 6'-6" in height beneath a framed floor structure and above the ceiling below, devoted to the distribution of all mechanical and electrical services, to feed up or down at any*

[21] See: Zeidler, E. H. 1974. Healing the Hospital. McMaster Health Science Centre: Its Conception and Evolution. Canada: Hunter Rose Company.p.11

point, reducing the need for access from (and consequent disruption to) the uninvolved occupied rooms below or above for purposes of alteration and repairs.[22]

The interstitial service floor carries all service distribution lines *horizontally*: It is the means of distributing services to the functional floors above and/or below it. Therefore it is provided between each floor. Mechanical services can include; air, electric power and wired communication, ventilation, plumbing and service piping, domestic cold and hot water, vacuum, high and low pressure compressed air, oxygen , nitrous oxide, nitrogen and natural gas systems, serving all areas that require them.

6.4.4.2. Characteristics,

Economy in the installation of services is accomplished with phasing and separation of trades. Services and installers can start work as soon as the basic building structure is erected and are able to perform their tasks independently of the finishing and fitting out trades in the user floors. Thus an earlier start with the installation of services is made possible.

This solution greatly minimizes the problems of vertical distribution systems where the intrusion of the rigid plan patterns of vertical ducts on each floor level inhibits the free organization of space and limits the flexibility of the service installation. The extended uniform horizontal areas of the service floors provide continuous and uninterrupted services for any point in the plan. This is justified by the variety of accommodation and high servicing requirements of complex buildings.

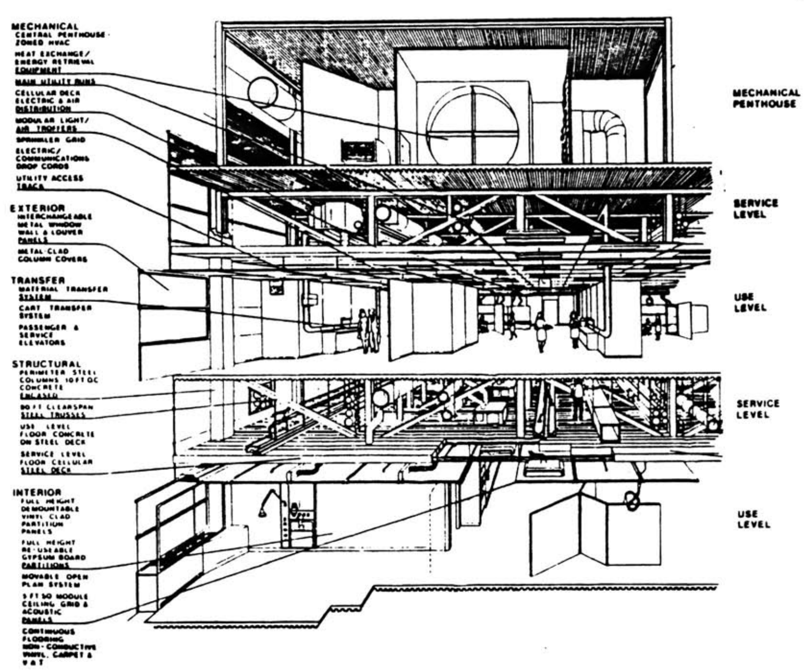
The services can be installed from above and below the serviced spaces. Maintenance is then simplified causing a minimum of

[22] Mathers & Haldenby. 1979. Interstitial Space in Health Facilities. Canada: Department of national Health & Welfare.Pg. 21

disruption or interference. The advantages of minimum disruption specially in areas of 24 hour operations, may play an important role than the facilitation of mayor internal change when considering the possibility of the service floor providing flexibility beyond which is really required.

6.4.4.3. Stratification of Services

The potential for flexibility in HTBs is much enhanced by the orderly stratification of the services within the serviced floor. This can be done according to type, and also facilitated by attributing hierarchy to elements within each type. They are divided into *permanent primary fixed elements* (that need never be changed), and *non-permanent secondary adaptable branches* (that are designed to be relocated or expanded). This organization allows for excellent access and room for extra services that might be required in the future. The most successful applications are those with a highly discipline and layout of M & E services.



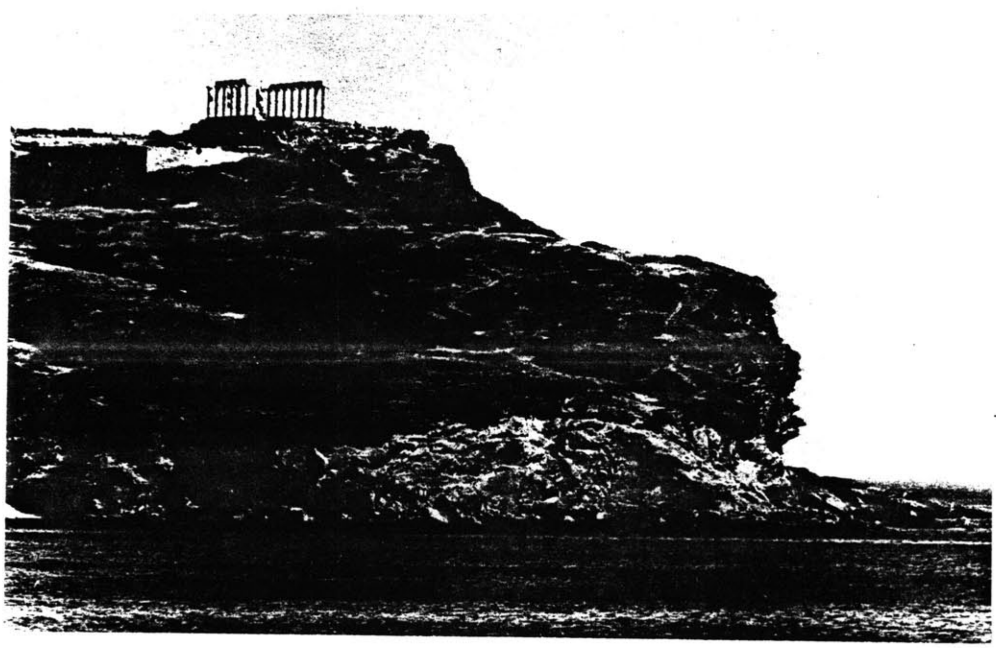
PART 4.

Chapter 7

PERMANENCE IN ARCHITECTURE

7.1. The Current Condition
7.1.1. Utility and Meaning.
7.1.2. Permanence and Change.

7.2. Permanence
7.2.1. Aging
7.2.2. Tectonic Authenticity
7.2.3. Surface Materials and Tectonic Expression
7.2.4. The Disjunction of Structure and Envelope
7.2.5. The Skin as Veneer.
7.2.6. Deceiving Use of Materials
7.2.7. Authenticity and Simulation



Chapter 7

7. PERMANENCE IN ARCHITECTURE

7.1. THE CURRENT CONDITION

7.1.1. Utility and Meaning.

During the 20th.. century, the way we value human-made objects has changed; buildings have acquired status of consumer goods and therefore are rapidly amortized, conveniently demolished and constantly replaced. They are becoming functionally obsolete before they physically deteriorate. This condition, has gradually changed the traditional role of "buildings" as generators of urban environments.

Continuous change and demolition has resulted from the constant loss of the buildings' capacity to be representative and meaningful to their users. The society in which we currently live, makes indeterminate not only the durability of our cities but also the possibility of establishing a permanent place within them.[1] In other words architectural artifacts (buildings) are being designed for limited life, as objects to be "consumed" instead of "used"by society. Therefore it is only in the destruction of the artifact, that it can then be replaced and consequently produced again.

If we observe the kind of constraints posed on Designers today, we can identify a growing tendency to support a "consumer" approach to architecture. However it seems contradictory and confusing that

[1]Frampton, Kenneth. 1982. *THE STATUS OF MAN AND THE STATUS OF HIS OBJECTS. A Reading of the Human Condition..* (Architectural Design, July 1982.)

it could become desirable for "useful" and "aesthetic" objects to turn obsolete almost with their creation. Our society seems to be getting intoxicated with the self-perpetuating cycle of consumption and production, leading to its incapacity to retain its own past. Moreover, its values have produced a split where the architectural meaning becomes separated from it's substance (Post-Modernism).

If we observe the consequences of this in the creation of our built environment we can understand that there is more to consider in building design than just responding to functional requirements or making a clear formal statement. It is not enough for a building to *be* something and *do* something; it must also *say* something. This task is also intrinsically related to the social and cultural conditions of a community. It has to do with the durability of Architecture and with the notion that what is specific of a building is its capacity to represent ideas more perhaps than its adaptation to specific functions.

With the recent evolution of HTBs, the increase in mechanical complexity has been balanced by the proportional loss of collective meaning (in a similar way as has happened with the evolution of our cities). The main approach has been to conceive HTBs as well serviced sheds. Most architects seem to have forgotten the connection between the mechanical, structural or process symbolism and the expression of social and cultural aspects. The notion that human created objects are rooted in time and place and that this in the case of HTBs, can also be included in the formal expression of new processes.

"We need to become emancipated from viewing form as merely a packaging device to cover structure or technology as some sort of Deus ex Machina for satisfying our whims."[2]

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[2]Dluhosch, Eric. *The Art and Science of Construction, Design and Built Form.* (Paper, MIT 1988)

7.1.2. Permanence and Change.

In Western consumer societies of today, the urban dweller feels lost in a confusing, anonymous, and ever changing environment and experiences the anguish of not being able to recognize a permanent place within it. On the other hand he also sees the possibilities of personal development being restricted by the rigid physical structures that shelter every day life. Hence an adequate response to this twofold condition is a "permanent" built environment that can constantly accept change.

Consequently, the pursuit of permanence in buildings (or, in other words, the struggle against obsolescence) appears as a fundamental design objective conditioning buildings not only to function adequately but also to respond to those requirements that will guarantee their permanence. HTBs, as stated before, because of a combination of their flexible character and their growing importance in the city are prone to be affected by this phenomenon. Hence, when designing HTBs for the future, architects place themselves in a delicate situation. In the case that they are designed as purely instrumental, they will be destroyed by obsolescence, however, if they also respond to so called "useless" requirements (aesthetic, artistic, etc.) they will have a better chance of permanence as tools and *signum* at the same time.

However constant change will probably identify the behavior of the urban dweller in the next century and therefore he will require his buildings to be flexible and adaptable. HTBs, because of their nature, are affected more than any other building type by specific and changing functional performance requirements, and consequently they have to be able to change constantly. However, the results of this approach will also threaten the existence of characteristics of a balanced built environment that have to do with permanence, symbols and collective meaning.

In building design it has been traditionally understood that beyond the satisfaction of "objective" and changing needs lay a vast area of metaphor and poetry that has to do with the permanent condition of buildings. It is the architect, through his control of form, who is specially suited to provide for this condition. The form making role of the Architect can therefore seen as directly increasing the well being of the user through the mediation of artistic creation. This attitude is compatible with the approach where it is the user who plays the active role in the building while the Architects role is to provide the framework that allows the user to choose his own behavior. The well being of the user is a result of his spontaneous activity made possible by the permanent framework of forms imposed on his environment by the Architect.

It is important to explore alternatives dealing with the obsolescence phenomenon and how it affects artifacts of our culture through pursuing the accomplishment of an ideal Architecture, *as that built environment which responds to human requirements in a harmonious way, over time*. The problem of dealing with the increasingly shorter life span of our buildings as they become obsolete, is a crucial one to address not only regarding the production of better HTBs but also in relation to the survival of the meaningful characteristics of the built environment as we know it today. The HTBs of the future, besides other characteristics, will then have to respond to both of these issues; constant change and permanence, possibly through specialized flexible environments coordinated with more generic, permanent, and meaningful built forms.

7.2. PERMANENCE

The present condition of an edifice which stands by itself at a distance in order to remain indifferent from the all encompassing influence of the existing temporal conditions, has been frequently frustrated by the effects of needed variations.

Both possibilities seem in todays conditions to be impossible to meet. The capturing of the ephemeral, the immediate response to the requirements of the moment and in the other hand the longed for objective of approaching the eternal, going beyond the material and its consequent order, itself beyond grasp of the model, and gain the ideal conditions of the Archetype.[3]

Hence in the design of HTBs we are presented today with two contradictions; on one hand, architectural works have to be *unique*, they are compelled to display innovation overcoming tradition, and, at the same time, having to show themselves as being recognizable and *repeatable.*

There is also a contradiction in the extreme *fragility* or neutrality expressed by most HTBs when contrasted with the pursued abstract configuration of a *firm*, definite architecture indifferent to change.

Throughout history, man has always demonstrated a special interest and concern for the durability of material and their resulting relationship to the permanence of their artifacts. The ability of the materials to withstand the destructive forces of both men and nature was was constantly evaluated and looked for.

Talbot Hamlin in his book *Forms and Functions of Twentieth century Architecture* (1952) cited three factors he felt should be

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[3] Franco Purini(1984) in his essay: *The Solitude of the Master Who Desires no Followers.* Francesco Dal Co & Giuseppe Mazzariol, 1984. CARLO SCARPA, The Complete Works. Electa/Rizzoli.

simultaneously present during the building design process. First was what he called *FEASIBILITY*, or the consideration of the functional aspects of a building. The second was *PERMANENCE*. Structures not only had to be solid but also give a sense of solidity (this idea was in opposition with the modern notion of the temporary building that denied its mass). The third requirement was *BEAUTY* in the sense of a coherent *Meaningful* pattern of forms that rendered a building pleasing to the eye.

Today we value the quality of the materials that compose our built environment mainly by their superficial or visual characteristics. For the user the beauty of modern construction materials is just skin deep, making this skin become more important than never before. In the past, the "permanence" of built form depended on the performance characteristics of the materials themselves as well as on the character of the building as perceived by the individual.

With advances in modern fabrication techniques we are now not only able to create materials which are more efficient, more economically produced, and potentially more durable than ever before, but we have also achieved a new understanding of the nature of building materials.

7.2.1. Aging

Today's consumer society puts ever more emphasis on the ability of building surface materials or skins to retain their superficial qualities over time so as to make disappear all evidence of aging and wear. This however does not imply that the same emphasis is given to the building as a whole. As has already been stated: quite the contrary is true; buildings are being ever more considered as consumer goods and will preferably be replaced rather than preserved.

Today people place a great value in the ability of materials to retain their appearance, to withstand decay, wear, and environmental abuse. Buildings are supposed to look as though they have been built with materials that will not only be durable but will also maintain their appearance over time. In other words the creation of an "ageless" image: an image unaffected by the time or environment. The "natural" condition or image which will honestly reflect the aging of materials is no longer commonly acceptable.

This has been made possible by advances in technology which have made a new image of permanence accessible to the public. This does not mean that building materials no longer age; they do, however they can now be wrapped with an impervious, permanent-looking membrane. The beholder is then led to believe that the exterior appearance of a building is authentic to its tectonic reality, but in fact they are quite different.

This "membrane of technology" has divorced us from contact with natural materials, textures and the aging process. The surface of the built environment is no longer answerable to time, wear, or aging. And , we expect this to be so. In an effort to preserve the original appearance of the visible world, we find ourselves desperately wrapping technology over all surfaces -from our buildings to our bodies.[4]

Before the industrial revolution, and its already described effects on the development of architecture, expressions of wear in buildings were understood to be a natural part of the ageing process. Moreover, buildings which showed their wear acquired an irreplaceable value to the community, who understood these imperfections to be a symbol of the maturity and the heritage of the built environment. The surface of these buildings is uniquely authentic, and therefore can give us a sense of our history, our cultural heritage, and the built environment in which we live.

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4 DeMaio,1989. Ernest Vincent. *Surfaces*, MIT Thesis. p.72

Conversely, today, consumer society tends to measure the quality of materials by their ability to withstand aging and wear; the building's surface is then regarded as representative of the quality of the object or material.

Ancient buildings such as the ruins of classic temples or Gothic cathedrals, express a powerful image of solidity and permanence, regardless of the fact that their materials show their age and wear over time. The simple, classical house, the temple, and the cathedral, have indestructible value because they communicate the thoughts and feelings of the people who built them. Such masterpieces are the precious inheritance of society. (Fig. 7.1&7.2)

Paradoxically, as a consequence of the same forces that permit more durable materials, building skins have become more temporary than ever before. Materials are being considered more common or temporary as a result of being industrially produced. It has become less important, to preserve modern building materials because they can be efficiently and cheaply replaced or modified. Western consumer society simply replaces materials which show their age or wear. Attempts to recycle or repair are no longer made. Materials become visually and functionally obsolete long before they actually "wear out." Although surfacing materials retain their surface appearance for longer periods of time, they are removed and replaced by the consumer society more rapidly than ever before.

Therefore the proliferation and availability of building materials, as influenced by technology, has devaluated its importance. In doing so, technology has increased the likelihood of change of the building as a whole - rendering the environment to be less permanent.

7.2.2. Tectonic Authenticity

Permanence in the built environment can then be understood in two different ways. On one hand it can be seen either as the physical durability of the whole building or, on the other hand, that of the materials with which the building is built. Moreover, durability as related to permanence can be understood as either the capacity to physically last "long periods of time" as well as the resulting "long life" of a building, not necessarily because it has been built to resist physical obsolescence, but because it has been preserved by several generations of a culture.

Only when man is capable of recognizing his environment as true to him as his own, and of identifying himself with it completely, will he also be willing to preserve it, in all its complexity.[5]

Tectonics in architecture is defined as *"the science and art of construction, both in the relation to use and artistic design."* It refers not just to the "activity the materially requisite construction that answers certain needs, but rather to the to the activity that raises this construction to an art form." It is concerned with the modeling of material to bring it into presence from the physical into the metaphysical. By doing this , tectonics begins to speak of a poetic of construction.[6]

The premise here is that building "permanence" will be dependent not only in the building's physical and visual integrity or in its capacity to be visually representative of the culture, but rather from its capacity to authentically express the *tectonic* conditions of its making. This in turn has to do with the semantic properties of the buildings aesthetic qualities put forth through its exterior "surfaces." The degree to which these surfaces will be faithful to

[5]Wachsman, Konrad. 1961. THE TURNING POINT OF BUILDING: Reinhold Pub. Corp.,N.Y. 1961

[6] See: Maulden, Robert (1986). *TECTONICS IN ARCHITECTURE: From the Physical to the Meta-Physical.* MIT Thesis. Cambridge Ma.

the material and structural characteristics of the building, has become ever more difficult today with the separation of the buildings structural and aesthetic systems and the capacity of variable surface representation made possible by technological development.

7.2.3. Surface Materials and Tectonic Expression

Today "permanence" of our built environment is strongly influenced by the "appearance" of envelope or skin materials, and not necessarily to the character or substance of the building itself.

The building's envelope has always been an element of visual expression. As an essential component of the "facade," enclosure materials they have been traditionally used as a medium to express the cultural and aesthetic values of the society which creates them. In pre-renaissance architecture it was possible to identify the construction methods and levels of craftsmanship which were used to craft buildings through an observation of the building's exterior appearance.

The construction methods, materials, structural principles and the basic craftsmanship used in the creation of a Gothic cathedral are made evident to the observer in the external expression of the building. We have come to understand that the materials employed in these buildings were not only carefully crafted by talented artisans through years of hard work, but that they are also responsive to the structural principles of the buildings' elements.

These buildings express an aesthetic which is consistent with the inherent structural characteristics of the materials being used and which compose the building's image. In other words they clearly express their tectonic reality and use it as a prime source of representation. However this does not mean that in the past, building materials were not used solely for aesthetic purposes.

7.2.4. The Disjunction of Structure and Envelope

Until the late nineteenth century, building materials had mostly been used to perform both structural and aesthetic functions. As a result of this co-existence between a material's aesthetic and structural qualities, architects were forced to consider both of these characteristics when employing them. Even if the purpose of the material was that of decoration it was supposed to support its own dead load; ornament performed a structural role even if the only loads supported were their own

Most of the construction materials such as wood, brick or stone were processed in their fabrication so as to be able to express their inherent structural qualities, rarely being produced so as to be employed exclusively as a "veneer." Even in the event that facades were built as a combination ornamental facades placed over "load bearing" walls such as stucco over masonry; the facade was still technically considered as a load-bearing element. In most cases the decorative motives that were added on expressed the structural characteristics of both the building material and the building as a whole.

As mentioned before, (Chapter 1) several buildings of the nineteenth century, changed the way Architects conceptualized the constructive aspects of their buildings. Among these were: the Crystal Palace designed and conceived by Sir Joseph Paxton in 1851 for the Worlds Fair in London, and the Chicago Frame Skyscraper as a building type.

As described previously, the physical and conceptual changes in building construction at that time were greatly influenced by emerging technologies; as a result of innovations and refinements to existing fabrication processes, particularly in the fabrication of iron and steel structural components.

Essential to the design concept of the Crystal Palace was the notion that the building's structural system (the cast iron frame) and the "closure" or Skin of the building (the glazing) were in fact, two entirely separate systems. With the modern iron and steel frames now providing structural support for buildings, the sense of "permanence" and "materiality" which characterized buildings of earlier eras was now replaced by structures and surfaces which aspired to "weightlessness" and "insubstantiality."

With iron-framed buildings the responsibility of surface materials to perform both structural and visual roles was no longer required. Materials could then be valued as possessing either structural and/or aesthetic qualities.

There are two important implications produced here:

1) The surface materials were no longer responsible for supporting significant structural loads.

2) Materials were now segregated into one of two categories;
   -materials that performed exclusively structural functions.
   -materials that performed exclusively aesthetic function.

The separation of the buildings skin from its structure had a far-reaching impact upon the values and understanding of people who interacted with these artifacts. Observers of this new generation of buildings could no longer look at a building and know precisely if the surface materials were, in fact, the materials that maintained the structural integrity of the building. A critical "point of reference" had been striped away from the observer of the building.

Konrad Wachsman (1960) had predicted some of the consequences of this phenomenon in the characteristics of the building that were to come in our time.

The idea of a building as a solid structural mass will gradually give away to the idea of combinations of functions and individual elements. The design will be dominated by the vertical and horizontal stratification of surfaces, conceived as planes of movement; at the same time these surfaces will establish the porous character of the building mass, enclosed by functional elements rather than solid walls. [7]

He explained how the load bearing elements of the building would retreat further and further into its interior spaces. The concepts of mass facade and monumentality would be automatically suppressed and the gleaming exterior surfaces of a building would no longer reflect the structural system, in the sense of "form following function." These surfaces would not be considered facades, since they would have nothing to do with the structure; they would be hung from the building independently, with the sole function of providing shelter.

7.2.5. The Skin as Veneer.[8]

Structural frames were also instrumental in creating "finish" materials that can also be seen to correspond to the notion of *veneer*. The term 'veneer" has the character of something that conceals with an attractive but superficial appearance. Their superficial quality implies that they must be applied over other materials.

"Superficial" can be understood as:
... being concerned with or comprehending only what is apparent or obvious; shallow; trivial; insignificant. ... apparent rather than actual or substantial."

As we will see, the building materials that make up the skin of many of our present buildings have become finish surfaces or

[7]Wachsman, Konrad. 1961.Op.Cit. p.231

[8] See: DeMaio,1989. Ernest Vincent. *Surfaces*, MIT Thesis,p.76 .

"veneers" therefore "superficial"; concealing that which is substantial to the being of the building.

The relationship between the building's structural frame and the veneers used to craft its exterior image was first addressed in the "skyscrapers" that resulted from the development of the "Chicago Frame." In these buildings exterior materials were used in a primarily non-structural fashion. Glass metal and brick, the materials chosen for the buildings' skin conformed a decorative enclosure secured to a structural frame. The role of the brick was closer to that of "decoration" than that of "structure." As mentioned earlier, these decorative skins hung from the structural frame were to evolve into the modern concept of "curtain walls."

One might then classify the steel-framed building with a brick facade as a "simulation" of a brick building, and not as a brick building in the truest sense of the definition. The function of brick veneers is then to deceive the viewer into believing that the building is, in fact, a "solid-brick building," and not a "brick-cladded building." The disjunction between a buildings skin and structure represented a turning point in the history and future of our built environment. An interesting consequence is that with the separation of the buildings structure from its surfaces, the function of the Architect and the Engineer have also become more and more separate.

Value was then placed upon reducing the weight of the skin materials that hung from the frame. This was most effectively accomplished by "thinning" all surface materials to their most minimal dimension. This new conceptualization of the building suggested that the structural frame be made as simple and as efficient as possible. Ultimately, however, more significant improvements to the structural potential of the building frame were found in the refinement of the building's *cladding system.*

7.2.6. Deceiving Use of Materials

Before the use of structural frames, stone was used in buildings as a material possessing great weight, strength and perceived economic status. Today they are exclusively used as superficial veneers. Marble sheets are precisely trimmed and sliced by computerized saws, and held in place with concealed structural frames. The ability to manufacture very thin stone tiles has allowed the material to be used in a way that defies the traditional way these materials were used in the past. This also ignores the natural structural characteristics inherent in the material.

It could then be stated that the visual role being asked these building materials and their combinations to assume contradict its tectonic characteristics. A structurally enhanced marble veneer assembly can be led to represent massive stone columns when installed. Therefore by enhancing the structural characteristics of these materials we are, in effect, deceiving the viewer; who is led to believe the surfaces presented to him are not only naturally and aesthetically pleasing, but also naturally and structurally sound.

7.2.7. Authenticity and Simulation

Stone temples of the classical era derived much of their presence and sense of permanence from the fact that their beholders understood them to be made of solid stone. The great weight and mass of these temples played a key role in the understanding and aesthetic value which was placed in these structures. The building's sense of permanence strongly relied on the firmness and solidity of the buildings' tectonic quality; clearly expressed in the building's exterior expression. However we must realize that ornament was also inspired in material constructive patterns that corresponded to different, usually passed realities. (Fig.7.3)

Today we are many times led to believe that contemporary buildings are finely-crafted artifacts of heavy, natural stone, homogeneous glass prisms and the like. Instead, this impression is produced by surfaces that are simply lightweight "curtains" decorating steel or concrete frames. Questions should then be raised about the value and authenticity of building surfaces which are in essence, merely "images" of stone, glass or aluminum buildings.

When veneer materials are manufactured from synthetic materials in an effort to depict or simulate natural materials, the conflict between using "authentic" building materials and "simulated" building materials becomes very confusing. Even though the concept of using one material to simulate another is not a new one; this process has escalated today to include every conceivable surface material.

In the past, the "authenticity" of buildings and materials referred not only to the "look" of the building or material, but also to the way these materials were crafted and the method by which they were assembled. The buildings in which this relation has been made explicit have been preserved through the ages to testify their condition today.

But how does authenticity and simulation of materials and processes relate to the permanent traits of buildings ?

Although we accept simulated materials as a new type of surface, society holds no lasting value or reverence for them. We would not think twice of demolishing a hollow card-board column; false images have little lasting value to us. An authentic marble column, however, would evoke a far different response: a desire to preserve, to restore, or to relocate. This can be said to happen because people understand that the visual value of the material is not the only criteria for the assessment of its cultural value.

Importance is also given to the building material's history and the craftsmanship involved in its making. These qualities today have to be made apparent to us through other mediums than just the visual and tactile characteristics of the material.

The use of these false independent building skins, so as to fix a thin, impervious, "membrane" of technology over the exteriors of the buildings, contributes to the creation of a built environment which is separated from its heritage and from reality itself, hence assisting to its temporary character. Consumer society seems to attach true value to the creation of effective simulations of materials and buildings, instead of the creation of "authentic" artifacts .The superficiality and deception evident in our built environment is only a reflection of our current changing values and priorities.

Our society uses technology to remove all evidence of aging, wear, or environmental abuse from the built environment. In doing so, we are further separating ourselves from the realities of nature, space and time. By continuing the trend of indifference toward natural materials and attempting to preserve false surface images, we have regrettably chosen to ignore the substance of our reality, denying our own condition of mortality and place within an evolving world.

But regardless of how perfect an image technology may create, it will always remain an image, and not the substance, of the "real" condition. However we have grown accustomed to the fact that it is often the things which are not immediately apparent which are, in the end, substantial and meaningful. The degree in which the visible enclosure of a building represents false images intended to deceive the beholder, instead of providing clues to the understanding of its meaningful characteristics, will influence the way the artifact as a whole will be valued and eventually preserved or destroyed.

Chapter 8

DESIGN FOR PERMANENCE

In the work of Carlo Scarpa
"Beauty"
the first sense
Art
the first word
Then Wonder
Then the inner realization of "Form"
the sense of the wholeness of inseparable elements.
Design consults Nature
to give presence to the elements.
A work of art makes manifest the wholeness of "Form"
the symphony of the selected shapes of the elements.

In the elements
the joint inspires ornament, its celebration.
The detail is the adoration of Nature.

Louis I. Kahn

Chapter 8

8. DESIGN FOR PERMANENCE

8.1. Introduction

We have previously explored design strategies as well as concrete examples relating to the provision of flexibility in HTBs. Also, the lack of response of High Tech architecture to the notion of permanence has been exemplified in the analysis of obsolescence in High Tech buildings.

What has been proposed here is the resurfacing of an architectural trait which we have grown with and has long been forgotten by most designers: the struggle for permanence of human created objects. In the process of adapting this struggle to the requirements of the coming twenty first century our intention is to revive it as an unescapable condition of great architecture.

We have already attempted a description of the forces that appear to lie behind the need for permanence in architecture as well as the historical background that has made them come forth. In doing so we have referred to the current condition of the built environment with specific reference to the capacity of permanent frameworks to express certain values as well as to suggest clues for the understanding of the tectonic reality of the building.

The general problem of permanence has been studied so that through its understanding we are able to identify patterns to follow in order to be able to formulate design strategies for the design of permanent frameworks (supports) for HTBs. This chapter is concerned with identifying these patterns and showing how they can be understood as intrinsic components of the strategies for permanence and change that have hereto been mentioned, namely the Support-Infill Approach.

However, the accomplishment of permanence in architecture is a more obscure or "wicked" problem to address. Only the passage of time can fully and truthfully demonstrate if a building has achieved such quality. Nevertheless we must not confuse the meaning of "permanent" architecture with a "durable" architecture.

In the history of civilization there are many great works of architecture where these conditions have been accomplished. These could range from Stonehenge to the chapel of Ronchamp passing through the Parthenon or the great Gothic Cathedrals. We can also explore how this condition has been present in the work of specific architects, again, ranging from Phidias to Le Corbusier, passing through Alberti, or Bruneleschi. However the task of listing such great works escapes the objectives that have been put forth here. HTBs are a recent Phenomenon in the History of architecture and their maturity is still yet to be accomplished. Therefore if our objective is to identify possible strategies for incorporating a "permanent" character to HTBs we must necessarily look at more recent models so as to extract from them repeatable patterns.

Nevertheless, it has become difficult to find representative architecture or architects within the High Tech movement that could exemplify the notion of permanence pursued here. It is not difficult to find within this context very different architects that have dealt, either through their designs or philosophy, with architecture as a medium for the creation of more permanent and meaningful environments. In the second half of the 20th. century, architects such as Frank Lloyd Wright, Louis Kahn , Carlo Scarpa, Luis Barragan, Paolo Soleri, and many others have made important contributions to the notion of transcendence in contemporary architecture, both through their works as well as through their discourse in writings and teachings. The philosophies and the works of Louis Kahn and Carlo Scarpa will be developed in some detail in the present thesis.

8.2. The Teachings of Louis Kahn and Carlo Scarpa

It is not the intention here to embark in any sort of analysis of their work but more specifically to refer to them only to the extent that they exemplify or illustrate concepts that have been recognized to pertain directly to permanence and transcendence in Architecture.

"Kahn has shown how to put to creative use what the mind can know, and has understood and written about the process of formulation more directly and humanly than any other contemporary architect."[1]

The work of Carlo Scarpa presents Architects with relevant teachings, and the lessons they offer lie in his construction of a coherent, tenacious language by using a vocabulary with profound and ancient roots.[2]

Throughout his life as an architect and a teacher, Kahn was able to communicate the basic concepts of his design philosophy. However, to be able to fully understand Khan's design philosophy requires a mayor intellectual effort. Scarpa, on the other hand, and also a teacher, was not fond of writting and his discourse has mainly been formulated in lectures.

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[1] Scully, Vincent (1962), LOUIS I. KAHN: George Brazillier Inc. N.Y. NY USA.

[2] Francesco Dal Co & Giuseppe Mazzariol, 1984. CARLO SCARPA, The Complete Works. Electa/Rizzoli.

What it is said in this thesis about the two masters relies mostly on personal observations of their work, referenced of course to the scholarly research about their work done by authors such as Francesco Dal Co and Alexandra Tyng.

The work of Carlo Scarpa and Louis Kahn are considered here in most of their realizations as carriers of a "monumental condition," in the sense that they have achieved, before their deaths, the ability to infuse their buildings with a transcendental quality. Their work is considered to be traditional and contemporary at the same time. They have perceived and respected the language of materials and that of the elements of nature while at the same time making meaningful cultural statements.

Scarpa and Kahn both seemed to respond to the notion of the existence of a powerful involuntary collective soul that they could share through the spaces they created. They believed in a similar sense of the eternal, responding to an a-temporal condition, in a way synthesizing in their work the primitive and the yet to come.

that In most of the realizations of both in Scarpa and Kahn we find that a certain archetypical level has been achieved, in the sense that they seem to be *alive*, because they evoke a *timeless character* and they *reveal the truth of their making*. Some of their buildings are infused with that life and therefore have acquired a *monumentality* that makes the observer certain of their permanent condition and their transcendental fate.

The Architecture of our century has embodied a conflict between two opposed tensions that in their strength have left a mark in the production of our built environment. This plot, addressed here as the simultaneous response to change and permanence, has in many cases been identified with a quest for the absolute —an attempt to interiorize the ordinary as well as to embody the course of history.

All this superimposed with an ambition to achieve eternity, to transcend the human. The work of Kahn and Scarpa share a desire to capture generic principles, the imperturbability of an Archetypical condition.

Franco Purini in his essay "The Solitude of a Master Who Desires No Followers" compares both Architects (Scarpa and Kahn) at the light of this two-fold quest of contemporary Architecture:

"Scarpa, one of the few Architects to have consciously eluded this division producing dialectic, has directly and deliberately proposed an idea of time as remote, unchanging by its very nature and not by its effect. For this very reason his work is clearly different from that "historicizing a-temporality" evoked, for instance, and much more noisily by Louis Kahn, a more conscious interpreter of dynamic immobility."

Scarpa and Kahn were split between a dialectic that dominated the architectural discourse of their time---the struggle between Beaux Arts and Modernism. Both had to struggle against falling into the sides. Both in Kahn and Scarpa we distinguish this dialectic force always present in their approach to design. In their work this subjacent structure is always present in different forms such as in the permanent and the changing, the measurable and the unmeasurable or as Kahn called it; *Silence in Light.*

They seem to agree at the end that an important aspect of a great Architecture of Transcendence is its permanence and that this permanence is solely achieved in the meaningfulness of the building for its culture, in the telling of the story.

In their work, poetry, wether understood as words, objects, or a way of existence, constituted the essential instrument with which to explore the hidden mysteries of present and past artifacts. They seemed to accumulate knowledge of their environment through the reading of a language full of history and traditions and using this knowledge as a basis for the development of a language of their own.

Both Masters also shared a simultaneous passion for the natural and technological qualities of materials and their processes, as well as for the poetic/artistic process by which architecture combines them to achieve permanence. Scarpa writes the following in the letter of the Venetian Architects (May 1931)

".. Great Art was created only when spiritual and imaginative elements appeared in it —the irrational, which constitutes its inspired, creative function..."
"It is precisely through this spiritual element, that animates brute matter that the future work of art will spontaneously enter into the sensibility of the forms of the spirit......"

8.2.1. Common Design Patterns

The following patterns are characteristics that have been observed in the work of Louis Kahn and Carlo Scarpa and are thought to have consciously or unconsciously contributed to their architectural production.

1. *The use of **Archetypical forms**:*
    - *A sense of the eternal: The design process as a discovery of the beginnings and as a synthesis of the Primitive and that which is yet to come,*
    - *The observation of the ancient Ruins as a form of enlightenment.*
2. *The consistent use of **strong geometrical configurations**.*
3. *The honest **expression of the tectonic reality** of the building.*
    - *The Detail as Ornament*

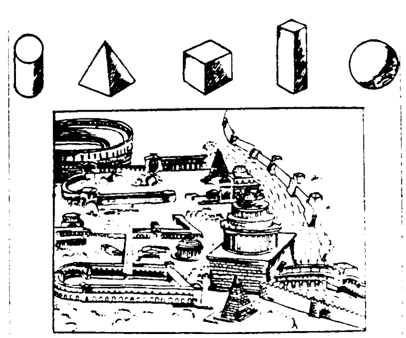
8.2.1.2. Form, Order and Design

Early on Kahn developed his own concept of FORM as that "inspired dream," the ideal of what a program "wants to be". FORM is immaterial, the beginning, the result of an ability to grasp fundamental configurations and ORDER. Consequently Form goes beyond mere function it is conceived order, therefore existing as a concept.

Form is then that stage at which a certain formal configuration is pictured as intangible abstractions rather than any measurable state. Being intangible, the FORM of a building is not affected by superficial architectural changes hence remaining TIMELESS.

What Kahn calls DESIGN, on the other hand, is completely tangible, a building with dimensions, style, and structure. It is the result of the FORM being tailored to fit specific requirements, it is through *design* that *form* is made material. Order in this process acts as a catalyst helping the form archetype become a design reality, hence achieving its most important goal; to express the buildings original form essence. Kahn believed this archetypical condition is what would give the building a permanent transcendental character.

8.2.1.3. Archetypes



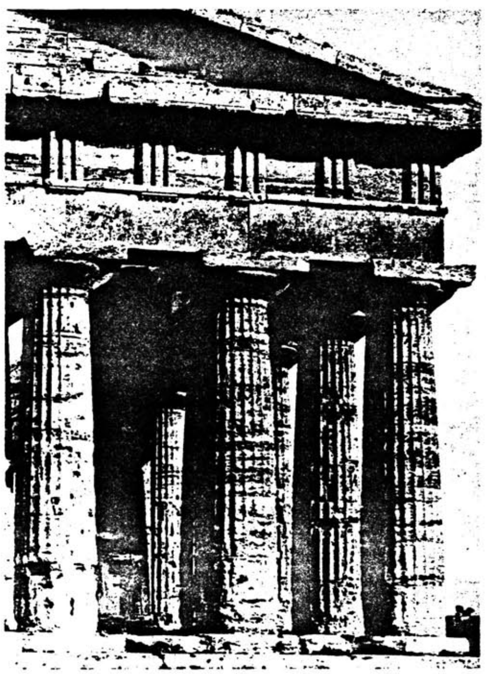
Archetypes can be understood as pre-existent stored patterns which feed from both individual experiences as well as the "collective memory". Without this presence, variations and transformations executed by the users have nothing to stand upon, no beginning and therefore can not last.

As psychological structures, archetypes have been considered as that model or first form that originate at deep levels of unconsciousness. As more than abstractions, they underlie tangible images that are so primitive, they can not be described. (However they may be understood through abstract structural forms such as the square, circle or the triangle.) (Fig.8.1)

To Kahn archetypes seemed to be *the unconscious reference to the formal configurations that lie deep in the collective soul shared by all human beings.*

All human beings regardless of their race, culture or personal background have the same ability to perceive life's experiences in reference to these meaningful structures.

8.2.1.4. The Ruin



The use of the concept of ruin in the design of permanent supports responds to our will to explore complex manifestations of our humanity.

The architecture of ancient monumental ruins could be said to have those conditions of longer permanence. Not only have these buildings resisted aging for many years but they have also been preserved because of their meaningful presence. The elements that are left to compose their forms are usually few and of universal significance. They usually have a strong relationship to the site and are composed of noble and long-lasting materials. Their forms reveal the basic tectonic principles of their origin as well as the compromise between the ecosystem and culture of the region. Their basic configurations do not accept modifications, can not be moved and do not impose specific or rigid functions. They are easily used and can be completely recycled. Their character is primitive not in the sense of being inferior but as that which existed first or could begin to exist for the first time.[3] (Fig.8.2)

Louis Kahn was known to be strongly drawn to the observation and analysis of Greek and Roman ruins. The knowledge that Kahn seemed to observe in Ruins was an attestation of the primitive.[4]

...the notion that the mysteries behind meaningful artifacts both present and past can be revealed through the observation of their ruin ....

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3 Luna, Pablo: DESIGNING FOR PERMANENCE, Convergence of Ruin and High Tech. Article in *Metamorphosis* Vol 1, 1989 (MIT, Cambridge MA, USA.)

4 See: Scully, Vincent (1962), LOUIS I. KAHN: George Brazillier Inc. N.Y. NY USA.

For Kahn, the ruin is capable of revealing not only the HOW these buildings where made but also WHAT made them be. It is what has been left over, that which suggests a final shape only to be completed in the mind of the observer. It is the state of built form where the artifacts lay open unashamed to tell the story of their making.

In his project for the U.S. Consulate in Luanda, Kahn tries to recreate the idea of a ruin wrapped around a building.

"..So therefore I thought of the beauty of ruins ...the absence of frames...... of things which nothing lives behind .... and so I thought of wrapping ruins around buildings""[5]

In his design for the Salk Institute in La Joya, California (1962-64), we are confronted with the direct application of the concepts of "Served and servant Spaces" but most of all we encounter the consideration of what he calls "Ruin." He used this same idea in his early designs of the Salk Institute Lecture Halls were the "Ruins" become self supporting square shells wrapped around circular buildings, and vice versa. Buildings for living surrounded by buildings for the sun. (Fig 8.3)

In this project, Kahn had began to consider the life-giving relationship between STRUCTURE and LIGHT and connected them to the concept of RUIN. His design depended on natural light to enhance its structure represented as support ruin. The openings on the walls could then give definition and life to the spaces behind. This section of the Salk Institute has not been built to date.

In this solution Kahn finds the connection between the desirable quality of light and the provision of meaningful cultural patterns.

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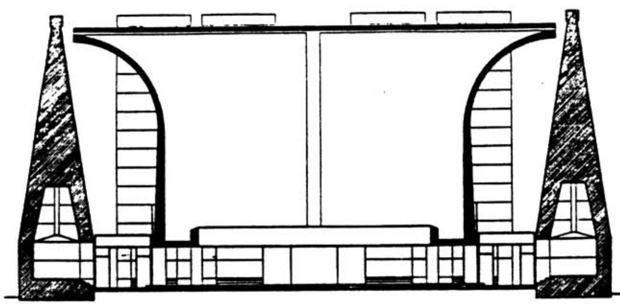
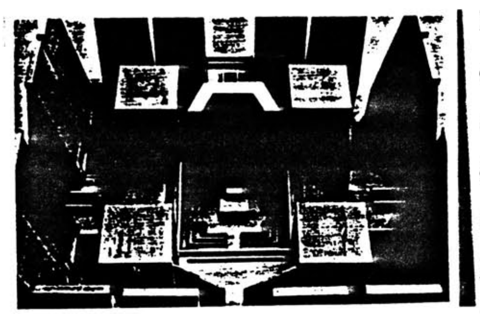
[5]Louis Kahn in Perspecta 7

However, he fails to connect the gesture with the tectonic reality of the building, appearing the "ruin" merely as a double facade. The incorporation of this relationship that Kahn called the *measurable* rational and technical requirements of the building and their clear expression would originate what could be called the archetypical support configuration of a building.



In the project for the Hurva Synagogue in Jerusalem (1969) — "Hurva" is the Hebrew word for ruin.— Kahn explained that he attempted to use light almost as a building material. For this he allowed existing ruins to remain and proposed the new temple beside them. The external walls were to be made of a material that would acknowledge the history of its surroundings. The rough textured walls and the simple geometry he proposed for the Hurva synagogue suggest a "Timelessness" that links the structure to the primitive fragments around it.(Fig.8.3)



Kahn had realized the connection that existed between the provision of a *ruin type configuration* in a building and the freedom from the servitude of performing the practical functions for which it was designed.(Infill) It also meant independence to express the support's spirit of "Form Essence." What he had really discovered was the life that could be given to a building through the action of separating the permanent meaningful configurations from the functional changing spaces, in a way a similar to the "Support Infill Approach".

"By juxtapositioning the old and the new, Kahn was saying that the significance of the ruin is not it's age, but the sense of silence that it evokes"[6]

Actually, Kahn also linked the Ruin with his concept of *Silence*. This was the word he used to describe the eternal quality in a great

[6] Alexandra Tyng in "BEGINNINGS, Louis I. Kahn's Philosophy of Architecture."John Wiley & Sons NY, NY (198?)

work of art that is recognized by all human beings. By observing the remains of a great building we can *feel* what Kahn means by Silence; *when a building is a ruin its spirit as in the beginning is again free to emerge.*

The notion of the ruin as form of enlightenment can also be found to be present in the life and work of Carlo Scarpa in the Venetian context.

According Francesco Dal Co (1984), these places for Scarpa *mark the periods of an existence directed towards celebrating the values of a certain intelligence of the past and search in these signs for the messages of the future.*

The Architecture of Carlo Scarpa calls for an interpretation of that which in the process of decanting the future into the richness of the past, is deposited and endures in experience.

This condition encouraged the creation of a unique vocabulary that Scarpa developed in his works, which would remain unaffected by the passing of time. His works would many times resemble ingenious experiments with constructional techniques. Even though they innovated they were also informed by the awareness of ancient traditions and building examples. His works, however, can not be considered fragments of History or of the future but, as in Kahn's, they are the remains of a solitary quest into the primitive.

8.2.1.5. The Use of Strong Geometrical Configurations.

Both Kahn and Scarpa as well as Wright began revealing their real contribution to the architecture of our time when clear geometric order was again being considered as correct. Consequently their projects of the time can all be seen to respond to, or include, clear geometrical patterns.

Throughout Kahn's architectural production it is difficult not to find a project that responded to strong geometrical patterns or archetypical configurations. Specially after the 1960s his works seemed as if they were developed within a framework of strong geometrical traces that gave dimension and location to pure geometrical objects containing habitable spaces.(Fig.8.4)

Rigid geometrical volumes are used in his buildings as an approach to the permanent qualities of the archetypical solids. The simplicity of understanding that these buildings evoke has led for them to be considered as permanent manifestations of culture. Their honest configurations have to do with the *silence* the ruin evokes.

" By SILENCE I don't mean quiet -but in the sense Malraux calls his book "Silence"... he means only the feelings you get when you pass the pyramids, you feel they want to tell you... not HOW they were made , but what made them BE, which means what was the force that caused them to be made ...... these are the voices of silence."

L.Kahn

Scarpa made use of geometrical configurations in a completely different way. He understood geometry as that form of knowledge that recognizes order as decisive in the process of making matter manifest, as *cosmos emerging from chaos* to provide meaning and purpose to his architecture.

We must not confuse this notion with what has been traditionally understood as geometrical "order" as referred to classical patterns. Scarpa seemed to reject any type of stylistic standardization, and certainly did not believe in any return to a classical type of architectural order.

Many examples can be found of this in Scarpa's architecture. However a characteristic item of his architecture that well illustrates this point is the consistent use he made of a denticulate moulding as a decorative feature that is also given specific functions of structural and compositional nature. (Fig. 8.5)

This geometrical pattern could be linked to similar forms found in Greek architraves, primitive Indian temples or textile blocks used by Wright. It is worked out through a combination of materials and it's main purpose appears to be to punctuate or articulate compositional decisions, to emphasize profiles or juxtaposed materials. In other words a figure that expresses an *edge* condition both between different material conditions and the matter and non-matter. (Fig. 8.6)

"The idea of measure immediately involves the idea of geometry, not because every measure is essentially geometrical; it is clear that here it is a question of a geometry understood first in the symbolic and initiatory sense, of which profane geometry is merely a degenerate vestige, a vestige devoid of the deep significance that it had originally." [7]

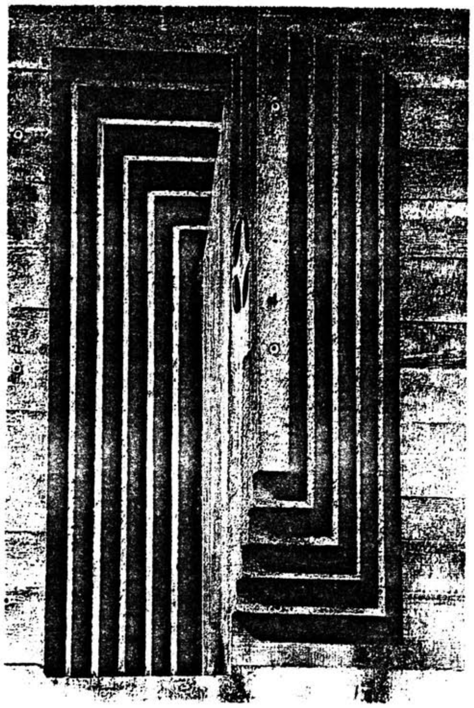
Scarpa:
"..from the appearance of the earliest ornamental pattern" we get the feeling that man is putting order into things."

Scarpa sensed the deep bonds between ornament and geometrical order, and so it was to this that he linked his own composition.

It is in the design of the Brion Family Cemetery at San Vito d'Attivole, near Treviso in Italy, that Scarpa achieves what many consider his masterwork. This project can be said to reflect the principal aspects of his architectural discourse. In the cemetery Scarpa makes use of a code made more complex by the refusal of the ornament to equate utility and significance. According to Dal Co (1984) it is the dialectic between order and disorder implicit in Scarpa's negation of order and rejection of style which is the soul of Scarpa's montages.(Fig.8.8)

Francesco Dal Co says the following about the cemetery:
"This work processes a strict inner coherency and intense evocativeness; yet at the same time it emphasizes the characteristic features of Scarpa's compositional procedures of which it describes, if anything, the extreme limit"

[7]Rene Guenon in " La Regne de la Quantite et Les Signes des Temps"



The need to control this dialectic by formal means is then betrayed by the sign of the boundary, THE EDGE. As will be described later on, here the figure of an edge is essential to achieve emphasis and balance in the details and bring out their richness." (Fig.8.9)

In the Brion cemetery, more than any other of his works, this figure seems to be the medium through which the building is connected to it's surrounding non material universe. The foot print of a transcendental world sculpted by man and materialized in water and air. Scarpa seems to complete his buildings with the participation of the void, the non material--in this case air, the sky. This condition allows for the play and the interaction with light.

8.2.1.6. Tectonic Authenticity

Kahn like Scarpa believed that materials should be used in the way their properties suggested (as first elaborated by Choisy and revised by others), and spoke reverently of the "existence wills" of concrete and brick. Such belief was made magical in the works of Scarpa and Kahn. In the authentic expression of the building's Tectonic qualities Scarpa and Kahn coincide in their design approach.

Vincent Scully (1962) argues that there is a connection between the Choisy structural axonometrics which Kahn studied, and Kahn's approach to building system design. This can be seen in the precast concrete construction of some of his buildings. (Fig. 8.10, 8.11)

Kahn's buildings are exactly what they seem. They express the process of their making. They seem to come alive within this notion, in the complementing of the non rational artistic claims with the rational intentions of technology and so expressing to the beholder the power of the truth.

On the other hand, Scarpa intends to bring together science, technique, and experience in his work. *His buildings want to be moments of life contributing to history in their making.*

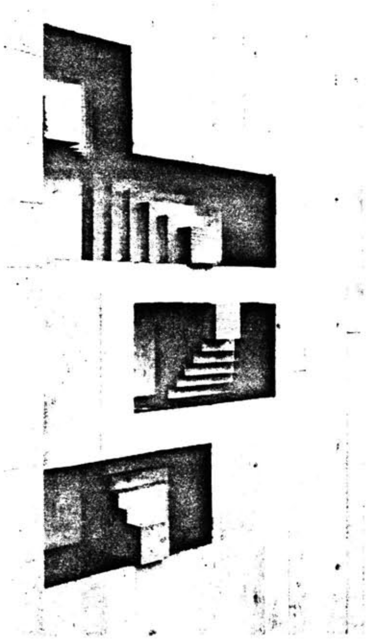
As mentioned before, Scarpa's formal culture was derived from observation; a sensitivity sustained by a careful study and analysis of materials. This eventually lead to the tectonic skill Scarpa expressed in his later works.

Any description of Scarpa's work deals necessarily with the the history of materials and the workmanship of a culture. The materials, and the use he makes of them are telling the TRUTH. In this way he achieved a further analogy between the changingness of nature and the mutability of art. He said his art was *"To give presence to the elements"*

Scarpa's quest for authenticity in his designs has two facets. One has to do with expressing the eternal and fragile corruptibility of materials that are destined to perish; the ephemeral quality of architectural artifacts. Hence his creations are left to interact with the natural environment and show their age and their wear.

The other facet has to do with the value of human artistic activity and the quest that stems from it. The work aimed in the direction of expressing material and manual truth.[8] Therefore the real nature of materials, their structural properties and the process of their assembly are merged with the telling of the story of the craftsmanship in their making. (Fig.8.12)

[8]See, Francesco Dal Co & Giuseppe Mazzariol, Electa/Rizzoli, 1984 CARLO SCARPA, The Complete Works



8.2.1.7. The Detail as Ornament

The significance of ornament reappears when matter ceases to be conceived as "utilizable." Before it becomes a "means" , "material" appears through its ornaments, i.e. through its own "measures."

Both Kahn and Scarpa related the concept of ornament directly to the expression of the tectonic reality of their constructs.

Louis Kahn wrote:
"..ornament would grow out of our love for the expression of method."

"The detail is the adoration of nature" .

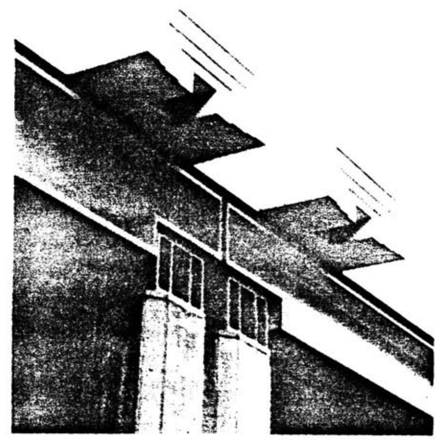
By this adoration we can interpret a respectful understanding of natures own *cognitive and creative powers.*

In Scarpa we can find the same approach to detail as expressed by Kahn. Scarpa transformed the dialogue with the old into a process of abstraction that guarantees the freshness of his tectonic inventions. This attitude necessarily brings about an increasing concern with detail. In his details Scarpa emphasized the materiality of the system.

Both masters came to conclude that it is in the detail that the history of the materials and that of the place come together. Thus the detail becomes *"The sign of the fundamental materiality of history."* We are then led to believe that in our quest for permanence, the notion of detail as ornament encompasses the patterns of tectonic expression and the sense of the eternal in the re-creation of the ruin.

This is reflected in the way the fragments of his buildings display their desire for incompleteness. The fragments of his designs seem to reinvent ancient meanings which grow from deep cultural roots. This will to go beyond functionality in the expressive quality of his designs, and is best reflected in the importance he gave to the design of details.

"Scarpa's details struggle against the banalization use imposes on architectural invention. The reduction of form to mere expression of function , to mere "washability" .... is rejected ..."[9]



At the same time he used his details as a medium to stimulate and educate the internal procedures of the materials and technologies as well as the form of *work* evoked in his designs. In this respect the use he makes of materials is aimed not just at displaying intrinsic formal qualities of his designs but also at combining both the evocative use of materials with their tectonic function. (Fig.8.13)

Good examples are the columns and structural joints in the Bank in Verona where his tectonic sensitivity is well expressed evoking archetypical images of the underlying structural configuration. Also, the circular apertures often seen in his projects are a good example of how, as the detail/ornament grew more complex, it acquired life of its own.

Scarpa's ornamentation transcends the mere functionalist approach where the value of ornament is seen as subordinated by technology in response to stylistic intentions, production processes or functional requirements. They evoke ancient cultural roots in their authenticity to the point that some of his designs seem to be justified and resolved by their manifestation.

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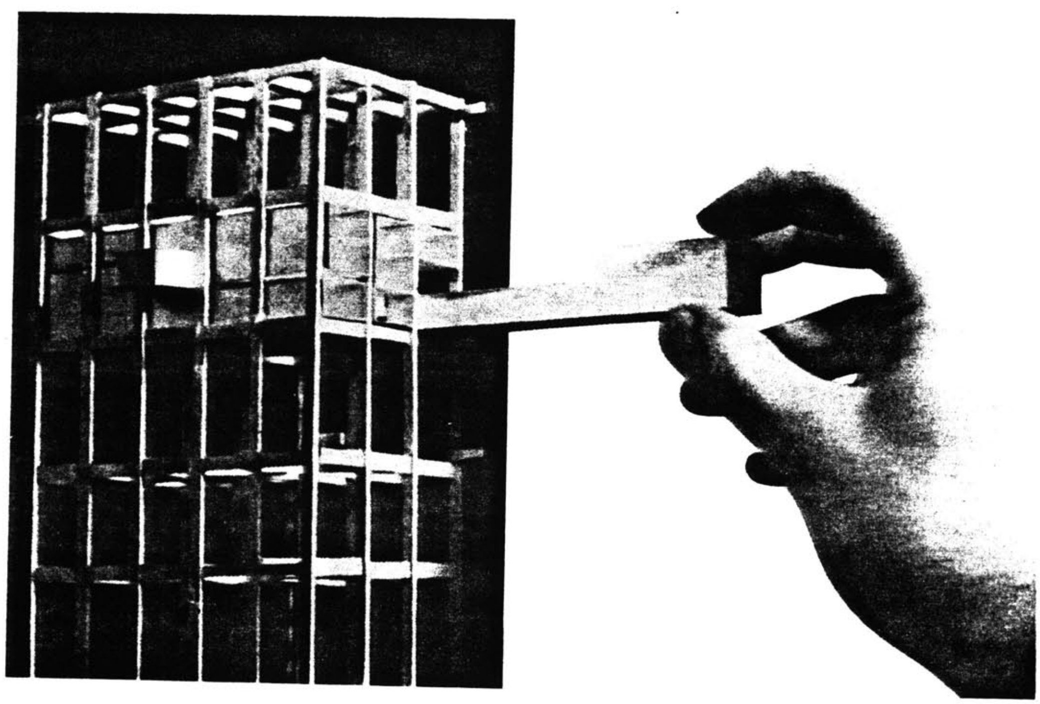
[9]Francesco Dal Co (1984) in his essay: *THE ARCHITECTURE OF CARLO SCARPA*, Francesco Dal Co & Giuseppe Mazzariol, in CARLO SCARPA, The Complete Works, Electa/Rizzoli.

PART 5.

Chapter 9

THE SUPPORT INFILL APPROACH



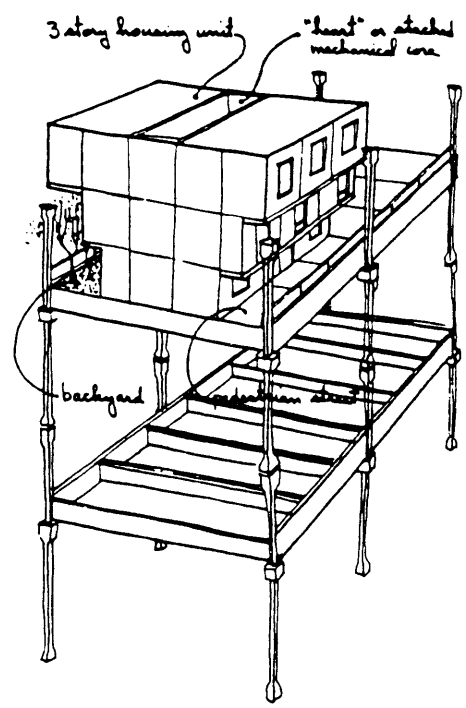
Chapter 9

THE SUPPORT INFILL APPROACH

9.1 Introduction

9.1.1 The Support-Infill Concept

The basic idea of the Support Infill approach to building design, as described previously, consists basically on conceiving the building as a coordinated integration of permanent and changeable parts. In other words the building is divided into frame components or "Supports" with long life characteristics and detachable units or "Infill" which are short-lived and easily replaceable.



The Support Infill concept embraces the belief that changes are facilitated by the clear distinction between the permanent and non-permanent elements. The permanent elements form the fixed framework of the building; the "Support", that usually remains unaltered during its total life. It basically includes the structure, and the main configurative aspects of the overall building, (Structural framework, walls, floors, roofs, interstitial spaces, etc.).The non-permanent elements are those that serve only special functions and that would have to be disposed of should the use of a space change. These could, to a certain degree, include the mechanical , envelope and interior systems.

However the notion of Support Infill is much broader than the formal situation just described. It is also a comprehensive way of looking at the whole design process, including its decision-making hierarchy, by providing conceptual and technical guidelines for the analysis, evaluation, and the generating of variety in design. It is not a methodology that favors "unique" solutions to the problems of flexible design in buildings, nor is it one that will automatically generate "all the answers". The Support Infill concept can then also be considered as a *means* by which change over time and variety in space come to be built into the design process as *potential* ingredients and as *technical* means to assure the practical realization of user-generated solutions.[2]

9.2. HISTORICAL BACKGROUND

Even though other theoretical and practical strategies that have dealt with the problem of permanence and change in buildings have been explained, their fundamental propositions come together in the the Support Infill concept. There has not been to date a more all encompassing concept for dealing with the problem of growth and change.

The origins of this mode of thought could be extensively traced to many different historical sources since it could be said to belong to the whole history of architecture. The Support Infill approach constitutes a fusion of several different trends. Nevertheless the description of certain precedents have to be made in order for the concept to be made clear.

At a formal level the superimposition of two structural orders has been present since Post-Renaissance architecture; while at the level of social content, its development can be found within the Modern

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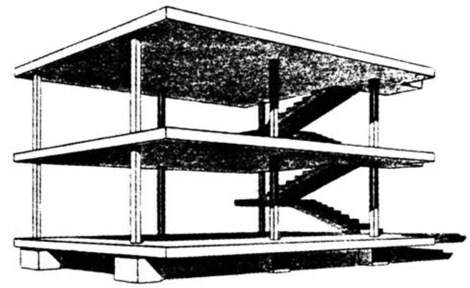
[2] See: Dluhosch, Eric (1978) *THE SUPPORT-INFILL CONCEPT AS A METHODOLOGY FOR USER PARTICIPATION IN MASS HOUSING PROJECTS*, Published in:*Programming for User Needs: Approaches for Improving Man Made Environments.* Wolfgang F.E. Preiser Ph.D., Editor. 1978.p. 105

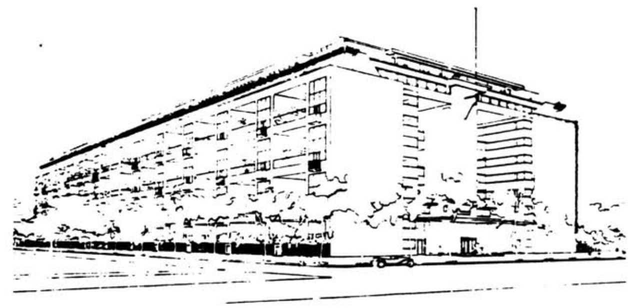
Movement, especially in Le Corbusier. and his early considerations for flexibility and economy.



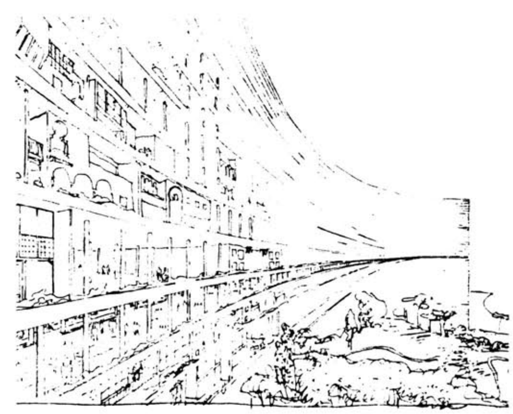
The first example of this notion in the work of Le Corbusier can be seen in his Dom-ino Housing scheme (1914) (Fig. 9.1). he developed this project as a quick and inexpensive means of rebuilding the devastated towns and villages of Flanders. He described it as follows:

"So we designed a structural system a frame completely independent of the functions of the plan of the house, this frame simply supports the flooring and the staircase. It is made of standard elements that can be fitted together, thus permitting a great diversity in the growing of the houses.... At the request of the town-planner or customer, such frames, oriented and grouped, can be delivered by a manufacturer anywhere in the country.

It then remained to fit up a home inside these frames... We conceived the idea of a f..rnts an affiliate of the first, which would sell all the elements required to equip the house, everything, that is, that can be manufactured, mass-produced in standard sizes and meet the various needs of rational installation: windows, doors, standard casings serving as cupboards and forming part of the dividing walls...Since the Dom-ino framework bore the loads; the walls and partitions could be made of any material."



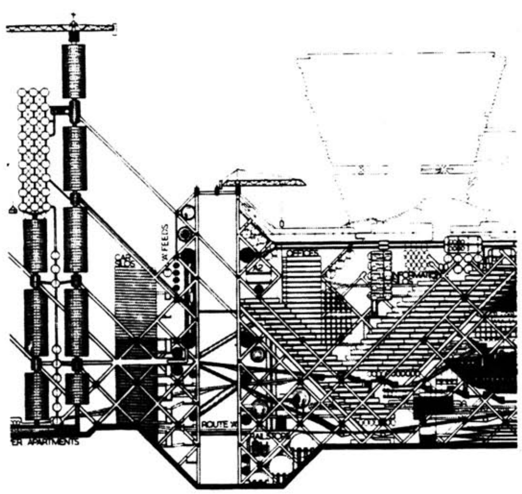
In Le Corbusier's Dom-ino system we can find the first traces of the notion of the structural and mechanical support that allows the flexible free plan concept. The Dom-ino system was, one of the first housing schemes which from the outset was designed in the broadest perspective of architecture and future conditions.



Additional projects designed by Le Corbusier also included the notion of architecture as a combination of permanent and changeable elements that could open the way for a new "modern" way of life. Such examples can be found in his "Immeubles-Villas"(1922) (Fig. 9.2) as an early expression of his idea of the "unité d'habitation" (1944) (Fig.9.3) or his project for the coast of Algiers (1930). Here he proposes a continuous building that acts as a framework for the self construction and design of the dwelling units by the users. (Fig.9.4)

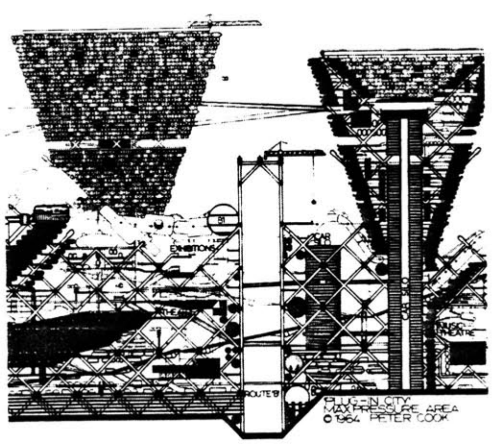
However, of the many developments that originated from the Modern Movement, the one that best reflects the Support-Infill notion of the built environment was the Megastructure Movement of the 1960s.

9.2.1. Megastructure:



Megastructure is defined by Reyner Banham as "a permanent and dominating frame containing subordinate and transient accommodations."[3] He also identifies two further ingredients: different rates of obsolescence in the different scales of structure and the notions of flexibility, change, and feedback. He traces the development of the movement in the work of several other architecture movements: the Japanese Metabolists, the French Urbanisme Spatial group, the Italian Citta-territorio group, and the British Archigram.(Fig.9.5 & 9.6)

Alan Colquhoun in his essay *Frames to Frameworks* makes a distinction between two types of megastructures: those in which the support structure is merely a sort of neutral grid, like the projects of Yona Friedman or Mies van der Rohe's "Universal Space"and those in which the support structure is monumentalized, as with the Metabolists .[4]



The main objective pursued by the Megastructure Movement of the 60's was to find a way to evade the typical problems of the

[3] Banham, Reyner. 1976, *Megastructures of the recent Past* (New York: Harper and Row, Icon Editions) p.9.

[4]Alan Colquhoun 1977. *"Frames to Frameworks"* Essay published in: *Essays in Architectural Criticism*, Oppositions Books. The MIT Press, Cambridge MA and London England. 1981, p.120

Megalopolis by integrating in one structural whole all the diversity of functions necessary for full urban life. Architects then would design gigantic structural skeletons which reflected their independence from the characteristics of the natural environment. They were covered by an exterior skin that was usually composed of private habitable spaces and would shelter giant common precincts for human interaction. These structures, theoretically, could be localized over the city, in the country side, over the ocean, in outer space or even move about the landscape.

The system, very conditioned to requirements of adaptability and flexibility is mainly made up of long life-cycle elements (the skeleton) and and short life-cycle elements (the infill). The permanent framework besides being the structural support, would shelter the service networks as well as allow for the "clipping-on" of smaller structural units built elsewhere.

The fundamental differences between these principles and the "Support-Infill" adaptation proposed in this thesis are based on the following:

- First, the same design concepts are applied to the design of a single building and not a whole urban environment.

- Second, during the 80's, the present and future human requirements in relation to the built environment are very different from the visions of the 50's and 60's.

9.2.2. The S.A.R. Experience

As was already mentioned in the previous Chapter the Support Infill approach to Building design was first made explicit in the theory of *Supports* developed since 1961 when N.J. Habraken published his book; "Supports , An Alternative to Mass Housing." Here he suggested the idea of forming housing infrastructures, or "Supports," constructed as permanent frameworks into which prefabricated elements where placed to form houses tailored to individual needs.

It was also explained how in 1965 Habraken and the Stichtin Architecten Research (SAR) from Holland proposed a method for the design of adaptable dwellings by means of "Supports" and "Detachable Units". The method, is designed to help designers provide maximum flexibility and variability by giving the occupants an opportunity to participate in the design of their dwellings.

The research had its origins in the 60's within a highly centralized organization of the housing industry. As in many countries, government subsidies and standards made possible the testing ground for the mass production of housing and a desire for industrialization.

Initially, the S.A.R methodology for the systematic design of supports was developed as a response to increasing criticism in Holland and other countries in Europe concerning the overwhelming blandness and monotony of many of the mass housing projects that had sprung-up all over the world.[5]

SAR was an effort to overcome the problem of the widening gap between the results of mass housing and the espectations of the architects. It investigated alternative ways to use the potential of industrial production to overcome the quantitative problems of housing in a way that would also enhance the quality of life.

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[5] See: Habraken N. John: SUPPORTS, An Alternative to Mass Housing. (Architectural Press,1972).

The uniformity and monotony was defended as necessary cost that had to be paid to achieve a more efficient production. Nevertheless industrialized systems did not seem to be competitive with traditional building methods. Hence, based on the principle of *user participation and user control* the idea of *supports* and *detachable units* arose.

9.3. Basic Concepts

9.3.1. The Need to Incorporate the User

Traditional design practices have proved to be incapable of solving the problem of functional obsolescence in the design of buildings that are required to be flexible, adaptable and have the potential for variability. Even though a given building or project may have been built following the rigorous application of performance specifications, considerations of social utility are often overridden by other imperatives—such as tradition, material selection, structural considerations, profit maximization, production flow, etc..However, only by including the user in the process of decision making can technology be "controlled," and be put to use as an effective means for achieving more flexible as well as permanent environments.

With the complexity that has become characteristic of current HTBs, users have been partially left out of the decision making process; not only because of the user's incapacity to comprehend the workings of his complex built environment but also because he is limited to do so by complex systems that do not allow further levels of user control. People should be able to identify with the spaces and systems around them. The functions of different parts should be understandable and combine into a coherent whole. The environment and systems should provide and impart a sense of human scale and comfort. However the possibility can be opened for be users to be able to not only participate in the design but also by directly participating in the selection, installation, modification and control of all infill components.

The concept of industrialized building and prefabrication has been frequently misunderstood and badly implemented, leading people to blame it for architectural miss-matches such as monotony. None the less it can be argued that it is the design process itself, when excluding the participation of the user that is mostly responsible for these problems such as monotony and repetition.

When the user gets involved in this process, personal decisions can be taken with relation to the immediate built environment, the formulation of desires, the freedom for expressing identity over possessions. Freedom to accommodate space to personal needs, to expand and reduce, in short; more importance is given to building as an impulse that prefers the act to the final product.

The unsolved problem then turns into *where to draw the line*, and how do you identify the limits to the roles of the different participants in the building process; the questions of who makes decisions when, where, and why. Undoubtedly the level of participation of a user in a HTB will be much more limited than for the average dweller.

9.3.2. The Task of the Designer

There is a misconception based on the belief that a more selective application of professional power to building design would end up diminishing the task of the designer. The contrary is actually the case. The design of user-responsive and user-participatory environment requires more effort, is more difficult, and carries a *greater* responsibility than design for a single client or an "average" user.[6]

Therefore a whole new approach to the traditional way of dealing with the problem is needed in order to incorporate aspects as "user participation" into the design process while also addressing the issues of Variability, Adaptability and Flexibility. A distinction has to be made between user "participation" an "control".

In designing supports it is necessary to examine:
- Who decides what.
- Who participates.
- Who has control.

The "Support-Infill" approach has demonstrated the validity of new design solutions that include both Rationalized Systems and User Participation, as technically feasible and economically viable. Moreover, ecxperiences in mostly housing have made possible a new attitude of the designer who has to learn to combine the many physical constraints of industrialization, prefabrication and system building with these new methods to provide for adaptability, variability and change in participation with the user.

9.3.3. The Need for a Methodology

Thus the Support Infill approach was also developed as a response to the need for a method that would allow for the accommodation of change in the future including the participation of the user. As stated before, the preoccupation with questions of flexibility, variability, and adaptability is a result of this requirement to design

[6] See: Dluhosch, Eric (1978) Op.Cit.p. 92

for both a "determinate" present and the "indeterminate," open future.

Such methodology.. *should be able to communicate value statements in terms of a conceptual and technical articulation of general system of environmental "supports" in a design-usable language, while at the same time provide a method for defining the limits imposed by the underlying agreements on future change. In other words, the methodology has to reflect the best criteria distilled from the present, while at the same time provide a clear operational structure to accommodate future change.*[7]

Therefore the understanding of the whole design production process becomes very important. Emphasis is made in testing the capacity of both technology and "Architectural Space" to accept a given range of design *variations*, which respond to clearly defined parameters of performance requirements.

Therefore the first task of a useful methodology for design decisions making must be to **provide a framework of reference** for decisions made on the collective level on the one hand and those made on the private-individual level on the other hand. If this is not done , the professional will inevitably end up imposing an environment on the user that may not be adequate and that almost inevitably end up resisting change.

9.4 The Support Infill Approach to the Design of HTBs[8]

The following conceptual framework for the design of supports for HTBs has been produced from a reformulation of the method developed by S.A.R. for the systematic design of Supports in housing. This thesis is an effort to consider the use of similar design principles also for the design of building types such as

[7]Dluhosch, Eric (1978) Ibid..p. 89

offices, hospitals, factories, and other HTBs. According to the problems that have been previously identified regarding the design of HTBs, this method could be considered as a starting point for the accomplishment of better results, in relation to the issues of permanence and change.

This reformulation can then be used as a framework for the design of Supports for HTBs. As stated previously, the original conceptual framework put forth by S.A.R., was originated and intended to relate to the design of housing schemes. However the S.A.R. method also makes explicit the fact that the generic principles that stand behind their methodological elaborations can, and should, be applied to the design of supports for other building types.[9]

For the purpose of this reformulation, some modifications have had to be made to some terms coined by S.A.R.. In order to integrate these ideas with the main discourse of this thesis, it has been necessary to accommodate certain generic principles stated in their book:

VARIATIONS THE SYSTEMATIC DESIGN OF SUPPORTS
by N. J. Habraken, J. T. Boekholt, A. P. Thijssen, P. J. M. Dinjens
The Laboratory of Architecture and Planning at MIT
The MIT Press, Cambridge MA, 1976.

Habraken's group makes specific reference to the fact that a "detachable unit " is not the same as an "Infill component" as it has been translated here. They also emphasize that "Support" does not mean "structural framework," which is also one of the

[9] N. J. Habraken, J. T. Boekholt, A. P. Thijssen, P. J. M. Dinjens. 1976. *VARIATIONS : The Systematic Design of Supports*. The Laboratory of Architecture and Planning at MIT: The MIT Press, Cambridge MA.p.15

configurations that are included in this work within the notion of support as permanent frameworks of buildings. However these adaptations, as others that will not be made explicit, do not in any manner contradict or restrict the original notions stated by S.A.R.

9.4.1. Support and Infill Units

"A support involves those decisions over which the community has control. The detachable unit is that area over which the individual decides."[10]

The term *Detachable Unit* coined by S.A.R. is hereto considered, for the purpose of this analysis, as equivalent to "Infill Unit". Hence the difference in meaning of support and Infill point to a difference in *control*; in decision making power.

Supposedly, the user is able to decide when and where the Infill Unit (not as structural element) should be located. If the unit were to be removed the structure should not collapse. The Infill Unit will be non-load bearing components attached to the support. The support will be a complete structure in itself. However the building is completed only when the Infill Unit has been placed in the Support.

The Support is a structure that is designed and built in a specific place. Therefore, it may very well be a traditional structure, but could just as easily be the result of an industrialized system.
It is considered here as the "permanent framework" of a building, intended to provide general order and meaning to the building. It will also provide the basic needs to sustain, to bear and to preserve the visual and structural integrity of the whole.

Infill in turn, is considered the body of flexible and adaptable parts and systems that are needed to make a support suitable for human habitation. Infill Units and Systems are to be ultimately controlled by the building's user.

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[10] N. J. Habraken,et. al , 1976. Ibid p. 21

Infill Units, should be adaptable, capable of being used in many different combinations or different support structures. An Infill Unit can thus be considered a *consumer durable* and as such it is very well suited for mass production.

The concept of *Spatial Unit* is hereto introduced as that habitable space composed of both general and special purpose spaces, that can function independently to other building units within the building. Examples of this can be laboratories in a research complex, a patient care unit in a hospital or a dwelling in a housing project.

Different criteria can be considered in order to determine which part of the *Spatial Unit* should be considered as the Infill Unit and which part as a support? Within a social criteria this depends on a question about *control*.. (What decisions should the user make for him or herself?)

This method mainly concerns itself with technical design problems, but concurrently, we are also dealing with a social problem. Hence, where Infill Units begin and Support ends must have different answers in different cultural and temporal settings. This means that the methodological analysis is *generic* in its structure, but *specific* to each particular context.

In order for the user to get the greatest possible freedom to make decisions, the mayor consideration is given to the design of a **set of rules** governing possible **variations.** These should be simple enough for the user to be able to visualize all the possible options for change available to him. This must be kept in mind in the design of supports and Infill Units. Also distinction has to be made clear regarding the nature of the building type. i.e. there is a difference between the "cellular" and "case" patterns in dwellings and office buildings respectively.

9.4.2. Support Design

The design of supports can be also considered a matter of *optimization*. Generally speaking, the best and most economical solution will be the one in which the only variable elements are those that, at some time in the future, will require adaptation. On the one hand with too few variable changes: the support will not be able to accommodate change. In the other hand if too is much made variable : money and effort will be wasted in providing possibilities that will never be utilized.

"A skeletal structure offers many possible variations in layout. However this type of support would require many Detachable Units causing problems with the heat and sound insulation, and also making it hard for the resident to identify with the open spaces within the skeleton. Such spaces do not immediately suggest a variety of possibilities."[11]

The best support is probably one that is neutral in it's spatial suggestions. However, as stated before, it is known that maximum flexibility does not lead to the best solutions. therefore the support that offers specific kinds of space, which can be recognized, and evokes many different possibilities will be more successful.

In other words, in designing a support, the objective is to find a solution that allows for all the desired possibilities of change while using as few Infill Units as possible. For this reason the support will generally be more than an empty framework, just as it is more than a mere skeleton. It can then be considered as an architectural product that will always represent a certain life style.

[11] N. J. Habraken,et. al , 1976. Ibid. Pg. 21

However, in previous chapters, we have been able to identify certain patterns in the change and growth of buildings, as well as design strategies that can adequately respond to flexibility and variability. These considerations have to be taken into account in the process of support design.

9.4.2.1. The Nature of Change[12]

Reasons for the need of buildings to change and growth have been outlined in previous chapters. The consideration of New technological or economic possibilities will always be crucial. We must not also forget that the main reason for the need of flexible buildings is change in the composition of the user group or organization, may this be a research team, office pool, or a family. However it can be useful to bring to the forefront additional relevant causes for the need of flexible environments in which the participation and control of the user is preferred.

However the need for user identification has proved to be a major cause for change in dwellings and in the future could potentially affect HTBs. People want to recognize themselves and to be recognized. The need for identification is a very basic need that has tended to be rejected in our 'functional' age. Buildings, and specially homes have always been used as a means of self expression. In the case of HTBs this results in the struggle between the "institutional" or "organizational" image versus the "employe" or "self-image" of the users. Technically it has to do with *control* of the selection, replacement, maintenance and operation of the Infill Units and its related systems. Changing life styles, caused by the contact with other cultures, new ideas about mankind and society

[12] Refer to Chapter 5: Growth and Change in HTBs.

and the *availability of technology* will also result in adaptations and obsolescence.

Increased affluence has placed a higher demand on the provision of services. Wealth has consequences not only in the acceptable levels of services, it also contributes to the desire for change. The high profitability of the high tech industry; not only has consequences on the level of provision of services but also contributes to the desire for change.

Moreover, it has been shown how systems fall into obsolescence at different periods of the buildings life-cycle. For example; exterior finishes will not last as long as the basic concrete structure. As replacement or improvement is always very expensive, therefore they should be designed with their easy removal in mind, in the first place.

9.4.2.2. Basic Principles

Three principles for the design of supports:[13]

1. Each unit in the support must allow for a number of different layouts.
   (when designing supports for HTBs different repetitive space types or "units" should be defined.)

2. It must be possible to change the floor area.
   - additional construction
   - changing boundaries of units within the support

3. Supports or part of the supports have to be adaptable to other functions different from the original ones.

Not every support will have to satisfy this criteria. The relevant criteria will have to be determined according to the particular situation.

[13] N. J. Habraken,et. al , 1976. Op. Cit. p. 45

9.4.2.3. Evaluation and Coordination

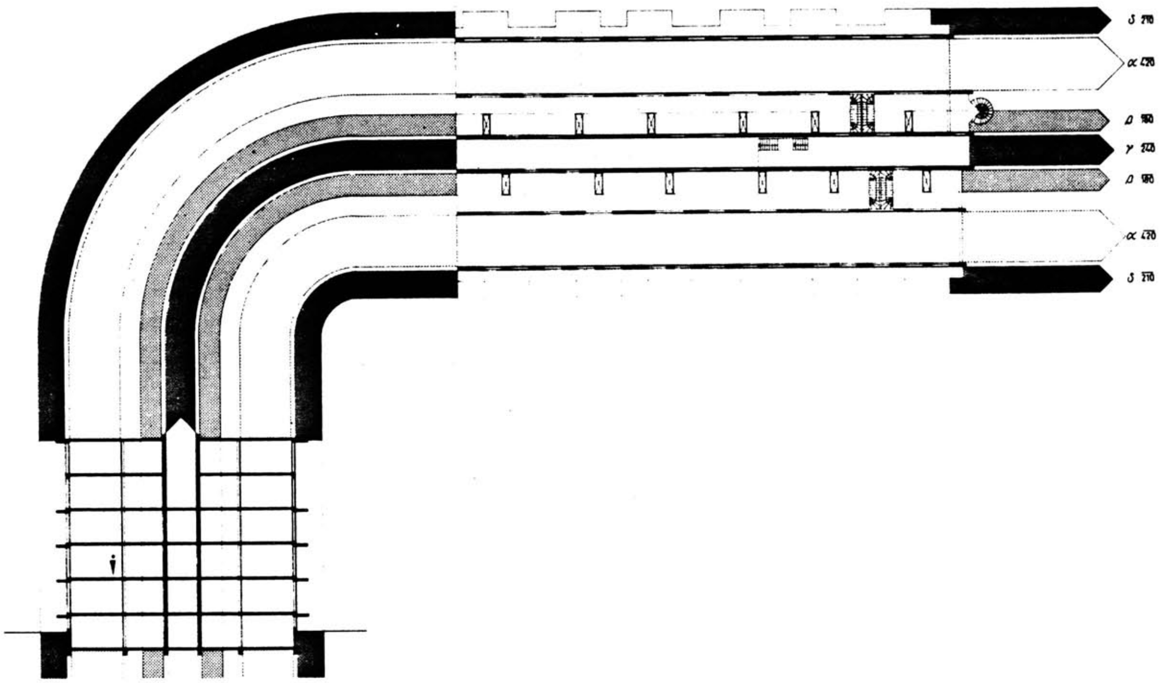
In designing supports there are two technical problems that have to be approached systematically. *Evaluation* and *Coordination.*

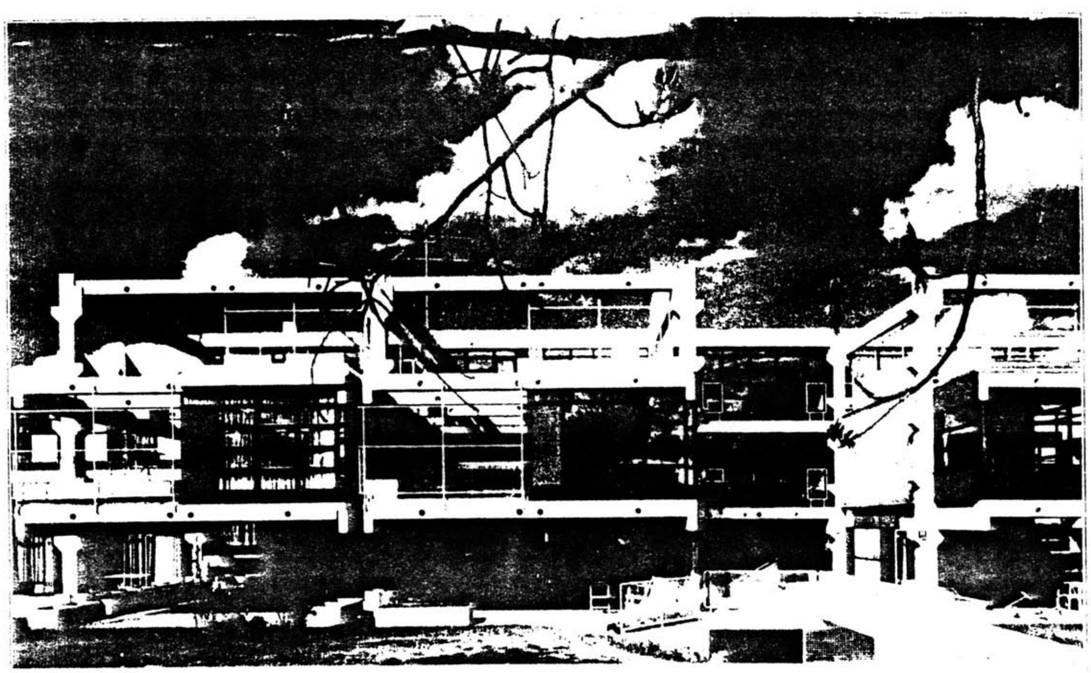
Adaptability is an essential characteristics of supports, a support is only really useful if a change can be made easily. However, a Support must be designed without knowing what Infill Unit it will be required to house.

Since the overall design process is not one that can be completely rationalized; neither can the design process be completely systematized. Nevertheless some parts of the process that are very dependent on fixed conditions or well defined performance criteria, can be rationalized and systematized such are the problems of evaluation and coordination.

Evaluation:
To measure architectural decisions in relation to the usefulness of the layouts that they generate. Evaluation of possible uses should be based on a method that checks which layout alternatives, that satisfy the criteria, can be accommodated by the support.

Coordination:
The interrelationship between support and Infill Units has to be carefully coordinated and integrated. When efficiency, prefabrication and industrialization are necessary for economic, high quality production the need arises for conventions about measurements and coordination.





Conclusions

1. The Physical Model

As explained before, this research has been carried out with the objective in mind that the results of this exploration could be used for the production of a physical model, namely the design of a support building system including a set of rules and agreements.

A possible continuation of this work could include the design of a generic support system for a specific HTB as well as the system design of a framework for coordination that would result from the combination of catalogues of parts, coordination agreements, and production and assembly sequences. Special reference would then have to be made to the relation of these to specific materials, structural principles and construction techniques.

As expected, in the near future, some of the main aspects of HTBs will be required to change (incorporating new materials and forms) and others to remain fixed accounting for the overall essential conditions of the building. The relationship between the primary systems (structural and mechanical) and the secondary systems (envelope, interior, etc.) in buildings is most important as a parallel situation to the coordination of the supports and Infill. Also it is mainly through integration in the building system design process, that the adequate coordination between permanent and changing parts of the building can be accomplished as well as the coordination of the different actors involved in the process of design (the professional and the users).

In High Tech buildings the issue of control over flexible and adaptable environments becomes crucial since more and more decisions are made independently from the architect. Since these decisions are directly affected by the necessities of the users, it becomes very important to understand and manage the process of *user participation and control* .

The *openness* of a support scheme could be tested for it's capacity to accept different materials and off-the-shelf Infill subsystems available in the market, producing different alternatives without changing basic design configurations. A series of scenarios or variations for interior layout possibilities would be produced in response to different possible programmatic conditions, so as to guide user decisions regarding Infill design. In other words, building design acquires the characteristics of a "Prospective" design. However, we know that the prospective design process (building scenarios for future possibilities), just as the inventive apparatus can not be completely rationalized.

The following strategies have to be given serious consideration when designing HTBs or buildings in general that need to be flexible.

1.1. Support Infill

This thesis has been based on the premise that the flexibility and variability that people of the future will require of their environment will be accounted for by the interaction between the permanent and changing parts of their buildings. The former would have to maintain the essential characteristics of the building over time, while the latter could be freely modified to respond to the user's ever-changing requirements. (Support Infill)

As has been described in previous chapters, the Support Infill approach provides the "loose-fit" necessary for the integration of "flexible spaces" to a meaningful structure. The plan, section and elevation of the building are to be capable of responding to the changes in user requirements without producing the loss of order.

1.2. Designing with Archetypes

By restraining the design of the skeleton to basic structural principles and archetypical configurations, we allow the main semiological characteristics of the building to outlast the physical changes of the building.

Following these steps so as to design a building to accommodate human activities in a future period of time, implies a previous definition of the permanent aspects of it's nature as well as the possible changes that could affect it. But today we can not know with certainty what these conditions will be in the future, what materials will be used, or what are going to be the user requirements.

However we do know that there are elements or architectural concepts that most probably will remain as time passes since they originate from more permanent conditions such as the essential characteristics of the human body or the climate, the site and the culture.
For example, these could respond to Archetypes such as:

1. Those related to *architecture* (the horizontal plane, ergonometrics, gravity, etc.)

2. Those related to the *building type;*

3. Those related to the *"Place"*; the landscape, climate, regional culture, etc..

4. Those that responded to an *analogies* or "metaphor."

3. Flexibility and the Consideration of the User

The traditional approach to flexible design consists in abandoning any attempt to anticipate changes in a building that would make it unsuited for it's function. Consequently, spaces can be provided with configurations that allow adaptations to be realized at a lower level than that of the initial design of the building.

However, in some cases provisions have been made in the design of HTBs to allow for flexibility that have proven to be inadequate mainly because of pressure from the users to leave spaces unaltered. In office environments today, users very rarely find it necessary to carry out major alterations. Mainly because building inhabitance has not developed at the same rate as have cultural or technological trends, and also because the technological possibility to do so in an economic way has not yet been developed. On the contrary, with the recent development of the "smart building" where interior and mechanical systems are controlled automatically by anonymous computers, In some cases this provision for change has ended up as "planned obsolescence" bringing up the question whether a *flexible space* is any more flexible than conventional ones, when it does not consider the user.

People should be able to identify to the spaces and systems around them. The functions of different parts should be understandable and combine into a coherent whole. We are reaching the point where buildings have to be considered as highly complex machines.

As buildings become more complex, they will be designed, operated and maintained by a range of specialists in individual disciplines.
Integrating and coordinating these specialties into the coherent whole .....

Thus this "Living Machine" must be capable of being designed, constructed, lived in, operated and maintained by people who cannot know or understand all complexities. The people who work in these places must feel that they can use and operate the facilities of the building

Many buildings are designed and built without an identified set of users and many technological choices will be made by them. A Flexible approach would then have to include a way by which transformations, reflecting changing user requirements, can take place in a economic way without disturbing the general order of a building. The participation of the user can then be accomplished through the understanding of the action of the building were they may, eventually engage in design and management as a means of transforming every day existence. The elements that can change should be able to be rearranged by them independently from the fixed elements of the support structure.

1.3. Support Infill Integration

Structural and *Mechanical* Supports. These are different from what is traditionally understood by structural or mechanical support-systems. They constitute the permanent framework of the building. The Structural Support would be composed of both the skeleton and its "finishes" with space defining characteristics, such as columns, walls, floors, etc. Accordingly the Mechanical Support would consist of all the permanent components of the system such as interstitial spaces, service spines, shafts etc. but not the systems themselves. The buildings Infill systems would then pursue functional independence of the structural and mechanical support systems. The following tools can be used so as to aid this process:

- three dimensional modular grid
- the separation of functions
- the extensive use of redundancy in interstitial spaces.

1.4 An Example:

The following is a Support Infill project developed by the author, which intended to comply with the requirements for permanence and change that have been stated here. It is the result of a research dealing with a specific architectonic case: *A Public Building in Prospective:* the study of a building type in response to future situations. The case explored is a Scientific and Technological Development Center for the Santiago-Valparaiso urban area in Chile, to be occupied approximately in the year 2050.[1]

In order to produce the project of a building meant to exist in the future a Support project was produced, accompanied by a series of images that would show its complementation with different alternatives of "Changing Architecture" or "Infill".

[1] Luna, Pablo (1987); "Un Edificio Publico en Prospectiva: Centro Nacional de Desarrollo Cientifico y Tecnologico," Thesis, E.A.U.C.,1987.

The support was composed of a central spine structured by a set of stone frames and terraces excavated and compacted into the mountain. The mechanical supports consisted on a set of Ribs, are a combination of excavated permanent rock stair ditches and modular steel structures growing over them. The ditches as well as the service ribs where designed taking in consideration strategies for growth and flexibility. The advantages of providing interstitial service spaces as well as certain level of space redundancy allowed the ribs to function as service pods while also to grow in accordance to its served space.

Independent structures containing the program, which were connected to the central spine and built over the terraces were the main components of the Infill. Their design responded mainly to the requirements of the program allowing for the adaptability, flexibility and variability of the building.

Three main systems interacted and linked the basic networks of the building as an organism:

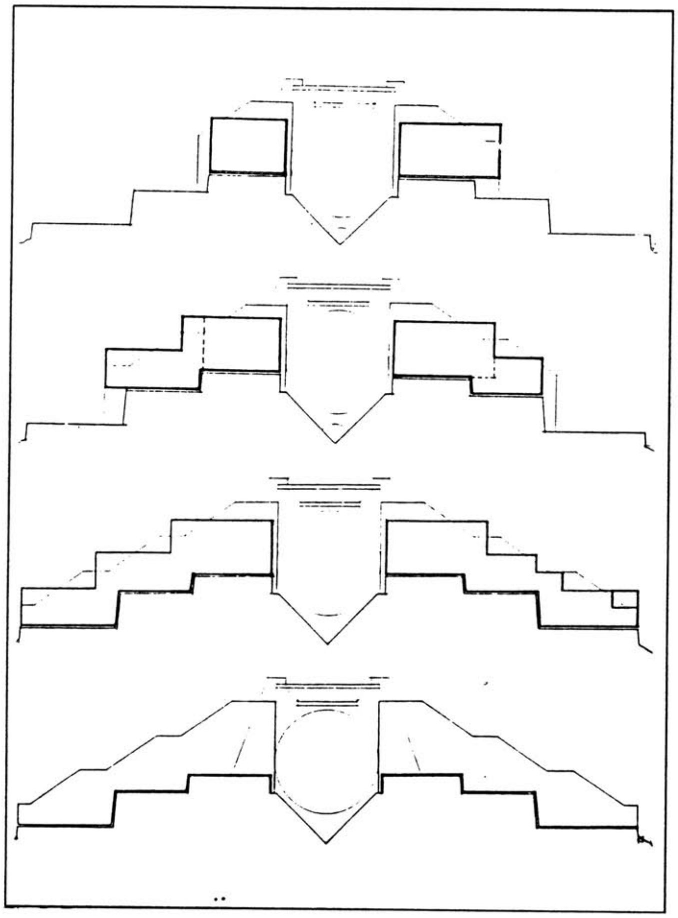
1. *The structural system* is composed mainly of the frames, the compacted terraces and the roof terraces.

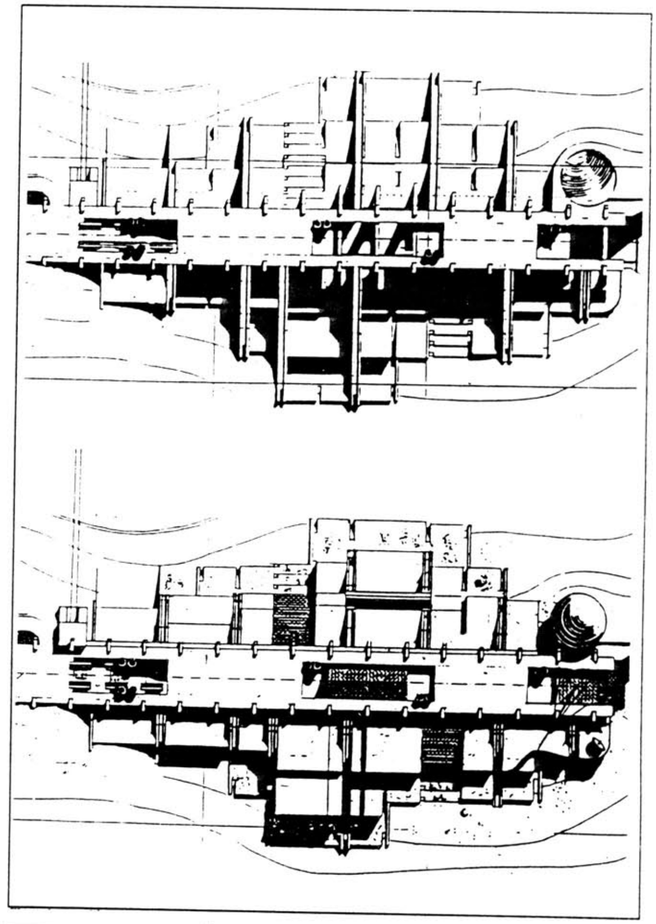
2. *The public circulation systems* which were located within the nucleus as well as in high speed elevated movement systems. The methods of circulations connecting the Infill buildings where elevators and stairs within the inclined ribs. Arrival to the building could be possible by air, ground and sub-terranean transportation systems always descending into the building from the top terrace.

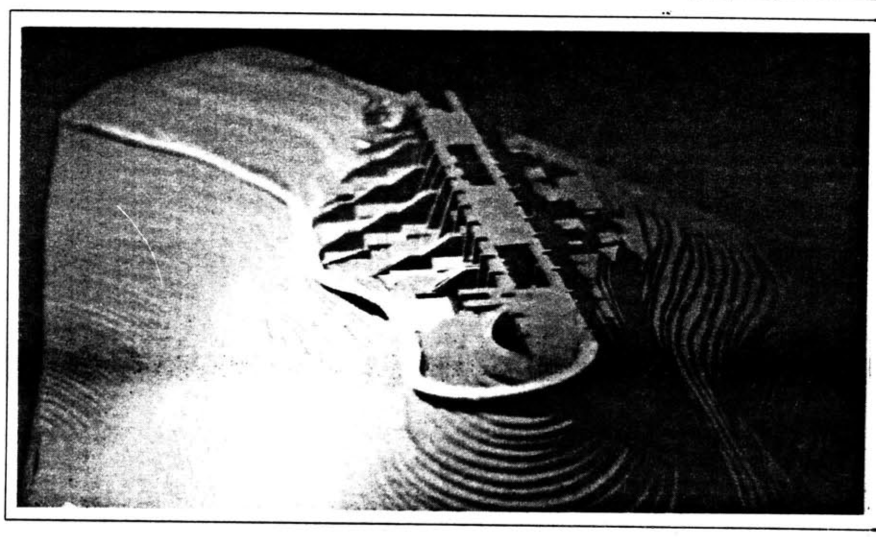
3. *The service networks,* connected a central service "keel"with Infill hollow service floors and mechanical ribs.

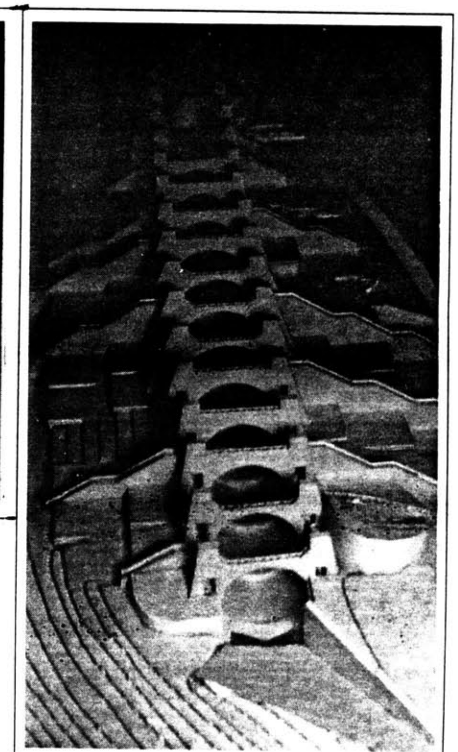
This growth system, allows buildings to expand filling the available terraces downward from the central spine. It was regulated by a set of rules based on the least control necessary and the greatest possible freedom.

The building could constantly adapt without changing it's over-all unity and character, based on the archetypical qualities of the supports. When the supports design was completed it established the base for a game. Applying different scenarios to the systems would yield new alternatives for the future of the building that when developed in our imagination, would allow us to test new materials , dimensions, styles, transportation systems and so on. It is this potential for inventing future possibilities based on present and past conditions, what really makes this project of prospective character.









2.Conclusion

Many architectural themes have been touched in this thesis, consequently many questions have been raised. Nevertheless this research has not been designed to provide answers, but rather to provide relevant questions. We have learned that by observing the "ruins" of meaningful buildings of the past, we are able to intuitively comprehend not only the essence of the institution the building harbors but also the story of its making. The translation of this understanding to concrete design strategies —if not a process to be rationalized— as accomplished by the "Masters", will increase the possibilities of HTBs to outlast functional and physical obsolescence. In other words, the more meaningful a building can become for a culture, while simultaneously providing for flexibility, variability and user control: the longer the building may last and be used by the generations to come. This approach has been regarded here as substantially different from traditional design methods for HTBs.

When confronted with designing High-Tech environments, architects, should be willing to explore new alternatives dealing with the obsolescence phenomenon affecting artifacts of our culture. This will imply the pursuit of an *ideal* architecture as that built environment which responds to human requirements in a harmonious way, over time. The designers task will then be focussed on the exploration and implementation of design strategies that will enable the building to respond adequately to the problems of Permanence and Change.

This "permanent" architecture should offer the user the potential for change and overall control of his immediate built environment, in which the totality maintains its formal and visual integrity yet allowing for planned and unplanned transformations. A dynamic relationship can then be established between change and permanence. Accordingly, as in the Support Infill approach, this could physically result in the provision of a permanent and meaningful framework that interacts with a kit of changeable parts designed to allow users to participate in the creation of their environment, inside and out.

For this we have to go beyond just incorporating the "Metabolist" attitude of buildings as frameworks to accommodate growth and change. The permanent frameworks should be charged with cultural and tectonic meaning. To accomplish this goal the "High Tech Architect," besides designing for flexibility or mechanical expression; should also explore the strategies for permanence previously described. Issues such as the necessity of incorporating special cultural meaning to the building require a exhaustive understanding of the physical and cultural context in which the building is to be inserted. HTBs of the future shall be designed so that their architecture can be rooted in time and place, where the notion of formal expression, ornament and style should also be related formally and iconographically to the "real" building and its structural principles.

However, designing buildings for permanence also means incorporating into traditional design methods, the use of growth systems, defining size alternatives or establishing sets of agreements. Dealing with these issues is just part of what can be considered to be a new way of designing that is slowly providing a direction to architects of the future with the hope that their work will not be rendered obsolete amidst an ever changing world. As architects we have not to elude the overall problem of HTB design by responding only to the modification of formalistically superficial end products, these will inherently end up as sub-functions of a technically obsolete world.

Appendix

SUPPORT DESIGN METHOD

A.1. Support and Infill

- A.1.1 Variationsi
- A.1.2. The Need for Formal Communication Conventions

A.2.Theoretical aspects of the S.A.R. Method

- A.2.1. Evaluation
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    - A.2.1.2 The Support as a Variation of a Space System.
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B.1. The S.A.R. Methodology

B.2. The Support System

- B.2.1. Zones and Margins
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B.3. The Infill System

B.4. The Final Product

Appendix

SUPPORT DESIGN METHOD

A.1. Support and Infill[1]

S.A.R. has defined "Supports" as those elements or structures that are subject to public-communal decisions, while *detachables* or *infill* are all those elements controlled by private individual decisions.

This responds to the basic principle of the support concept which considers the building as the result of two spheres of responsibility in the decision making, taking into account the role of the user.

In the "Support- Infill" concept part of the built environment is clearly within the realm of the dweller which he can change and adapt as he wishes, while the other belongs to an infrastructure about which the individual cannot decide upon, but must abide by the rules and conventions of the community or organization.

In the balance between the private and the communal in this context, the active dweller is a recognizable force. Even though the support concept derives from the age old traditional human relationship to the built environment, it is revolutionary in the sense that by activelly including the user, it challenges the structure of issues and roles in which professionals have learnt to operate in this century.

[1] Based on N. J. Habraken,, 1976. *VARIATIONS : The Systematic Design of Supports.* The Laboratory of Architecture and Planning at MIT: The MIT Press, Cambridge MA.

A Support is any building intended to contain a number of dwelling units, which can individually be adapted to the ever changing needs and desires of the users over the course of time.[2]

In traditional building projects the floor plan is always the result of complex negotiations between architect, client, builder, structural engineers and other professionals. In the case of supports, the final floor plan is not predetermined and has the potential for varying over time.

The method is designed to provide maximum variability and adaptability giving the occupants the maximum choice without requiring technical expertise. By separating "support" from "infill", the methodology avoids the trap of designing for the "ideal" plan. In other words, the methodology acts as a conceptual and technical framework capable of accommodating change.

In order that these processes will produce compatible systems, the problem of *coordination* and *integration* becomes crucial. Both problems of evaluation and coordination are concerned with relating supports and detachable units. In one case the emphasis is on the spaces and in the other on the physical components that make up these spaces.

Hence the SAR method then basically offers a method by which a series of operations which allow such comparisons in complex situations, can be carried out.

- Given the width of a bay, what meaningful combinations of spaces and functions can be accommodated?

- In certain locations within a support structure, what kinds of activities are possible?

or conversely:

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2 Ibid. p. 11

- Given certain necessary relationships between functions, what bay width offers an optimum solution to them?

A.1.1 Variations

The systems described here are all abstractions. A system cannot be visually represented; it is no more and no less than a set of formally defined elements and the equally formally defined relationship between them.[3]

A system can only be visually recognized by looking at its **variations.** Therefore we see a system when looking at a series of different layouts. In this respect the *Variation* can be considered as a *physical model* of the space system. In the same way, a specific design for a support is always a variation of an abstract system.

Variations are the result of each separate operation within the method. They are a number of possible solutions that give us the information we need to make decisions in the design process. In order to avoid ambiguity and to make them comparable, variations are generated and annotated in a systematic way. This is needed if several participants are involved in the decision making process, if the problem becomes to complex, or if the norms and standards are not explicit enough.

According to Habraken the need for a systematic approach to design becomes apparent when;[4]

1. Several participants with different interests and skills are involved in the decision making process.

[3] See N. J. Habraken,et all, 1976. Ibid. p.210

[4] Ibid..p. 14

2. Matters of quality must be made explicit in terms of standards and norms to be understood and agreed by different participants.
3. Decisions must be made incrementally in such a way that each decision leaves open a number of options to be dealt with at a later stage.
4. Several participants need to be able to operate independently but simultaneously in a coordinated way.
5. Different participants need to be able to operate independently and sequentially in a coordinated way.

A.1.2. The Need for Formal Communication Conventions

The need for formal communication conventions arises when the design process is considered one by which decisions regarding the physical forms are made by coordinating different participants. This is needed since it is necessary both to record and to evaluate the decisions that are made.

Since the basic concept of support design presupposes the participation of more than one party, it is important to consider:

- What options did the first participant leave the second?
- How can these be analyzed and annotated?
- How can this contribute to the coordination of the infill components?

Because the method stresses coordination and communication in the design process it is of little use for an individual to apply in isolation. The method is useful within the context of design as essentially a decision making process where coordination and communication deem themselves as essential.

A.2.THEORETICAL ASPECTS OF THE S.A.R. METHOD

The theory behind the the Support-Infill approach can be best explained using the concept of *the Systems Approach to Building*.

As explained at the beginning of this thesis, every building can be regarded as a system of components ordered according to certain rules. Alternatively, a building can be considered *a system of spaces*, —a system where spaces are the components, and the relationship between those spaces conform to certain rules.

The method offers the means of solving two different design problems that will be explained: **Evaluation** and **Coordination.** The problem of *evaluation* concerns spatial quality, while *coordination* is concerned with the relation between physical components.

In the evaluation there are two *spatial* systems which have to be related while there are systems of *physical* components to be considered for coordination. To solve both of these design problems a *formal, spatial framework* is used.

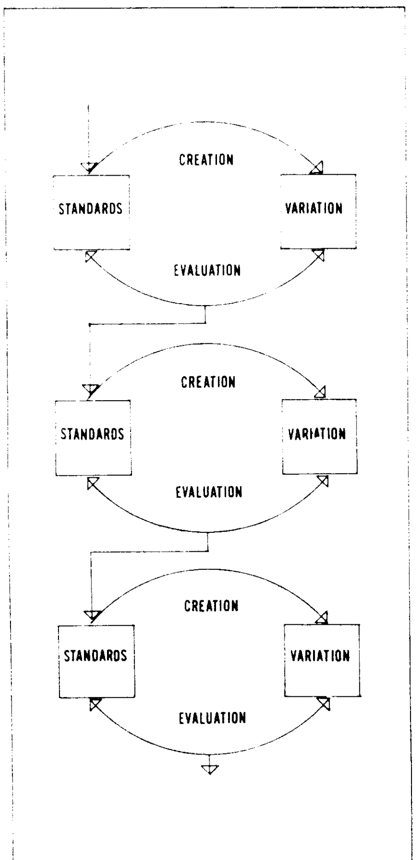
A.2.1. Evaluation

The process of evaluation has the task to test what is possible in a given structure (possible floor plans) against what is generally desirable (performance specifications and standards).

The process is necessary since the support design has to be judged on its potential for accommodating plans which satisfy the individual requirements of different users, throughout its life span.

The evaluation of any support implies asking the following question:

To what extent can layout variations for the program be developed that can be accommodated in the support, while conforming with certain predetermined standards?



At least two procedures are necessary to answer this question:

1.A well designed generic building type must be defined. (Housing, Hospitals, Schools etc.). This is done with the use of spatial performance specifications or standards that must be formulated in such a way that they can be used to test the layout.

2. It must be possible to proceed with the development of layout variations which;

a. will conform to such pretended standards.

b. can be accommodated in the support being designed.

A.2.1.1. Standards for "Good Building Design"

Before any space can be an element in a system it has to be defined usually in terms of its position, dimensions; length, width, and height. Thus the functions that a space of a specific size could contain can be determined. Any statement that tells us something about the positions, or the dimensions, or the functions of space, and which can be objectively tested can be used as a standard.

A relationship established between certain functions and spaces of certain sizes can be seen as an agreement. *Agreements* are those norms, standards, rules, conventions, and patterns that are accepted by all as governing a given man-environment situation.

A *Standard* is nothing more nor less than a verifiable prearranged *agreement*, which is valid for a specific length of time, within a specific context and for specific people. A standard may establish a relationship between the set of spaces and the support. The participants in the design process can then assign a certain function to a certain space on the basis of a formal analysis or by agreement.

A.2.1.2 The Support as a Variation of a Space System.

As shown previously a combination of standards can be seen as a description of a system (performance specifications). Therefore we have that a set of standards can describe a *space system where the* elements are spaces and the relationships between elements are their relative positions.

The support, as defined previously, can also be considered as a coordination of spaces, which does not belong to the space system described by the standards. The elements of this space system are the spaces defined by the floors, walls and columns as well as other permanent elements such as stairs, shafts, etc. of the support. According to the S.A.R. method, the spaces that are the elements of the support are defined as "sectors"

Thus the problem of evaluation can be seen as a problem concerning the relationship between two space systems. On the one hand, *the space system for supports*, and in the other, *the space system for well designed building type*. A variation of one system provides the environment for variations of the other system,. The better support is that which can accommodate more variations of the system for the "well designed generic building."

A.2.1.3. The Design Process

A solution to the evaluation problem; can be described as:
the analysis of the capacity of one variation of a space system (supports), to accommodate a number of variations of another space system (good design of the generic building type).

In other words, the design process is as much the developments of standards, which are a representation of the values of the designer, as the actual design that will finally follow those standards.

A.2.2. Coordination

In a support building two production processes have to be considered: The production of the *support* and the production of the *infill components*. However at the design stage it is impossible to foresee what kinds of *infill components* will eventually be used in the future.

The problem of coordination arises from the relationship between the support and the infill components. Infill is a set of detachable units that can be understood as a number of elements that have to be combined in space. Accordingly, elements and conventions establish their possible relationships in space.

A.2.2.1.A System of Components

Since the elements are physical components, we can then speak of a *component system* as different from the *space systems* described above. Therefore we can speak of the support also as a variation of a component system. The elements of this system could be floors, walls, columns, etc.

Conventions must be provided for the joining of components from the different systems. Such conventions must be formulated effectively if the relative positions in space of the components are known. The use of *building systems integration theory* can be helpful at this stage.

Thus the *relative* position of the elements in space must be predetermined. This knowledge is in fact the important prerequisite for the design of these systems in a coordinated fashion. Conventions must give some indication of the relative locations in space of the various components to be designed.

A.2.2.2. The Spatial Framework

In the design of buildings the systems always have elements that are volumes, their relationships are their relative locations. A spatial framework is necessary in order to describe these locations. Formal spatial frameworks are used to study the relationships between both systems.Relationships between systems can only be described if there is a method to place the systems within a shared spatial framework.[5] The *zone distribution* and the *tartan grid* are such frameworks.

B.1. The S.A.R. Methodology

A series of explicit design methodologies that try to incorporate the user participation and aim as well at more flexible, adaptable and variable solutions where developed parallel to the S.A.R. method in the last 30-40 years. Such include Christopher Alexander's "Pattern Language" or Yona Friedman's "Scientific Architecture"

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5 See N. J. Habraken,et all, 1976. Ibid. .p. 206

Within this framework the S.A.R methodology for the systematic design of supports has been chosen for being more representative of the Support Infill concept.

Since the conventional design and building process consists of essentially linear and sequential processes controlled and dominated by professionals, it is only in the final occupancy stage that the user can "participate" by simply moving in. Thus, the current process is conceived, planned, programmed, designed, and realized by "experts" in almost all its phases and quite often tends to rely on decision criteria that may or may not represent the real interests of the user.

At the time the planning and design of mass housing projects in conventional practice was usually based on the assumption that the "building" is essentially a technical or "tamed" problem.[6]While in reality it must be considered highly "wicked,"[7]since human problems are generally not amenable to one single solution but many.

"Faced with complex problems we tend to try to simplify them if they cannot be dealt with. This is a fruitful strategy when purely technical problems are involved, but if the human, social and psychological needs are over simplified the result is the reduction of human life itself."[8]

The S.A.R. methodology (that will be subsequently explained in further detail), was then elaborated as a response to the actions of

6 "Tame" Problem in design is a term coined by Professor Horst Rittel from the Dep University of California in Berkeley. It refers to those problems in design that are a solutions—that is, those that can be clearly and easily quantified in technical terms.

7 "Wicked" problems in design are defined by Horst Rittel as those as problems in d *solution:* In order to solve a *wiked* problem, the formulation of all its causal relatior However, this is impossible as there is no clear distinction between posing a questi

8 N. J. Habraken,, 1976. *VARIATIONS : The Systematic Design of Supports*. The La Planning at MIT: The MIT Press, Cambridge MA.p. 16

the various forces and powers generating change within a framework of clearly established "agreements". It was to be capable of serving *both* the professional and the user, and should act as a tool of communication, decision-making, and design while at the same time defining the parameters of "freedom" or "restraint" for each actor in the process. Thus the methodology provides, first a *means of communication*, and second a *document for implementation.*

The suggested procedure for the systematic design of supports is the following. First the performance criteria for the support is clearly stated. Based on this criteria the support is then developed following the steps listed bellow:

1. Criteria for support design
2. Support system
    - Sector groups
    - Zoning Analysis
    - Sector Analysis
    - Basic Variations
    - Details of sector Analysis
    - Sub-Variations.

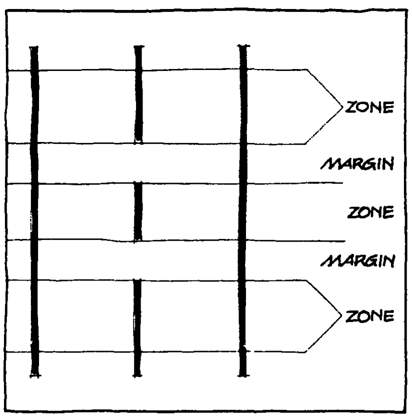
B.2. The Support System

The following is the reformulation of the S.A.R. method for the systematic design of supports to the problem of designing HTBs.

As explained earlier, the design of supports is realized through the accomplishment of two basic tasks: **evaluation** and **coordination.** For the evaluation of supports: it is necessary to determine all the fundamental variation in layout to assess the viability of the support.

In order to do this the criteria for the planning of the dwelling unit must be formulated explicitly so that during the design process can be evaluated. The systematic examination of a support design will reveal the limitations on layout alternatives resulting from the positioning of support components.

B.2.1. Zones and Margins



The concept of *zones* and *margins* has been developed to allow for the formulation of *general statements* about the distribution of spaces within the support structure without having to make exact floor plans —only *possible* floor plans.

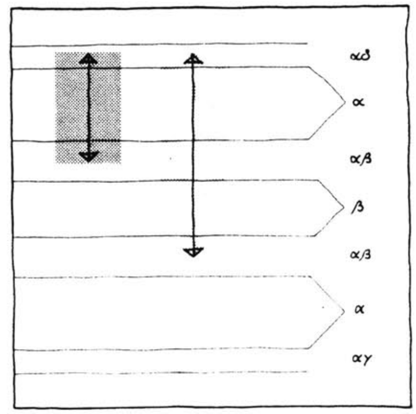
The use of zones & margins helps in the design of a supports that will accommodate unit layouts that conform to previously determined standards, helping to distinguish areas suited to different types of rooms.

People will value certain parts of the available space more than others. This is important to consider when the designer has to decide the location of different kinds of spaces and functions. It is up to the user to decide where certain types of spaces are located.

Within the support; two areas can be distinguished:
- on the *perimeter*
- totally *internal*

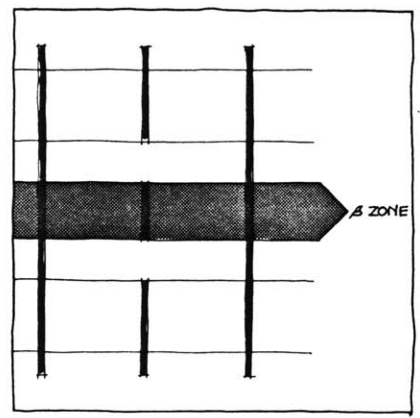
Each of these is suitable for a different purpose.
For example when you consider what rooms should be located next to an external wall; two reference lines can be superimposed on the plan of the supports indicating the minimum and the maximum depth of such rooms.

Then two lines can be drawn parallel to the facade so as to define an area within which a certain kind of room can be located. The areas described by these lines are called *zones and margins.They* are fixed bands within which spaces can be placed according to certain conventions. For example:
"Certain rooms may overlap one or more zones bust must end in margins"



B.2.1.1. The Four Basic Zones

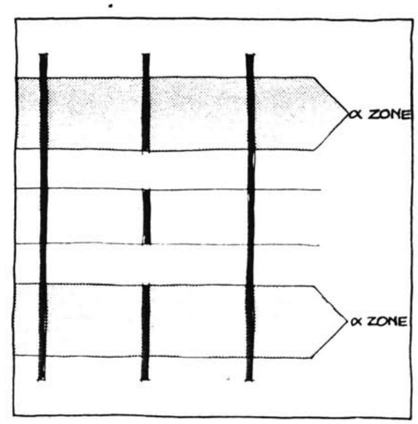
S.A.R. calls the zone adjacent to the facade the **ALPHA zone**: An independent area for private use and adjacent to the external wall.



It has there basic characteristics:
- area within the unit
- internal space
- area adjacent to the external wall

The internal area not adjacent to the external wall, intended for private use is called the **BETA zone.**

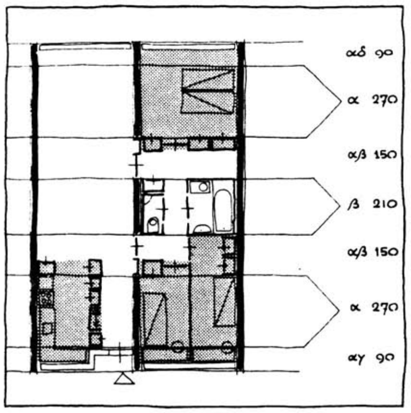
There are also spaces that are outside the dwelling itself:
The external area intended for private use is called the **DELTA zone.**



The internal or external area intended for public use is called the **GAMMA zone.** (this area usually provides public access to the building.)

B.2.1.2. Margins

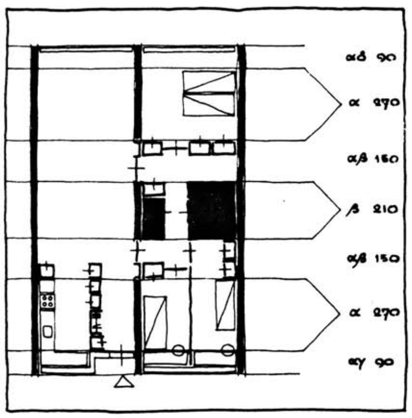
Is a "lose-fit" area between two zones, with the characteristics of both of these zones and taking its name from them.
Therefore the ALPHA-DELTA margin is the area in which the facade must be located.



The preceding zones where developed in the S.A.R. method according to the types of spaces common to housing. Therefore when designing supports for other building types other specific zones can be created.

A system by which the relative position of zones and margins are determined is called the **Zone Distribution.**

A zone does not have to be straight, have a uniform width or any width at all.

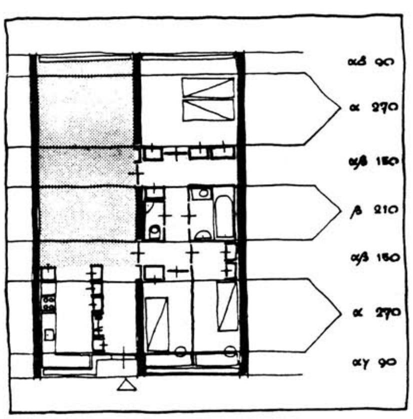


B.2.1.2. Spaces and Zone Distribution

Looking at the program, possible plans can be derived. Based on this, assumptions can be made about the minimum and the maximum size of spaces. Also one can determine the location of the space in relation to other spaces.

To determine how spaces can be located in a zone distribution, zones or margins are categorized according to which particular spaces are situated and/or terminate in them.

1. Special purpose spaces. A space which is intended for occupancy over a certain length of time.



2. General Purpose Space. Characteristically the largest single space in the *dwelling*, can have a wide variety of arrangements and accommodate different types of activities. It is a space that allows a combination of specific activities that can not always be determined in advance.

3.The Service Space: Spaces meant for short time occupancy, are utilitarian in character, the size and layout of which can be determined through an analysis of their function.

Since some spaces could be classified according to more than one category, an individual must indicate to which category he or she wishes to assign the spaces. A *chart for special purpose spaces* can be used to record the relationship between function and space.(Fig.B.1)

In every zone distribution three positions can be distinguished:

Position 1. A space which overlaps a zone and ends in the adjacent margin.
Position 2. A space that overlaps more than one zone and ends in a margin.
Position 3. A space that begins and ends within the same margin.

Therefore, based on the program, spaces can be classified within one of the three categories (special purpose, general purpose or service) and then be located in a zone distribution scheme, in one of the three positions.

B.2.1.3. Space and Function Analysis

In the different analyses it is important to have a clear understanding of the relationship between *space* and its *function*. as indicated by the *program*. **Charts** can be used to make easier to envision the possible layouts and consequent sizes of shapes of special purpose spaces. The smallest size in which a characteristic arrangement of furniture can be accommodated is called the **critical layout.** Since service spaces can be standardized, they can be easily manufactured as prefabricated components.(Fig. B.2)

B.2.2. Zone Distribution of Components

Data concerning the adequate depths of certain types of space and their relative position in a zone distribution, must be made available for the design of a support. According to this information limitation are put to the layout possibilities regarding the position and dimensions of:

- *walls, floors, column, ducts and stair cases*

The zones will determine the general character of the "support" as well as its generating dimensional order. By basing the design of a support on the ***zone distribution*** limitations can be studied and their acceptability determined. In this way a support design can be evaluated.

A *zoning analysis* indicates how the different functions can be located within the *zone distribution.* It will incorporate any conventions relating to the location of the spaces and will show the **critical layouts** for spaces of different functions and lengths.

The "**zoning**" of a given support allows the following operations:

- *Evaluation* of support in terms of a given preferred generic type;
- *Location* of openings and pipes on floors and walls;
- implied (spatial) feasibility for *plan alternatives* (i.e. the variations)

B.2.2.1. Zoning Analysis.

The zoning analysis is made to formulate a set of conventions about the location and size of different kinds of spaces. A drawing may show in sequence the critical layouts for a combination of zones and margins.Special emphasis is made in setting standards for special and general purpose spaces. The sizes of zones can be determined by analyzing how well the intended activities fit into zones of different dimensions.(Fig. B.3)

B.2.3. The Sector

Zones are aggregated into sectors. A **Sector** is a part of a zone and it's adjoining margins that is completely open and can be planned freely. Accordingly, a **Sector Analysis** indicates the relationship between a sector and the functions it can accommodate. The main intention is to divide the area into parts in order to analyze the possible layouts.

The designer "tests" the support by drawing into the given zonal spaces alternative layouts to clarify technical details and to asses the ability of the support to accommodate the required functions and their alternatives.

It is not necessary to make an exhaustive study of *all* the layouts and combination of functions. The purpose of this analysis is for the designer to indicate, with a minimum number of variations, the characteristics of the designed, or yet to be designed, support

A **Sector group** is a combination of interconnecting sectors. Once the structure has been designed, it must be possible to determine how many useful layout alternatives a certain sector group offers.

B.2.3.1. Sector Analysis

Determines the way in which a sector can be divided into spaces by means of partitions by observing what combinations of functions are possible in spaces of different sizes.(Fig. B.4)

B.2.3.2. The Basic Variation

To determine the utility of a sector it is necessary to list the basic variations that it can accommodate.The limitations stated in the program will reduce the number of alternatives.(Fig. B.5)

A Basic Variation indicates the position, in a specific sector group, of a certain group of functions, which together form the program of the space unit. It does not fix the size of spaces for the different functions.

Once the support characteristics have been tested and accepted as valid, it is useful to determine how many alternatives of the basic variation can it really offer.

B.2.3.3. Sub-Variations

A Sub-Variation of a basic variation is a complete layout in which the positions of the functions is the same as in the basic variation. At least one sub-variation of the basic variation must be drawn and should be accompanied by the basic variation from which it was derived. (Fig. B.6)

When designing supports for complex buildings types, where a series of different spaces , functions and combinations of these are required, the number of possible variations and sub-variations becomes very large. Therefore, only those that appear to be significant and corresponding to the program need to be expressed.

Decisions about the position and size of *support components*, will have an important influence on the number of layout possibilities. Such decisions involve the positioning of walls, columns, and floors as well as the choice of span and the location and size of openings.

By analyzing sectors and sector groups, the advantages and disadvantages of different locations for service ducts can be evaluated. By plotting the basic variations it is possible to determine the viability of a particular support.

Thus the *zoning analysis* will not merely show the positions of the functions that are chosen, but also the positions of the support components.

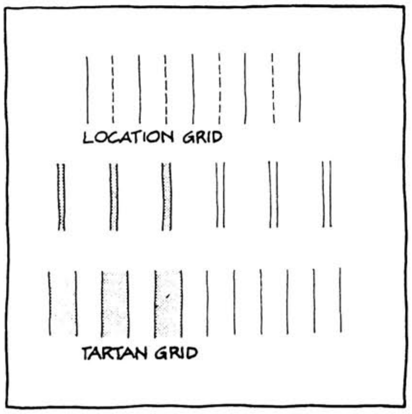
B.2.4. Design Evaluation

Thus the S.A.R. methodology defines a series of concepts that can be used in the formulation and specification of standards for the location and the size of spaces. Also a number of analytical operations provide a means for analyzing spatial arrangements, the results of which are in the form of drawings which can be used as a means of communication. The final design is then composed of the results of the fixed sequence of these operations (zoning analysis, sector analysis, basic variations, and sub-variations).

Even though an analysis always will always reflect a certain value system it does not dictate which variations will have to be used. Other variations and sub-variations can, and probably will arise when individuals plan and control their own building unit.

Analysis of variations may result in the modifications of standards, therefore starting a new cycle. Nevertheless, in the design of Supports, the analyses don't have to be performed in as sequence; different designers will approach the task in different ways. These cycles are then repeated until the design is considered satisfactory. (Fig. B.7)

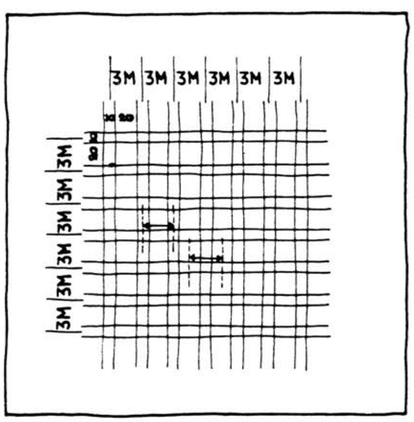
The analyses only give the *critical variations* of the support. They do not tell the user what to do. Therefore they are an integral part of the design because they explain the layout possibilities of the support while at the same time documenting the intentions of the designer. Therefore they act as an aid to the designer as well as a means of communication.



B.2.4. Location and Size of Components

The basic conventions that constitute the foundations for the development of a standardized approach to the design of supports and infill, have to be defined. Their intentions are to provide the basic framework for the determination of exact locations and dimensions of spaces and infill elements within a framework.

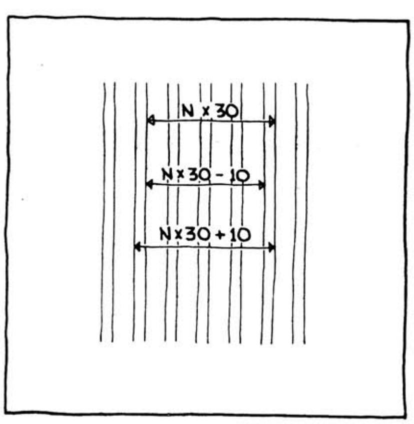
B.2.4.1. The Tartan Grid



In the development of supports and infill alternatives the location of the structural components must be capable of being clearly described so that the dimensions of the elements and the spaces that they form are unambiguous. To aid this process the utilization of a "tartan grid" is suggested in which the distances between the grid lines represent an agreed module.

Tartan Grid provides the technical means by which to design a support system without exactly knowing how and when a given function or space will be accommodated in the final project.

B.2.4.1.1.Location of Components



A series of conventions can be stated regarding the location and dimensions of components. These can include, the selection of the basic modules that will define the wide and narrow bands in the grid or conventions on where components are placed according to the grid.

For this purpose conventions regarding sizes are defined.

Nominal Dimensions are those sizes of spaces and components that are always a multiple of the main module of the grid being used. This convention responds to the fact that the real size of building materials will rarely be an exact multiple of the module on which they are based. (masonry/bricks)

B.2.4.2. Modular Coordination

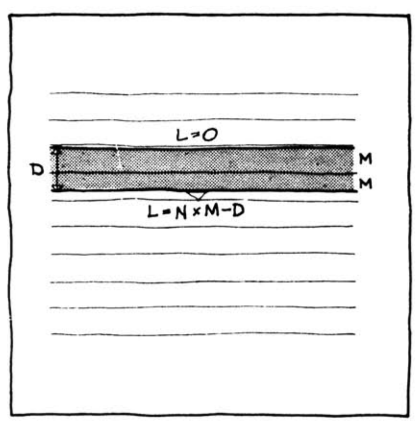
One of the recurrent discussions in the field of modular coordination has to do with deciding which distances should be modular; those from "center to center" or those from "face to face."

Structural Engineers, who are more concerned with the positions of components, prefer to place the **center lines** of walls and columns on the modular grid. They are concerned that the dimension to the center line of a material should be known exactly.

In the other hand, Architects, whom are more concerned with the dimensions of spaces, as well as the producers of infill components, prefer modular dimensions for spaces. For them it is important that a certain clear dimension will be achieved.

The Tartan Grid is a excellent framework in which each of the groups can work on their own goals without conflicting with the other group. However the real issue is to have a system with which everyone can work, both for positioning elements as well as for dimensioning spaces.

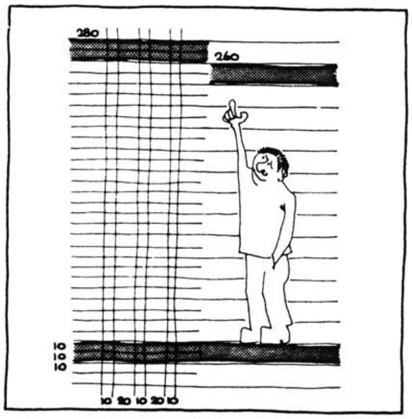
B.2.4.3. Locating Dimensions



Within the modular coordination framework other conventions are also specified so as to rationalize the possible location of components within a support.

The **locating dimension** is the distance between the component and the next grid line. By indicating both locating dimensions, positions of components can be determined exactly in coordination with the modular system. The variation by which the location of a certain element can vary is called **tolerance.**

These **conventions** make design development possible without prior knowledge about what materials or what thickness will be needed. This permits that within these limits, changes can be made in the dimensions without producing the drawback of having to re-design.



Three Dimensional Grids

Horizontal and vertical modular grids should be used for the integration and coordination of the different support and infill systems. However, vertical dimensions are usually determined based on the type of support being used, the required floor to ceiling height and other factors. Moreover, there have been no international agreements about the preferred module for the vertical plane.

B.3. The Infill System

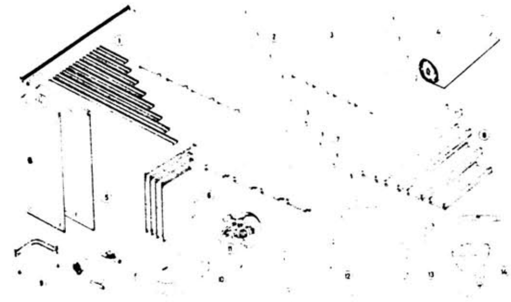
Everything needed to make a support suitable for human habitation can be considered as part of the set of Infill Units. The user should have ultimate control over these.

Social criteria that are used to determine the degree of control by the have an important effect on what can and cannot be regarded as a Infill Units. The set of Infill Units can be considered as a system composed of a number of components that relate to one another and to the environment, which is always the support.

A *component* is the smallest element over which the user has control.

A combination of components can form a *group* that does not necessarily have to be produced by the same manufacturer. This

when the components are designed according to the same basic conventions. For example:
- Space creating systems
- Partition systems
- Appliance systems
- mechanical systems



COMPLETE SET OF BATHROOM COMPONENTS

1 FRAME COMPONENTS
2 CORNER FLOOR COMPONENTS
3 INFILL FLOOR COMPONENTS
4 FLOOR COVERING
5 DOOR PANELS
6 WALL PANELS
7 CEILING CORNER COMPONENTS
8 INFILL CEILING COMPONENTS
9 PIPES
10 WASH BASIN
11 FAUCET
12 SHOWER TRAY
13 BATH
14 WATER CLOSET

B.4. The Final Product

The SAR methodology represents a radical restructuring of the whole process of decision-making. However it must be regarded as merely a first step in the general direction of a more open-ended an responsive way to approach planning and design The framework, with its basic belief that design of the built environment can only be responsive and effective if it includes the active participation of the user, offers an effective means to make such participation technically and organizationally possible..[9]

In this context the designer must only come up with a tentative "ideal" plan, but, in addition, with an explicit determination of its overall context (the "support") and all the potential options (the "infills") that may change into other solutions and that may or may not coincide with the first image of the "ideal" solution as seen by the designer.

The SAR methodology is interested in floor plans only as *potential* solutions to a *generic* problem and as possible candidates for inclusion in the overall "support" system. The support is conceived *both* as a set of rules about the position and dimension of materials and as tool for space allocation.

[9]See: Dluhosch, Eric (1978) *The Support-Infill Concept as a methodology for User Participation in Mass Housing Projects*, Published in :*Programming for User Needs: Approaches for Improving Man Made Environments*. Wolfgang F.E. Preiser Ph.D., Editor. Article as a part of the Community development series. Donden, Hutchinson & Ross. 1978.p. 105