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Performance/Cost Evaluation of Buildings -- An Information Aid to Decision Making

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PERFORMANCE/COST EVALUATION OF BUILDINGS - AN INFORMATION AID TO DECISION MAKING

by

George S. Birrell*

INTRODUCTION

To lower the cost of building housing it is important that its performance is not reduced below the desirable level.

To achieve desirable performance and (lower) costs requires that they be related, one to another.

This relationship should be available in the design phase of a project because it is there that the building is crystalized.

The designer's inputs, process and outputs are all in the form of information and therefore the above relationship of performance and cost should be couched in an information context. For maximum use of that information it should be structured in the most appropriate manner for its uses. This paper describes such an information structure.

The function of the information tool is to aid the designers in providing the appropriate Performance of the building at the most feasible cost. It comprises an information structure which rationally divides buildings into subsystems and subfunctions, whose matrix intersection elements are the locus at which detailed performance and detailed cost can be related. Because Building Codes have a constraining influence on building construction, performance and cost, their correlation to the buildings will be included in the information structure.

ANALYTICAL CONSIDERATIONS OF BUILDINGS

Performance is considered as the technological performance of the materials and components and is the degree to which they satisfy the performance required of the building, e.g. water has to be conducted efficiently from outside the building to the various locations in the building where it is to be used. The materials and components chosen to conduct the water must enable that performance to occur with minimum loss of efficiency.

The derivation of the need for each performance within each user space (e.g. room) of the building is from the Users Needs and for this paper is considered as being given.

Cost is being considered as the life cycle cost of the building, (1) made up of (a) capital cost and (b) functioning cost i.e. maintenance and operating costs over the life of the building. The capital costs can be related directly to the detailed parts of the building analysis, from the building construction process. The functioning costs often have to be allocated to these detailed parts of the building from the functioning cost of each whole subsystem. Some functioning costs have to be allocated from groups of subsystems, whose maintenance and operating expenditures are derived from a single maintenance account source e.g. cleaning of ceilings, walls and floors.

A further divisor required for analysis of buildings is Building Codes. As they exist at present, they are a severe constraint on a systematic approach to building design, construction and analysis. This is because their information structure is one which has evolved from the trade nature of the production process of buildings rather than a systematic analysis of the end product of buildings. The context of these existing Building Codes is directed at the construction process as well as the performance of the end product. Some of the draft proposed Building Codes continue this practice. In evolving an information structure to aid design decision making it is of advantage that its structure is compatible to the most appropriate structure for Building Codes. To specify the required safety values for buildings requires that they first be analyzed to parts which can be individually specified.

In effect, it is more probable that the most appropriate information structure for Building Codes is that which is most suitable to aid design decision making because it is in the design process that the Building Codes are "incorporated" into actual buildings.

While only technological performance, costs and building codes are presented here, the concept should and can be extrapolated to other necessary considerations in the design and use cycle of buildings. All matrix core elements should be considered as the information lowest common denominator (the "what" criterion of inbits in information theory) for all the processes and transformations required in that design and use cycle of buildings (2) (3). (See Figure 1)

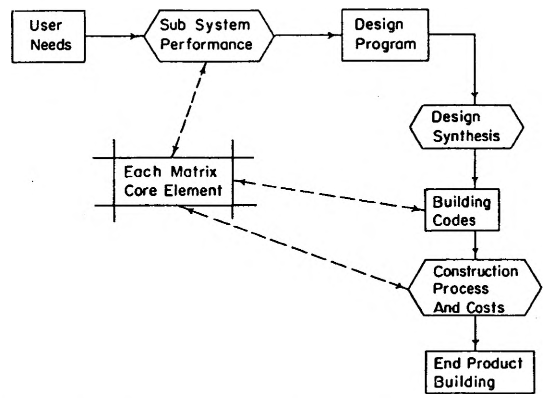

Fig. 1. All Matrix Core Elements As the "What" Inbits to the Building Design and Use Cycle

ANALYSIS OF BUILDINGS

In this building analysis matrices are formed by having the various building subsystems on one axis and the possible types of subfunctions on the other axis. Each intersection of subsystem with subfunction will be called an element of the building. It is most likely that in individual subsystems only certain subfunctions will be operational e.g. in the Services subsystem of Sanitary Fittings the only operational element will be Outlets.

Upon the elements which are operational can be traced the incidence of information (performance, costs and code requirements etc.) which are derived from each type of building e.g. a one-story house with a hyperbolic paraboloid roof will have a vast amount of information on Roofs, some information on External Walls/NonStructural and none on External Walls/Structural. A four story walk-up will have only a small amount of information on Roofs and a great deal of information on External Walls/Structural and Internal Walls/Structural.

This analysis of Buildings deals exclusively with Buildings and does not include an analysis of Site works beyond the outer face of buildings.

Buildings comprise three major groupings of subsystems, which are

-1- the Fabric

-2- the Services and

-3- the Link.

Briefly, the difference between -1- and -2- the Fabric and the Services and -3- the Link is, that for two similar buildings on different locations only the Link will be different i.e. it is the Link between the usable spaces of the buildings and the Site. The differences between the Fabric and the Services is that in principle, they perform a different kind of function. The Fabric subsystems provide a filter function between user spaces in the building and the Services provide a conducting function between the user spaces and the source of each service.

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THE FABRIC SUBSYSTEMS (See Figure 2)

The subsystems which comprise the Fabric of the Buildings are the physical barriers which segment the spaces of the building from the external natural conditions and segment the various individual user desired spaces within the building. Such barriers provide complex filters between these spaces.

The building subsystems in the Fabric are -1- External Walls, -2- Internal Walls, -3- Openings (Visual and Access), -4- Shafts, -5- Floors, -6- Ceilings and -7- Roofs.

Each of such subsystems can be further analyzed into individual subfunctions. Such subfunctions of Fabric subsystems are in two major groups (A) the Core and (B) the Surfaces e.g. 2 in. x 4 in. studs, base and head plates are parts of the Core and insulation board, plasterboard and shingles are parts of the Surfaces.

The Core group comprises (a) Framework, (b) Structural and (c) Nonstructural subfunctions. The surfaces group comprises (d) Finishes-Supporting Work, (e) Finishes-Surfaces and (f) Finishes-Decorations.

These subfunctions are of the building and not of each subsystem; e.g. Structural refers to the building structure and not to the subsystem strucutre. In the Surfaces group (d), (e) and (f) could be lathing, plaster and paint respectively and may be in any or all of the the External Walls, Internal Walls and Ceilings subsystems.

The surfaces and their various subfunctions may be on one or both sides of the subsystem and/or may be of different constitution on each side.

Sub Function \ Sub Systems		External Walls	Internal Walls	Openings (Visual-Access)	Shafts	Floors	Ceilings	Roofs
Core	Framework							
	Structural							
	Non-Structural							
Surfaces	Finishes - Supporting Work							
	Finishes—Surfaces							
	Finishes — Decorations							

Fig. 2. Fabric Analysis

THE SERVICES SUBSYSTEMS

The subsystems, which comprise the Services of the building, conduct the various requisite services around the building from their point of supply to their use locations in the user spaces of the building or in the opposite direction depending on the nature of the services.

The Services subsystems are -1- Vertical Movement (i.e. Elevators and Stairs), -2- Air Conditioning (this includes the conducting of it through the building), -3- Power (e.g. electric power required for motors at various locations in the building), -4- Light (the lighting outlets and their supply conductors), -5- Heat (the heat units and the supply of energy to them), -6- Communications (e.g. phones) -7- Water, -8- Sanitary Fittings, -9- Waste Removal and -10- Installed Equipment (e.g. special equipment for use in the building).

Each of the Services subsystems can be further analyzed into individual subfunctions of each subsystem. There are three major groups of subfunctions (A) Service Creation (if it is created within the building), (B) Conducting (which is the major group of subfunctions in Services Subsystems) and (C) Outlets (the physical outlets of each subsystem e.g. a ceiling light fixture). Service Creation comprises the subfunction (a) Plant and Machinery for generation of the service. Conducting comprises the subfunctions of (b) Conducting Machinery (e.g. pumps), (c) Conducting Main channels (e.g. water mains), (d) Conducting Finishing Channels (e.g. connection piping from watermains to sanitary fittings), -3- Intermediate Containers (e.g. water cisterns) and (f) Protection (e.g. protecting the subsystem from damage or as an aid to its function e.g. protective insulation to heat pipes). Outlets comprise the subfunction (g) Outlets for each of the Services subsystems (e.g. a ceiling light fixture).

Sub Functions \ Sub Systems		Vertical Movement	Air Conditioning	Power	Light	Heat	Communications	Water	Sanitary Fittings	Waste Removal	Installed Equipment
Service Generation	Plant and Machinery										
Conducting	Conducting Machinery										
	Conducting Main Channels										
	Conducting Finishing Channels										
	Intermediate Containers										
	Protection										
Outlets	Outlets										

Fig. 3. Services Analysis

THE LINK SUBSYSTEMS

The Link comprises aspects of the Fabric and Services which constructionally are below the datum floor level at or near ground level. Excavations and Foundations constitute other major groups within the Link.

The elements so derived under Link Fabric are -1- Link Framework, -2- Link Structural -3- Link Non Structural, -4- Link Openings (Access), -5- Link Shafts, -6- Link Floors, and -7- Link Finishes (Supporting Work).

The elements under Link Services are derived from a matrix analysis of all the Services Subsystems with the subfunctions of Conducting Main Channels and Conducting Protection.

The subsystem of Excavations is divided into the elements of Bulk Excavation and Trench Excavation. The subsystem of Foundations is divided into the elements of Basic Foundations, Raft Foundations and Piling.

The division of the building into Link and NonLink Building is an important one for use in performance analysis, construction management, and cost analysis, thus affecting the structure of analysis of the whole building.

The exact dividing line between -1- and -2- Fabric and Services and -3- the Link is the horizontal upper surface of the structural floor of the datum floor level. In simple buildings the datum floor level would be the floor at or near ground level and in complex buildings it tends to vary in horizontal level in different parts of the building. The link will include the vertical construction between these various horizontal levels. In skyscraper buildings the Link is what is commonly known as "the tank". In small buildings the "substructure" approximates equivalency to the Link.

It should be noted that all elements of the Surfaces group of functions for the Floors subsystem at that datum level should be included in the Fabric and not in the Link, as they form surfaces to the user space above and the user functions therein.

All parts of the end product beyond the outer face of the building will be considered as part of the Sitework for the whole project (and thus beyond the scope of this paper); the author has found elsewhere that a similar form of analysis is appropriate.

TOTAL BUILDING ANALYSIS

One way to help achieve lower cost housing is to maximize the use of the information available to the designer. An important ingredient of this is the appropriate structure for that information.

The whole of the above analysis can be structured

-1- as an hierarchy with Total Building at its apex and all the elements at the base and (a) having the subsystems between (See Figure 4) or (b) having the subfunctions between and -2- as a matrix (combining the above three matrices together).

Each of these structures provides an aid to the design decision maker. The designer's task is to select materials and components for each element which (a) fulfill the required performance, (b) satisfy the appropriate Building Codes and (c) satisfy the design budget for that element. To do so for each element on its own may be difficult but that is comparatively simple compared to optimizing all elements, one to another, over the whole building due to the necessary complex iterative trade offs.

By using the structured information analysis of buildings, which exposes subsystems and subfunctions of the building, such trade off processes and decisions can be tackled on a more rational basis.

Within a single subsystem the performance and cost target can be more easily achieved by adjusting the location performances and costs between different subfunctions within that subsystem--e.g. to provide adequate hot water at an outlet will entail the use of pipes, but should insulation be put on the hot water pipes or should the equivalent cost be used to provide outlet water heaters? Having the subsystem performance and cost broken down over its subfunctions enables the designer to more objectively appraise the issues and make decisions.

Intersubsystem trade offs, between subfunction of one subsystem and all other subfunctions of all other subsystems, can be made in a rational step by step search pattern across the matrices. For example, if circular ceiling lighting outlets are desired as a replacement to square ceiling lighting outlets, it is clear that the origin of changes is in the element Light/Outlets. The available types of circular ceiling light fixtures can be examined as to their Performance and Cost, couplings and required Conducting Finishing Channels, any necessary changes in type and power of Conducting Main Channels (electric lighting mains) etc.

The proposed change from square to circular fixtures will affect the Ceilings Surfaces subfunctions of Decorations, Surfaces and perhaps Supporting Work. If such changes, individually or in unison are sufficiently radical, they may cause changes in other subsystems of the Fabric e.g. Floor subsystems.

This enables the correlation of performance and cost subfunctions of both Fabric and Services subsystems, especially those of Finishes and Outlets in the same user space in the building.

The major point is, that having a rational building analysis information structure, such changes required in the user spaces of the building can be traced step by step, reverberating over the information structure just like the ripples caused by a stone being thrown into a pond.

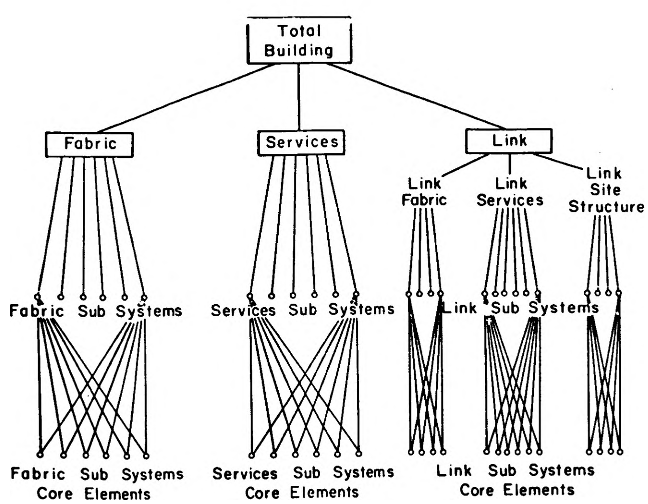

Fig. 4. Total Building Hierarchy

THE HIERARCHICAL INFORMATION STRUCTURE AND THE DESIGN PROCESS*

The input into the selection of materials and components segment of the design process will be a clear and full description of each of the user spaces required in the building. The space surrounding the building can be treated similarly. This description of each user space will be grouped into (a) inherent conditions (i.e.) the required atmospheric conditions e.g. heat range and velocity of air change), (b) boundary conditions (i.e. the types of surfaces required e.g. plaster and paint or wood lining), (c) dimensional space requirements (i.e. the physical dimensions of the user space e.g. length, width, height) and (d) the locational juxtaposition of the user space relative to other user spaces (i.e. which user spaces, having specific inherent and boundary conditions are separated by specific walls and floors). From these are developed the technological requirements of each subsystem of the building. (4)

COSTS OF THE SUBSYSTEMS AND SUBFUNCTIONS**

The cost of each element of the matrices can be arrived at from the quantities of materials, subcomponents etc. and the consumption of resources in the construction process of each particular project.

The element of the matrices, i.e. the intersection of subsystem and subfunction is a definitive characteristic of work activities on any construction process plan. (5) It answers the question "What?" regarding each work activity. Such work activities for a project may be expressed in a bar chart, critical path network, a line of balance plan, a cascaded matrix plan, etc. or any other construction plan which rationally displays the construction process. Because the cost of the work can be related to the work activities of the construction plan, the cost of each subfunction on each project can be obtained by adding up the costs of the work activities which have that element as their "what" characteristic.

The costs of each individual function within each subsystem can be added up to provide the cost of each subsystem. It follows that by the upward flow of such cost summations through the hierarchy that the total building direct cost is reached at the apex of the hierarchy.

CONCLUSION

To achieve lower cost housing while not impairing its performance requires more exact decisions by the designer on the relationship of performance and cost of the building.

To enable the designer to make such a quality of decision requires that his information be structured to help that decision-making process.

The building information structure described in this paper is such a structure.

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*This will be more fully described and discussed in the verbal presentation of this paper as will the consideration of nontechnological performance cost Externalities in the design process.

**This will be more fully described and discussed in the verbal presentation of this paper as will the relationship of construction process to cost and cost to design process.