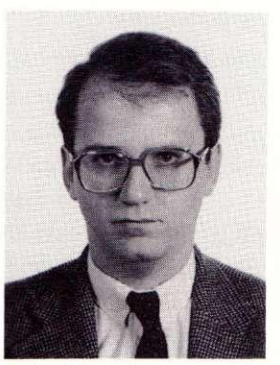
Evaluation and Formulation in Design

– the implications of morphological theories of function

by John Peponis



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Design involves *formulation* – the exploration of aesthetic aims through the manipulation of form – and *evaluation* – the examination of proposals with respect to functional performance. The emergence of theories of general function based on the representation and description of spatial morphology provides for better integration between design and evaluation. More importantly, it brings function within the purview of formulation.

SIMON THOUGHT that "design ... is concerned with how things ought to be, with devising artifacts to attain goals" (1969, p. 59). If we accept this definition for architecture, it follows naturally that we will want to evaluate the actual performance of buildings against expectations and use the results of evaluation either as feed back, to adjust buildings and their use, or as feed forward, to provide criteria for generating and selecting new alternatives (Preiser, 1989 b). As the processes of building programming, delivery and management become more involved, evaluation addresses facility managers and policy makers as well as designers (Rabinowitz, 1989).

How does evaluation contribute to the knowledge-base of design? It would seem that its contribution is linked to the development of explicit research paradigms and comparative frameworks. Yet, the growing number of Post Occupancy Evaluation reports have largely evolved without explicit theoretical foundations. The emphasis has been to improve design decision making, by providing information about building performance (Zimring, 1989). There have been early predictions that this approach was likely to lead to diminishing returns. Most notably, Hillier, Musgrove and O'Sullivan (1972) have pointed out that most design decisions are taken and most specialized information is used after the outlines of a basic solution have been reached. They suggested that solutions are, as a matter of fact, not produced at the latter stages of a process of *analysis and synthesis*, but right at the early stages of a process of *conjecture and testing*. Design conjectures, it was argued, are

drawn from implicit or explicit cognitive prestructures. Research could influence prestructures by contributing to the design, construction and testing of exemplar solutions. For all its merits, this approach would risk inhibiting creativity and raising problems of poor interpretation. The alternative is for research to work towards restructuring the principles through which designers develop and understand their repertoire of fundamental solution types. I will discuss certain issues that arise within this perspective.

Morphological theories of general function

The way in which the design of buildings affects patterns of behavior and space use would seem to call for specialized evaluations and fact finding. After all, the growing number of functional building types seems to be complemented by a trend towards greater specificity, complexity and sophistication regarding functional requirements. Pushed to the extreme, the question of social, organizational and behavioral function would seem to challenge the very idea of a generalized competence to design buildings. In what sense, if any, can we hold a general theory of building function?

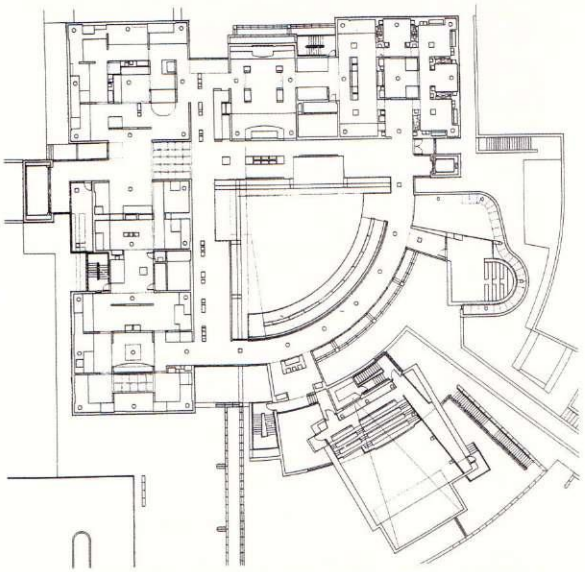
It has been proposed (Hillier, Hanson, Peponis, 1984) that we should draw a distinction between specialized functions which are particular to a building type, and general functions which seem to transcend types. The techniques of analysis that are associated with *"space syntax"* have been instrumental in the development of a testable theory concerning at least one general function, namely the creation of a *field of movement, awareness and encounter.*

As buildings grow large, their spatial layout seems to have a consistent probabilistic effect upon the pattern of movement of their users. The identification of these effects has depended upon the appropriate representation of spatial layout. So far, the analyses associated with "space syntax" have relied on three kinds of representation. Layouts are first described in terms of the longest linear stretches of visibility and permeability that link their parts to one another. The minimum set of such linear components that covers the whole layout and makes all the available connections is called the *axial map*. Layouts are also described in terms of the largest areal components that are fully visible to a user from any of their parts. The minimum set of these components is called the *convex map* (Hillier & Hanson, 1984). Finally, layouts are described according to the range of visibility from any of the points of an axial or convex component, by adaptation of the definition of the *isovist* originally proposed by Benedikt (1979). Figure 1 gives an example of these representations.

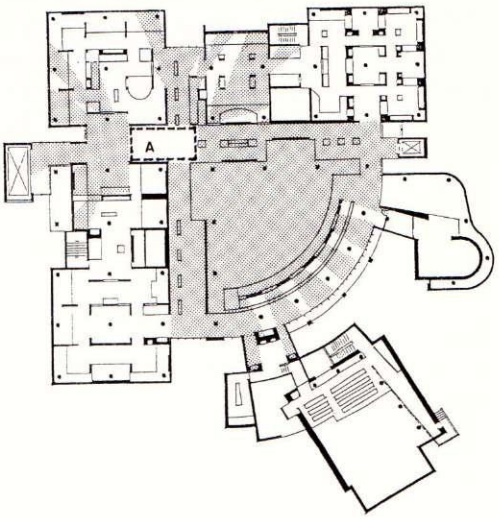
On the basis of these representations we can quantify the properties of layouts as systems of connections. *Connectivity*, measures the number of direct connections from a space. *Integration* is a function of the number of other spaces that must be traversed to reach all the other parts of the system. *Choice* is a function of the number of routes that go through a space. Using some device of visual differentiation to map the rank order of spaces according to such measures back into the original representation of a layout, we can obtain a picture of its underlying spatial structure, including the set of spaces which constitute the spatial core of integration (see Figure 1).

It turns out that this is also a picture of systematic properties of the pattern of space use. More precisely, syntactic properties, and most notably integration, are correlated with the density and distribution of movement (Hillier, Hanson, Peponis, 1984; Peponis, 1985; Hillier, Penn, 1991). By implication, the syntactic properties of layout create a potential for encounter. This maybe strengthened or weakened depending on whether major uses are syntactically linked to the spatial core of highest encounter potential. As this happens, the organizational culture of meetings and formal communication is complemented by a broader spatial culture of awareness and socialization.

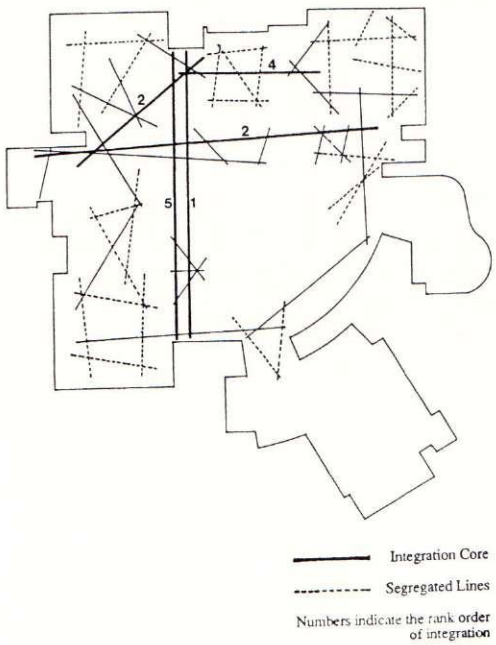
Movement, encounter and awareness, are seldom thought to be the main goals when buildings



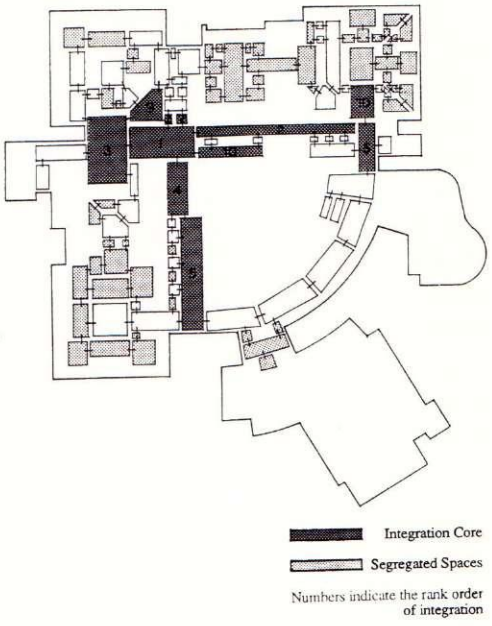
Second floor plan of the High Museum of Art in Atlanta (Architect: Richard Meier, 1983).



Isovist diagram for a selected space.



Axial map showing the pattern of axial integration.



Convex map showing the pattern of convex integration.

Figure 1. Spatial representations of a building plan.

are programmed. Rather, they are the means whereby social and behavioral goals can be handled by designers. Each of the articles mentioned above discusses the different ways in which the explicit and more specialized functions of particular building types are affected by the general function. Some organizations, for example, seek to maximize and to draw the greatest advantage from spatially sustained encounter within the work environment in order to maintain a competitive edge in the performance of tasks that do not lend themselves to routine and proceduralization. For other organizations, spatially generated encounters may be a secondary consideration, something to be directed to specialized amenity areas or to be controlled altogether. The fundamental insight, however, is that design operates against some background of lawfulness and that lawfulness is itself rooted in the properties of form. This, above all else, defines the morphological approach to the study of buildings and their functions.

Research is likely to extend and modify our current knowledge by correlating the properties of layouts mentioned above with further aspects of space use and performance. Additional general functions may become better understood. For example, all buildings can be analyzed as explorable patterns of space. The intelligibility of spatial layout to first time visitors may be a primary concern in the design of museums or hospitals and a secondary concern in other building types. Whatever the case may be, there are indications that the syntactic properties of layouts determine the ways in which buildings are explored (Peponis, Zimring, Choi, 1990). Given that the morphological analysis of function is a relatively new field, the fundamental advances in the longer term are likely to arise from our ability to represent and quantify the properties of architectural form itself in new ways.

Using morphological evaluation to make design more intelligent

Research that directs itself to a better understanding of the morphology of the object can interface with design more easily. In recent years, space syntax has been frequently used in urban design. I will, therefore, deal with the application of morphological evaluation to design at this scale first. The use of space syntax has proceeded from the following premises: Analysis has shown that in traditional urban environments, the pattern of integration of streets determines the diffusion and density of pedestrian and vehicular movement over and above the effects of land use (Hillier, Burdett, Peponis, Penn 1987; Peponis, Hadjinikolaou, Livieratos, Fatouros 1989; Hillier, Penn, 1992). This has implications not only regarding the provisions for pedestrian and vehicular traffic, but also regarding land use (since economic vitality often depends on liveliness), safety (since the presence of other people provides a safeguard against crime), and community (since the awareness of others is fundamental to urban society over and above interaction or common beliefs).

In a typical project involving the design of a large urban site, space syntax is used first to analyze the larger context, frequently extending to a radius of more than one mile. Pedestrian movement patterns are observed in a sample of spaces around the site in order to test for the expected correlation between movement density and spatial integration and to establish a working model of the system. The analysis is used to determine which links have a greater potential to become entryways into the site and conversely which connections are likely to be used less frequently. The analysis is also used to test which routes *through* the site are likely to contribute more to the integration of the larger urban fabric as well as to attract movement to themselves. At the earliest stage, the routes may be drawn intuitively or be derived from extensions of the surrounding grid or by overlaying the site with some arbitrary regular grid. The aim is to use analysis in order to arrive at some basic configurational design premises. For example, the shape of major routes and the primary connections to the surroundings may be sketched in outline.

As full design solutions are proposed they get analyzed on their own and as parts of the larger context to test whether the structure of spatial integration is appropriate to the aims of the designers. This involves checking whether the intended grading of movement is consistent with the pattern of integration and also whether the assignment of land uses matches the likely densities of movement. Thus, design and analysis proceed interactively. As design aims become better defined, and as the constraints arising from the relation of the program, the site and the context are better understood, the analysis helps to generate further principles to guide design.

Unfortunately, there are no projects finished on the ground that could enable us to examine the accuracy of syntactic predictions and the appropriateness of syntactic prescriptions given some design aims. Regarding the present argument, however, it must be noted that, according to the above account, space syntax was used as an objective analytical technique which is fundamentally neutral to the aims of the project. It contributed as a tool for testing solutions but it also helped as a heuristic device to explore solutions.

Formulation in design

Design is about formulation over and above problem solving. Scruton has expressed this well by suggesting that design is about the intimation of aims that cannot be stated in advance of their realization (1979, p. 228). I would like to describe "formulation" by referring to a well known example. In his "*five points of a new architecture* ", Le Corbusier presents the grid of structural columns, the unconstrained arrangement of partitions in plan and of openings in elevation, the roof garden, and the strip window as generative elements of architectural form (*Oeuvre Complète, 1910–1929,* p. 128). He sets his proposals in contrast to the vocabulary of traditional architecture, thus linking the enunciation of new ideas to the presentation of a systematic comparison. The comparison clarifies the overall internal coherence of traditional and proposed design practice as well as their difference point by point. Later, Le Corbusier produced a comparative sketch of four of the houses that he designed according to the five points (*Oeuvre Complète, 1910–1929*, p. 189). He showed one clearly irregular composition and three cases where irregular shapes are set within the framework of a regular structure. Evidently, the diagrams represent an attempt to come to terms with the dialectic between irregularity and regularity and to retrieve a description of the compositional principles that arise within the discipline of the five points. For example, Le Corbusier suggested that the dense packing of irregular shapes to fill a regular perimeter is most difficult and satisfies the spirit, alluding to the villa at Garches and to the compositional devices and outcomes that Colin Rowe (1976) has described so well.

These statements illustrate how design involves self-imposed compositional disciplines, over and above the satisfaction of the programmatic requirements and the negotiation of the geometrical constraints involved with individual projects and sites. It would seem that formulation in design is about the enhancement of our sense of morphological possibility through a clear grasp of alternative principles of composition and coherence. Le Corbusier is unusually explicit in stating the principles of formulation in quasi-theoretical fashion. In this account, however, we miss out an essential dimension of design, namely the design of function as an implication of form. The question is whether function can be brought within the purview of formulation.

Aspects of morphology and function in museum settings

I would like to use museums as an example in order to deal with this question. Museum functions include the systematic arrangement of objects in space for the purposes of display, enjoyment and education. As visitors explore spatial arrangements, they become aware of classificatory principles and comparative possi-

bilities. This raises questions concerning the relationship between layout and patterns of exploration. Museums are also public buildings which turn display into a social occasion by generating encounters as a by-product of the exploration of space. This raises questions about the relationship between visitor encounters and the patterns of circulation and visibility.

Yoon Kyung Choi (1991) studied both kinds of questions in eight museum settings in the USA, using syntactic concepts and techniques. Choi's analysis of visitors' paths showed that more people visit spaces that are more integrated. At the same time, the frequency of visits, including repeated visits by the same person, depends on the connectivity of the space. Both kinds of correlations arise in layouts which do not impose a single viewing sequence to equalize the spatial attraction of different spaces. We can, therefore, distinguish between probabilistic and deterministic implications of layouts over patterns of movement and exploration.

Probabilistic systems have interesting properties. As museums grow larger, the paths of people become *selective* rather than *exhaustive*. From a curatorial point of view, the interesting question is whether selection is biased towards certain spaces. Choi found that more integrated and intelligible layouts are more evenly used over samples of visitors even though they allow individuals to be more selective.

Choi's findings are no less interesting regarding the pattern of encounter. The numbers of people *in* museum spaces were not correlated with the syntactic properties of the spaces nor with the number of objects displayed *in* or visible *from* them. The number of people visible *from* spaces, however, was correlated with the strength of the isovist, and this was in turn correlated with syntactic integration. Thus, the awareness of other people is related to the experience of spatial structure, not only as a series of direct visual impressions but also as an overall pattern of relationships.

Museum layouts, therefore, have consistent and subtle effects over the ways in which people explore space and become aware of one another. Understanding this overall lawfulness provides the ground for developing new comparative frameworks and through them a better understanding the morphology and the functions of museum buildings. In turn, comparisons lead to new conceptualizations of the potential goals of design and of the strategic alternatives that are available when the earliest design conjectures are formulated for a particular project.

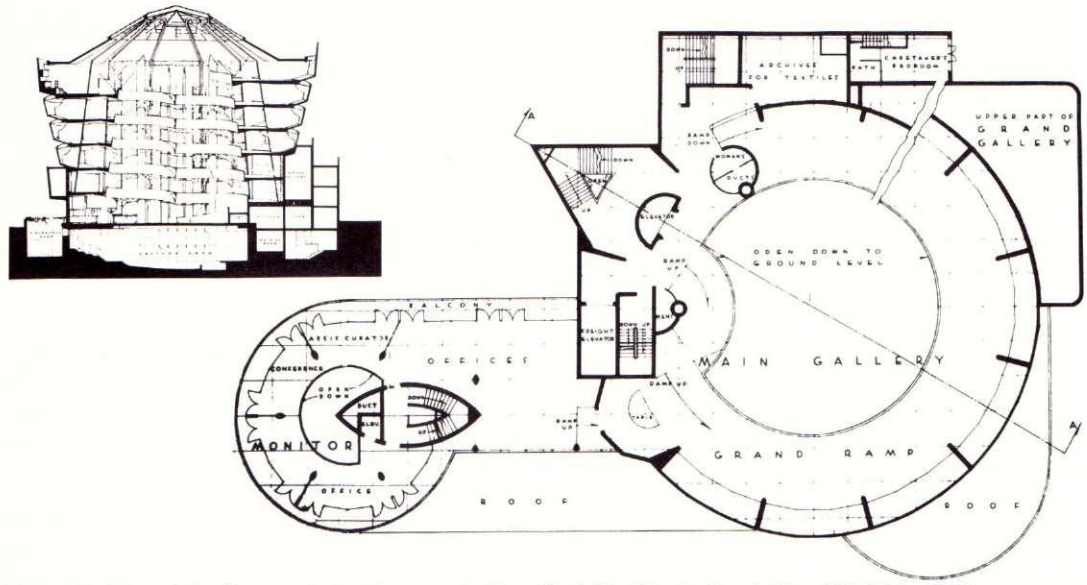


Figure 2. Plan of the Guggenheim Museum in New York (Architect: Frank Lloyd Wright, 1958).

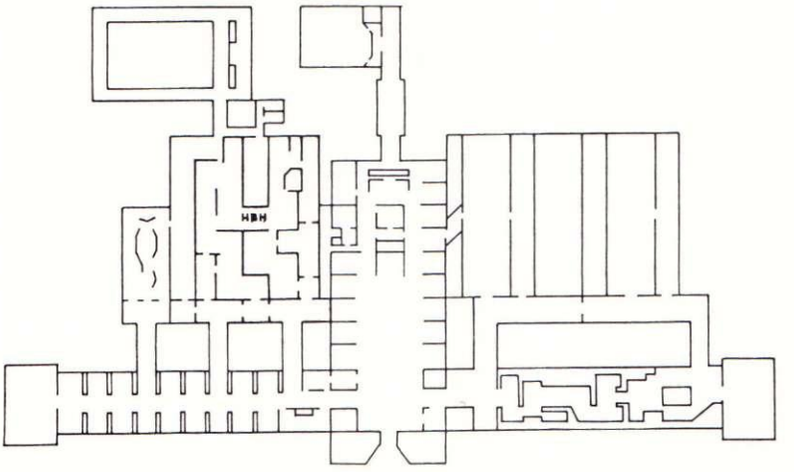
Morphological comparisons and the formulation of strategic design alternatives

Finding the right balance between different requirements is essential to the resolution of design problems. In the case of museums, comparative analysis suggests that three spatial considerations are included among other design concerns. First, public spaces associated with the identity of the building as a whole, such as foyers and major circulation routes, must be linked to spaces associated with individual exhibits. Second, the appreciation of the museum as an architectural object has to be balanced by the creation of exhibitions which are effective in communicating their own messages and impressions. Third, the scale of the building as a whole has to be interfaced with the varying scales of the exhibits.

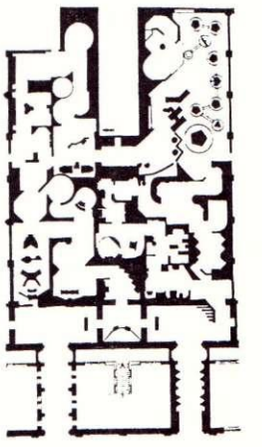
For the purposes of keeping the argument brief, the range of alternative resolutions of these dilemmas can be illustrated through reference to radically different examples. In the Guggenheim Museum (Figure 2), the public space of the atrium dominates over the viewing spaces for the different paintings. The major flow of circulation leaves no room for alternative paths nor for probabilistic effects of layout over exploration and encounter. The potential communication of exhibition messages is limited since it is hard to suggest spatial groupings. The interface between the individual painting and the building as a whole is direct, even if the direction of viewing is centripetal when one looks at the building and centrifugal when one looks at the paintings. Thus, scales of viewing come together into a single experience.

In the Human Biology Hall which is designed into the old fabric of the Natural History Museum in London (Figure 3) frequent changes of direction as visitors move into and around the exhibition prevent any sense of orientation with respect to the building as a whole. The architecture of the building recedes as the complete environment becomes an exhibit. While models and displays are constructed at different scales, the overall experience is limited to a sequence of local exhibition clusters and any reference to a larger scale is carefully controlled. There are limited choices in the overall sequence from the entrance to the exit but there is a larger number of local alternatives as visitors negotiate the route around individual exhibits within the general progression of the exhibition.

Thus, viewing sequence is explicit in the Guggenheim and implicit in the HBH. The ar-



Diagrammatic plan of the Natural History Museum in London (Original architect: Alfred Waterhouse, 1881), showing the location of the Hall of Human Biology.



The spatial organization of the Hall of Human Biology.

Figure 3. The Hall of Human Biology, Natural History Museum, London.

chitecture of the building dominates over the exhibition in the first case but becomes an invisible scaffolding in the second. The sense of global scale is celebrated in the Guggenheim but eliminated in the HBH. Over and above the different exhibition contents and messages, we are dealing with dramatically different spatial experiences.

Syntactic analysis can be used to illuminate the subtle logic of a third and very interesting alternative which is represented by the High Museum of Art in Atlanta whose plan was offered in Figure 1. Conventional architectural criticism would readily identify several interesting properties. An atrium space with a ramp, reminiscent of the Guggenheim is combined with the provision of intricately subdivided exhibition areas. The relationship between the atrium and those areas is mediated by balcony-galleries. A clear structural grid defines the edges of the atrium and marks the main direction of movement in the exhibition areas, while at the same time deflecting the paths and slowing down the pace. There is a layering of light from the bright exterior to the shaded zone of the ramp, the top lit atrium and the darker exhibitions.

From a syntactic point of view the atrium is a space of social occasion. There, other visitors occupy the foreground and displays recede to the background. The narrow ramp imparts movement with a processional character by restricting its direction and speed. In the galleries, paths can vary but still converge in their overall direction thus generating predictable encounters. Encounters become less regular and shorter in the exhibition areas, where the works of art assume the foreground and visitors appear at varying depths in the visual field. This is due to the nature of subdivision rather than to the presence of many circulation alternatives. Indeed, there is a relatively limited number of entries from the galleries into the exhibition areas, and once inside these areas there is a single general direction of movement in spite of the local bifurcations of paths.

These properties allow the museum to act like a built choreography of movement and encounter. Analysis shows that movement paths converge in the use of the atrium and gallery spaces and diverge in the selection of exhibition spaces. There is no further pattern of correlation between spatial properties and movement densities. The rate of awareness of other people, however, is very strongly correlated with integration.

The design also allows for some flexibility in the arrangement of exhibition messages. There is a plurality of ways and of scales for grouping objects, suggesting alternative comparative principles. It is possible to use the whole floor for a single and longer exhibition, or to have several independent sequences with their own entries and exits. More importantly, the isovist from the exhibition areas is regularly allowed to penetrate towards the atrium, thus providing visitors with a sense of the larger scale of public space to punctuate their experience of exhibition messages.

Two syntactic properties play a key role in the spatial structure of the building. First, the integration core encompasses the gallery spaces around the atrium and the entries into the exhibitions (Figure 1). Thus, the core works as an interface between the different spatial qualities of the museum. Second, visibility is always more extensive than direct axial permeability, so that while movement is determined or even restricted, awareness is allowed to remain more flexible and expansive. These properties define a distinctive museum morphology which involves a direct interface between two domains and two scales, one where social encounters and the architectural order are primary and another where social encounters recede and the architectural order is manipulated to accommodate exhibition messages.

The above argument demonstrates how the same analytical framework can be used to develop morphological theories of function and also comparisons aimed at clarifying strategic design alternatives. The two aspects of the analysis are

complementary. By understanding the lawfulness that underlies function we can begin to evaluate designs. By understanding the formulation of function we can begin to set appropriate evaluative criteria.

The use of an analytical approach to study formulation requires more than systematic comparison. It requires that normative questions be asked about buildings. The normative question implicit in the analysis offered above concerns the relationship between design, pedagogy and socialization in museum settings (Peponis & Hedin, 1982). I believe that normative concerns do not contradict the claims to objectivity if they are addressed back to the record of evidence before they are projected forward into new design. The essential point, however, is that normative questions themselves can arise through the interrogation of designs and our intuitions about them in the light of what we come to understand about morphological function.

Design as solution and design as formulation

Hillier (1985) has pointed out that in equating them with the study of design process and method, Simon (1969) implied that the sciences of the artificial do not concern themselves with the laws of the artificial object itself. Rather, they deal with the adaptation of the laws that govern the object and the laws that govern the environment to some human purpose. The criticism is fundamental. It is not immediately self evident because Simon draws many of his examples from engineering, where the laws that govern the object and its environment belong to physics. Hillier is certainly correct in pointing out that cultural artifacts, including architecture, have their own laws that are a proper, legitimate and central concern for the sciences of the artificial.

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I believe that a second criticism can also be leveled against Simon (1969). His analysis seems to assume that purposes are given before design starts, and that design is essentially a process of generating and evaluating alternative means towards specified ends. This leaves out an essential component of artifacts as intellectual constructions. Sometimes, the aims of design are not fully known before design begins. This certainly applies in the realm of aesthetics. I am arguing that the same can equally apply to function. Design is about trying to understand the laws of the artificial and through this about trying to formulate functional aims as well as aesthetic ones. This may remain obscure while we equate function with specialized requirements. The development of morphological theories of general function, however, carries with it the possibility that function, like aesthetics, becomes better understood as the subject of formulation.

Indeed, at the root of architecture as a cultural artifact, aesthetics and general function are less easily distinguishable. For example, architecture is about being seen as well as seeing (Kourkoulas, 1986). The modulation of the reciprocal relationship of the gaze through the arrangement of boundaries and connections lies at the foundations not only of its social function but also of its aesthetics. Le Corbusier's diagrams of formulation concern the dialectics between the intellectual constructibility and the aesthetic experience of the unpopulated architectural object. The arguments presented here concern the interaction between the spatial arrangement of society and its aesthetic experience as movement and encounter in populated built space. Both dialectics are equally germane to architectural formulation.

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