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Notes on 'Open Systems' in Building Technology

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Careful reading of the literature, in light of recent developments in theory and practice in building, suggests that systems theory as understood in the field of building technology is ready for updating. These notes support the movement in 'systems' discussions toward an explicit recognition of the concept of control—or the action of assembling or transforming elements in the staged assembly of buildings. The notes suggest that technical issues, while critical, are insufficient to explain innovation, failure or other aspects of change in technical systems for building. A more adequate understanding is, it is argued, necessarily linked to questions of control.

INTRODUCTION

RECENT departures from 'conventional' research and practice (in particular in the USA, Japan and the Netherlands) in the fields of design and building technology have made it possible to raise new questions about the utility of the concept of 'systems' as it has generally been used in the past 30 or more years in those fields.

It is interesting to raise these questions because 'systems thinking' is so predominantly accepted as the model for understanding design and building processes, and for providing the intellectual muscle to the continued development of building technology. However, events in the field are cause for reflection. There is a very large gap between the high expectations for the application of 'the systems concept', and the results and even successive failure over many years of efforts to innovate successfully in building technology, rooted explicitly or implicitly in 'systems thinking'.

If these observations have merit, there is also reason to question the conventional distinction between what are called open and closed systems. These concepts, too, have appeared in the literature on building technology over the same period, and seem also to be rife with confusion, and are also the cause of disappointed aspirations.

In brief, the research and practice referred to—which has broken some of the conventional modes of thinking—has made several important distinctions that seem to clear up some of the confusion we have experienced from an overdependence on open and closed system concepts.

The first is that a distinction should be made between man-made physical systems and natural systems. This is an important one, because it aims to put people, and intervention by people, back into systems language we use in understanding the built environment. A second is the distinction between levels of technical systems and levels of control, as we can understand them by observing change [1]. Both of these ways of seeing the physical world have brought with them a recognition that control is the central distinguishing measure of man-made systems. Shifts in control among disaggregated powers, not fixity of control in one power, are indicators of great significance to explaining fundamental principles of the built environment of concern to designing and building.

Unfortunately, most research in building hardware has ignored questions of control. Most work attends either to matters of physical properties, or to matters of social organization. The reciprocal and dialectic relations have by and large been bypassed in research. They have, when they are recognized, been taken for granted.

The work of Habraken, Dluhosch, Hamdi, Akbar, Gross, Wang and Kendall (US); van der Werf, van Randen, Carp, and Bax (the Netherlands); Ando, Sawada, and Utida (Japan), and others, in design methods research, architecture practice, building technology and computer methods, begin to demonstrate a new paradigm.*

These matters are of more than academic interest. It is current in industry circles in the USA at least, to once again discuss the need to 'industrialize' building; to sug-

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* Reference is given to work of several researchers and practitioners: *Habraken*'s work is noted below; *Kendall*'s work is in the area of SHELL/INFILL studies in US 2×4 construction, and in the development of methods for mapping interactions of control and hardware in the staged assembly of buildings; *Gross*'s work in computers and design methods deals with Design as the Exploration of Constraints (PhD Dissertation, MIT); *Wang*'s work is in Ways of Arrangement—Basic Operations of Form Making (MIT PhD); *Hamdi*'s work is in Support Planning Methods for housing and settlements in developing countries (MIT); *Dluhosch* (MIT) works on prefabrication and maintenance strategies. In the Netherlands, *van der Werf*, *van Randen*, *Carp* and *Bax* are in practice, research, and teaching dealing with methods to enable coordinated reorganizing of control in building processes. In Japan, *Ando*'s work deals with industrialized vernacular housing practices; *Sawada* deals with the introduction of new decisionmaking levels in housing technology; *Utida* studies production and technical issues in component coordination.

gest, again, the automobile industry as the exemplary model for housing, of aggregated demand and streamlined assembly (while the USA automobile industry is rapidly spinning off divisions to a model of decentralized 'out-sourcing'—a model of disaggregated control which the Japanese automobile industry has adopted and which the USA industry is scrambling to follow) (E. Westney, personal communication); and to write books on building systems integration, once again attempting to give an 'objective' technical classification scheme of systems and systems interfaces.

These movements suggest that the image of 'industrialized' building, a misnomer and contradiction in terms itself and the language of systems and all that it brings, is still powerfully framing our research and practice.

NOTES ON READINGS IN THE 'SYSTEMS' LITERATURE

Dominating the writing on 'systems' in my own field of design and building technology is an almost unbelievable faith in the power of individual minds and collective bodies to develop and implement 'total, coordinated, integrated systems' for building (terms often used), to replace the 'fragmented', ' unsophisticated', 'laggardly', 'uncoordinated', 'craft dominated' procedures and hardware (also terms used) we find in the industry as it now stands.

The impression easily taken away from reading this literature is of a whole professional theology, with perhaps the best of intentions, but with a presumptuousness that is quite remarkable if one steps outside the professional circles. What is being proposed is nothing short of a completely unified (read controlled) constructed environment, unified by the exercise of professional intelligence, reason, scientific method, and of course professional judgement.

It is tantamount to a kind of tyranny of the professional in the domain of environmental form; or so it seems from the writing. On the other hand, there is little recognition that professionals have never managed to control the built environment—and should not if they somehow could. The built environment's existence does not and cannot rest on professionals. If professionals who claim expertise in building technology did not exist, buildings would still be built. This is not, of course, to argue that professionals and experts have no appropriate roles, but only to put our role into perspective.

The writings referred to are also a very clear manifestation of the ideology of autonomous progress, a belief that progress is an inevitable outcome of rational human behavior. The obsession with certitude, and the attempt to split method from context creates the conceptual core of the ideology of progress which seems to be so evident in much of systems talk in our field.

Part of this belief pattern is a presumption of the superiority of professional wisdom (witness even Christopher Alexander's provocative repositioning of the newly merged architect/builder into the center of housebuilding [2]). Also part of this pattern is the presumption of control by professionals over the making of the environment. It is possible, and desirable, so the thinking goes, for professionals to make systems, an idea which is not an apt description of a causal link between people and the kind of artifacts we so depend on for making buildings. Man-made physical systems are cultivated, not made. The distinction is not insignificant. What is also apparent is the lack of evidence that many of these presumptions have produced results, in their terms, compatible with expectations, in buildings or practice.

What is it that drives this belief in the capacity of professionals to 'invent' 'total systems' for buildings, despite the evidence to the contrary? Herbert begins to discuss this [3], but it too seems to look at the phenomena from within the logic of the thinking that has failed to produce the expected and sustained results. Russell almost breaks free [4] and Habraken does manage to break the bindings, by introducing important new concepts to the discussion [5, 6], some of which are found in this paper.

It is clear that we do not know very much about how human artifact systems come into being. The fields of anthropology and archeology and the work in what is called 'material culture', have useful insights about this [see e.g. 7]. It may be that artifacts emerge first as types; then they *may* become systems as they are adopted into general use by a constituency, and developed into what might better be called 'thematic systems' [8], distinguished from systems in nature.

OPEN AND CLOSED SYSTEMS

If we want to probe, and go beyond these concepts of systems and the associated ideas of open and closed systems, how can we do it? One technique is a rhetorical one, illustrated below in which we say, in an imagined discussion, 'What we want is to find out when we say open and closed system; what characteristics do we identify when we recognize one?' What follows are some propositions in response to this question.

(1) If I only know one system, then it may seem open, but as soon as I know two, then each may seem closed, if I have no access to the other one. That is, if I think I know my universe of elements and how the elements relate to each other and to me, then I may well believe, since it is all I have, and I know of no other, that it is open. If another system were to appear, I might not, then, see two systems, but instead a larger more elaborate single system from which to make my artifacts. This may require some adjustments and unforeseen relations, but the act of seeing the two as one implies a process of understanding how the systems might work together for my purposes. On the other hand, perhaps I would see two systems, separately. This would imply that for my purposes I could see no fruitful interactions between the two systems, and I would therefore conclude that I was seeing two closed systems. As soon as I begin to see fruitful ways of using the two systems together, I open two closed systems into one open system.

If I know concrete blocks and mortar, and it is all I know, then it is an open system to me. If a new element is brought in, e.g. rebar, then suddenly it may seem that the blocks and mortar constituted a closed system, because a new element not there before has arrived. But then, it snaps back to being an open system, once I learn to use the new element in it.

(2) A system may be brought forward by someone. It has parts and the parts have definite relations to each other. It stands apart from other systems in certain respects, it has a name, although it is derived from the shared repertoire of more rudimentary elements, and uses elements also found in other systems. But no one wants to use it, even though it is being produced, marketed and distributed. Then, a few people begin to use it, and later it becomes widely used, and widely available; different producers make parts of it; variants of it emerge under different labels; and people use it in many unforeseen ways. Then, its use begins to wane, it loses producers, markets, and finally disappears from circulation for all intents and purposes. In this development–deployment–decay–disappearance process, the system has moved from a closed to an open system and back to a closed system.

(3) If I saw a system, but did not know how to get or use it, I would call it closed, to me, although I could observe that someone else could find it open, since they could get it and had the knowhow to use it.

(4) 'Breaking the rules' is a move to open up systems that may seem closed. For example, making a wooden addition to a mobile home; making a traditional Japanese wooden addition to a Misawa Palc/steel frame prefab house; putting a double hung window into a Techbuilt house, which typically uses horizontal aluminum sliders; these are moves which, to someone seeing the things added to as systems, would be breaking the rules, but to someone who does not distinguish the starting points as systems would see these moves as simple transformations in a larger system which is inclusive of the elements in the above moves.

If I don't recognize something 'A' as a system, while to someone else it is, and if I introduce a new element, someone else might say the new element is 'outside' the system 'A', while I, not having recognized 'A' as a system, will say that the new element is not outside, but is part of a larger array of availabilities which also includes the new element in its universe. I might then call this wider universe an open system.

(5) Systems in the built environment are entirely what people agree to make them. By defining limits to a system—limits in the possible universe of elements—we close it. By naming a system, we close it. Therefore, every system identified by people is a closed system, as long as people share the naming of it.

If I stand outside all these named systems, I see, if I look one way, a number of closed systems; if I look another way, I see one system in which these 'named' systems become simply element groups in an assembly hierarchy.

(6) Naming systems is a behavior of exerting control over a particular domain of the shared universe of environmental forms. Any complex set of elements can be named a system, as in mechanical system, structural system, wiring system, and so on. In most ordinary practices, one would never hear of open and closed systems, only useful or good designs. In fact, I would think that people would resist use of such terms since they arbitrarily constrain their freedom of selection of methods and elements from the wide universe of possibilities.

(7) As elements in a hardware repertoire become more rudimentary (unalterable), they become ready for use in many possible 'systems' and push toward open systems; the inverse also seems to be true: the more specific and complex elements become, the less frequent will be their use in other systems, and they push toward closed systems.

(8) If we want to close a system, we will act in three areas: acquisition, use, and transformation. We will make it more difficult to get, by controlling sources, distribution, as well as production; to make it more difficult to use, we will control the method of assembly as well as skills and approval and image; to make it more difficult to change, we can control configurations and assembly (making the subsystems irreducibly attached). Finally, we can exercise these aspects of control at different levels in the assembly hierarchy.

(9) If we want to close a system, we should assemble previously discrete elements so that they cannot be disassembled, so that, even though we can identify and name the elements, it is not possible to delegate responsibility for their control to different parties, nor is it possible to replace or interchange elements.

(10) To close an open system, it may be moved from a system in the public or shared domain to a system under single or monopoly control. This movement is hard to imagine. Most systems seem to move, over time, from something we conveniently call closed toward what we tend to call open, not the other way; they seem to move toward shared or vernacular systems, or to disappearance, not from vernacular to proprietary.

(11) To open a closed system, we could break up a particular control pattern, unlock a unibody technical configuration, or introduce a new element and recognize it as a legitimate part of the system.

What may emerge from these propositions is a picture not of certitude about open and closed systems thinking, but a picture of a relativity of these concepts that hinges on three factors: (a) if we define the level of assembly we are discussing in a technical hierarchy; (b) if we define the control of the configuration in question; (c) if we define the position of the observer in relation to the configuration in question; then we may come closer to understanding the complexity of systems talk. Further, we may need to introduce three other points of reference: (a1) the production of technical elements; (b1) the use in design/building; and (c1) the change over time. If we can study the interaction of these six factors, we may find out what lies under the efforts to simplify in language what is generally recognized as very complex interactions between people controlling technology, and the hardware of buildings.

LIMITS TO SYSTEMS CONCEPTS

The rest of the discussion in this essay deals with a presentation of some quotations from prominent books, and reports. They reveal to me some of the confusion that surrounds the use of 'systems' talk in the field.

The problem of concepts

Building 'systems talk' often seems based on a tacit modeling of hardware on the order of natural systems (e.g. biological, physiological, etc.). This supposition of the 'natural system-like' attributes of building technology, and the presumed 'objectivity' of particular hardware solutions with respect to values and human control, finds its place in efforts to develop 'improved' building technologies. Here we constantly find attempts to 'define' building systems in the same part-whole hierarchy familiar to the natural sciences, work which at least tacitly assumes an objectivity to these 'definitions'.

While there is nothing incorrect in this, it is simply, and damagingly, incomplete. These efforts have reoccurred for too many years, bearing little fruit. They leave out the socio-political dimension, a dimension not only excluded, but considered a nuisance.

The second most prevalent conceptual model is that of the machine. The discussion of interchangeable parts as a central characteristic of 'open systems' can be seen repeatedly. Fortunately or unfortunately, buildings are not machines, although machines can be placed in buildings, and are often used to make parts of buildings. Buildings are artifacts into which people enter for a full understanding of the artifact, while machines are understood as it were 'from the outside' (see ref. [9] for discussion of this seemingly obvious but nevertheless critical distinction based on the position taken by the human observer/user relative to the artifact).

The problem is one of concepts. The concept of an hierachy of systems and subsystems, drawn clearly and often explicitly from general systems theory, cannot contribute much more than it already has to knowledge in the building technology field, without the added dimension of an hierarchy of levels of control exercised by people, with all their diverse values and their conventions.

Critical to the introduction of this new variable, control, is that while levels exist in both the control and the hardware, they are often independent. What matters is to recognize them, to distinguish them, but not to separate them. Hardware cannot exist without control, and control of the built environment or any assembly in it is not possible without the artifact being there to be changed.

In recognizing these points, it may be possible to find out what it means to link a particular level in an assembly hierarchy with a particular level in the control hierarchy.

This of course puts people back into the conceptualization of hardware. It says that hardware is also people.

Systems thinking in technology, nurtured during the Second World War in the headlong rush to improve the implements of war, propelled researchers into a kind of accumulation of technical means [10], often devoid of response to any cultural definition of values or goals other than the rather unitary goals of 'scientific research'. This was an entirely understandable development under the circumstances, but one nonetheless insufficient for purposes of cultivating the hardware used in the staged assembly of buildings (if not elsewhere in man-made systems), in a highly disaggregated marketplace subject to change, multiple interactions and variety.

The problem of the concept of systems in our field and the recurring and apparently still confused search for the 'correct' definition, can be seen in these citations:

"Another important concern central to General Systems Theory is that of the open and closed system. A closed system is one in which there is no import or export of energy—the common example given is of a number of reactants brought together in a closed vessel. However, truly closed systems are hard to find and it is most useful to think of the terms as relatively descriptive and in this way they have a purpose. For a system to be identifiable at all, it has to have a degree of closure and it is again what constitutes that closure that is of interest. As many systems theorists are fond of pointing out the concept of the closed system developed from the physical sciences with their roots in Cartesian rationality . . ." [11]

"The prefabricator must choose between 'open' and 'closed' systems. The former are systems which have a general compatibility with components outside his own system; the latter are systems of components related only internally. While in the long run, *open systems are unquestionably more valuable, successful prefabricators have found that building lacks the industry-wide framework needed to make them function effectively* (author's emphasis) .... The bulk of the successful prefabricators, although their approaches differ, use a closed system. Parts are dimensioned and joints are designed to go together easily in a limited series of configurations." [12]

"Closed System—an industrialized building system which is internally compatible, but which cannot be combined with other functionally similar systems and does not therefore, permit the assembly of hybrid or mixed systems."

"Open System—an industrialized building system which is made up of components or subsystems which are interchangeable with those of other systems—through modular coordination and the use of compatible or standardized joining techniques." [13]

"If the utilization of precoordinated components in residential, industrial, or commercial buildings is to be achieved, both a closed and a nationwide open system will evolve. But, the closed systems will in all probability utilize the open system. In the chicken or the egg connotation, we feel that *only when we evolve complete coordinated control of distribution programming* (author's emphasis) will we be able to concentrate on the known market and generate sales to justify the true technical precoordination required." [14]

"SEF has added significance as the world's first truly open building system. (The subsystems in an open building system are widely interchangeable, whereas the subsystems of a closed building system are locked into one system)." [15]

"SEF was attempting to develop an 'open building system' as opposed to a 'closed building system'. . . . The development structure planned by SEF was purposely suited to an open, building systems approach. A *closed building system, such as the CLASP system* (author's emphasis) was rejected as it was thought to be too restrictive and tended to encourage a monopoly." [16]

"*In the CLASP system*, for the first time, though not explicitly stated, the desired interchangeability of components and their use for projects varying in size and design *led to a largely open system.*" (author's emphasis) [17]

Systems seem to have only functional criteria

Secondly, most of the systems talk seems to require a severe limiting of the actual complexity of artifacts finding their place in the staged assembly of buildings. This is accomplished in part by reducing the criteria for their analysis and deployment to functional attributes, reducible to quantitative measures. This seems to be part of the attempt to make the discussion compatible with presumed scientific, replicable, and testable methods, and the attainment of an objective status.

"It seemed reasonable to expect that there would soon be a variety of premanufactured systems available in this country. In the school house area, progress was well along and was being followed in other areas. Availability of a variety of components—structural, ceiling, wall, floor, partition, mechanical, and other—appeared imminent. NBS felt it would be highly desirable if development of these *components could be coordinated so that they would be interchangeable and compatible to form total, prefabricated construction systems* (author's emphasis). . . . It was believed that the philosophy of such coordination should not be to develop closed systems, but to establish guidelines for open systems so that all systems, components and parts could be fully interchangeable as far as possible. In addition, such an approach should provide for variety of placement and flexibility of design. . . . *The task appeared to be primarily an engineering task*." (this author's emphasis) [18]

"The further question arose as to whether the hardware specification should follow an 'open system' approach—where subsystems would be solicited from individual suppliers, thus to encourage the interchangeability of components; or a 'closed system' approach—where consortiums of suppliers would be invited to bid already-integrated systems of components. American, Canadian, and English precedents existed for both open and closed systems by the late 1960's . . . . *The choice between open and closed system ultimately reduces to a trade-off between freeing the designer to reach functional optimality or imposing on designers such constraints as are needed for deliverability, reliability, and economy* (author's emphasis). On the one hand, open systems offer for the designers of a specific building freedom to choose from among a great variety of standardized parts and allowing those designers to assemble one of a very large number of theoretically possible permutations of those parts on a specific site in a uniquely optimal way. Closed systems, on the other hand, strive for a maximum degree of subsystem integration with greater assurance of total system reliability and cost control, relinquishing some local designer autonomy and system optimization in the bargain. Presented with this dichotomy, the General Services Administration (GSA) it appears, struck a third choice between the two poles. That choice achieved some important BSP (Building System Program) objectives but also increased appreciably the operational difficulties of the program. GSA chose to treat the *total* federal office building and its site as an open system while treating the interiors of the typical office floor as a closed system." [19]

Unfortunately, functional criteria, while necessary, again are not sufficient. What is missing is the question of use by independent parties, bringing us to the problem of *capacity*, which is the complement to the problem of function. Capacity asks what is possible in a spatial configuration when it is occupied over its lifetime by different people with different patterns of behavior manifesting different values not under the control of the designer or builder. This is not at odds with function; it is the other side of the coin.

To distinguish a building from a machine, with which we most easily associate functional criteria, it is more correct to say "the environmental form is an object that invites performance and behavior of people, whereas the machine is an object that performs and behaves . . . thus we may speak of 'capacity' when we judge a form's quality as a context, while we may speak of 'function' when we consider that form's qualities as a thing." [20]

Systems aspire to validity at all scales

Systems talk seems to aspire to be equally valid at all hierarchical levels, from small building configurations to cities. The literature abounds with reference to images of technical artifacts from cars to cities, all understood as systems and subsystems interacting as 'total' systems, again devoid of any recognition of a socio-political context. The picture is confused.

"A further possibility may be contemplated, however. Mass produced units may be desired for use in any structure whatsoever. Such units could be used either for part of the structure (partially open system of construction) or they may be used for the whole of the structure, which could then be an assembly of catalog elements bought from different manufacturers (that is, a fully open construction). . . . It is clear, therefore, that these conventions on quality, shape and dimensions of open system units should be accepted by all, whether designers of buildings or manufacturers who want to establish a market for the open system. *A market of this sort could cover one region of a given country, or the whole country, or a group of countries, or indeed the whole world*." (author's emphasis) [21]

"What is the 'Open System'? Let me explain as I understand it. . . . An entire house can be constructed by amateurs if it is composed of 'open' components that can be readily obtained on the market. This is one of the ideals visualized by the advocates of 'Openization' of building components. If buildings are divided into components which are produced by specialized organizations, and if these components are standardized, the building can be produced at lower cost, faster, and with higher quality than at present. This is the aim of the 'Openization' of building systems. . . . In the field of industrialized building production, the system encompassing the construction of an entire building is considered a total system and the production of parts composing the total system are considered subsystems. Further, the production of subsystems has to be applicable not just to certain buildings, but to any building. The production of total systems from subsystems is regarded as a sure step toward realization of the 'Open System'. . . . *By recent definition, 'Open Components' comprised mostly nails and hardware, but now the scale of these components has been enlarged to room size* (author's emphasis). Further, rather than selling only components, many companies include the installation costs in the selling price." [22]

Systems apparently are at odds with complex social processes

Systems concepts in building technology seemingly seek to shed off messy social interaction problems in changing the hardware and assemblies which they claim to explain. The language of 'systems' building technology is typically neat and clean, abhorring the 'wet' trades, wanting unambiguous technical clarity, uniformly seeking to eliminate work 'at the site', seeking 'total integration' and thus eliminating 'complicating' decision-making levels. The language seems most comfortable with concepts of aggregated or unified control, and what is more, unified professional control, seen as objectively superior in all cases to lay or popular control.

"In broad terms, a systems approach simply means that a problem will be solved in an *orderly process that will define the goals, analyse the means of achieving them, and then carefully organize the actual achievement* (author's emphasis). In construction, the systems approach necessitates an improvement in building technology, but it demands a revolution in management techniques." [23]

". . . but systems would not have succeeded unless EFL had aggregated a market large enough to justify the cost of developing the technology." [23]

"Systems building projects have demonstrated a method of reorganizing the cumbersome building process into a rational, orderly process, *freed of the building industry's built-in frictions and obstructions.*" (author's emphasis) [24]

Systems has become the exclusive language

Finally, systems talk has come to be the accepted, perhaps even the exclusive language by which to discuss questions of 'binding together all the discordant phenomena'. [25] This is perhaps the most interesting and troubling development, in light of what is excluded from consideration in such conceptual ordering of the world of the built environment.

The rift between what can be observed in the non-professional's tacit knowledge of the varietry of control of building technology, and the presumptions suggested above, often taught in schools of architecture and engineering, can lead to extreme schizophrenia. It is possible to observe this struggle almost daily in the language and behavior of designers and builders who have one foot rooted in serious praxis, and the other foot rooted in the recent traditions of derivative theories which mantle our field.

"These men—Fuller, Wachsmann, Gropius—saw the totality of the whole and the significance of the part as reciprocal aspects of an integrated system. . . . The concept of 'system' was beginning to enter into the architect's thinking at that time, although the term itself was not then in common usage. In the intellectual climate of the twenties and thirties the idea of the system was emerging to find expression in diverse and challenging directions. (The emergence of the idea of systems has been summarized in ref [26].) [27]

"A variety of images is conjured in the mind by the phrase building system . . . how is it . . . possible that the notion of a building system has come to mean something quite specific both to architects and to the public at large? Part of the answer lies in the relationship between the ideals of the modern movement in architecture and industrialization. Whether called prefabrication, building systems, systems building, or industrialized building, the *name has usually carried assumptions which favor, encourage and reinforce the necessity of applying the methods of industrialized mass production to the building process.*" (author's emphasis) [28]

CONSEQUENCES OF CONCEPTS AND TERMINOLOGY

It may be that some readers will become impatient with this, seeing the argument as 'simply' one of terminology. This should not be the case, however, as soon as the consequences of the uses of a particular terminology are considered, because terminology is deeply connected to the concepts that we share.

In our case, it is the question of the technological ambience—and specifically the 'measure' of this context in the concept of control—which is absent from systems talk. It helps to understand that the question is in large measure a matter of cognition, as Edward Constant points out in his discussion of the cognitive and social dimension of what he calls a 'technological paradigm':

"We define a technological paradigm as an accepted mode of technical operation, the usual means of accomplishing a technical task. It is the conventional system as defined and accepted by a relevant community of technological practitioners. A technological paradigm is not just a device or process, but, like a scientific paradigm, is also rationale, practice, procedure, method, instrumentation and a particular shared way of perceiving a set of technology. It is a cognition . . . a technological paradigm is passed on as a tradition of practice in the preparation of aspirants to its community membership." [29]

We can perhaps see that our use of the concept of systems has become a tradition in a particular community of interest, and that it is not intrinsic to the artifacts of the world of building. It is one way of seeing the world. We have somehow agreed to call things we use to build with, systems, in much the same way that we employ conceptual shorthand to grasp other complex phenomena.

What is being suggested in this essay is that this tradition needs to be reexamined, and amplified, because this conceptual tradition may be both too coarse and just conceptually inadequate as it is understood and used in our field.

Not only that, however, because after many years of adherence to the structure of thinking typically associated with the systems concept, after great intellectual energy put to exploring this way of ordering the world in building, and after great expenditures of financial capital to 'systems' development, we see very little in the way of either projects or more substantial methodological developments, which we can attribute to this conceptual framing.

It is particularly telling, to this writer, for example, that such an interesting project as the SEF school building initiative should be claimed by someone we assume to be knowledgeable in the field, to be the "world's first truly open building system" [30]. This statement tells us what is excluded from that observer's consideration for membership in the august ranks of systems, and open systems, where this view of the world places its most respected examples.

One example that this way of seeing ignores is the remarkable North American 2×4 building strategy, whose history and application suggest that it much more aptly fills the requirements of an open system, if we need use the term. This way of building has remained stable for 150 years, entirely within the requirements of industrial production of building elements, and an often ignored synergism between professionals and non-professionals, producers and users, and the manufacturing and service sectors.

It may be, as with other movements in our field, that we now need to reexamine the assumptions, extract some general principles, and use the work of the people who have developed the logic of systems thinking as a building block in developing a new generation of concepts for our work of managing complex environments under conditions of change and disaggregated control. These notes should be read in that light.

What we may need, to avoid the limits of terminological definitions, but to gain a clarity of thinking, are new methods for mapping the interactions between the elements out of which we build, and the control that is exercised over them by people, when they design, build, and change their physical environments.

Such a mapping method would certainly help in revealing distinguishing characteristics of our field of endeavor from that of the physical sciences, who necessarily attend to the matters of hierarchies of natural systems, and it would also distinguish our work from the social sciences. It would be possible to say with justification that it is really only in the field of environmental design that the relation of people to environmental form is found as the central question of practice and research.

CONCLUSIONS

It may be so simple as to say that we should forget about using the concepts of open and closed systems. The distinction seems no longer useful; in fact, it may positively be a hindrance to development of the necessary clarity of thinking which is needed.

But it is not necessary to criticize the proponents of this picture of building technology, who have developed these ideas over the past 50 years. That work may have been quite appropriate at the time; it should now be built upon, not thrown out.

It may be justifiable to suggest, however, that new issues present themselves today, and make us move further on the basis of what we have been taught by the experiences of these past years of attention to the concepts of systems.

The pressing issues are principally those of variously disaggregated patterns of control of variously disaggregated elements and assemblies of buildings under conditions of change. Concepts of open and closed systems will no longer suffice; nor will a narrow focus on the interface problems of 'integrated building systems' provide the leverage that we need.

We need a more precise picture of the meaning of shifts of control in assembly hierarchies. This is a conceptual reordering in the way we see buildings, that will only happen when we have methods by which we can confidently explore the complexity that we see when we change our ways of observing the built environment.

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