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Architecture Planning Built Environment Studies

Guest Editor

Nikos A. Salingaros

Chief Editor

Ashraf M. Salama

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Farzad Pour Rahimian

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Includes

- Original Research Articles
- Review Papers / Trigger Articles

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Focus and Scope

ArchNet-IJAR Objectives

ArchNet-IJAR objective is to establish a bridge between theory and practice in the fields of architectural and design research, urban planning, and built environment studies. It reports on the latest research findings and innovative approaches for creating responsive environments, with special focus on architecture and planning in developing countries. ArchNet-IJAR is truly international and aims at strengthening ties between scholars from different parts of the world with contributors and readers reaching across geography, boundaries, and cultures.

ArchNet-IJAR publishes research studies, criticisms and critical analyses about the creation, use, and evaluation of different types of environments at the macro and micro scales. The journal includes original empirical research papers, analytical case studies, and high quality position papers that contribute to the advancement of knowledge in architecture and urbanism.

Four major areas are covered by ArchNet-IJAR:

Architectural and Design Research

Topics include –but not limited to: architectural pedagogy and design studio teaching practices; architectural and sustainable design; design methods and architectural theories; architectural criticism; design and project programming; environment-behavior studies; information technology; Islamic architecture; computer applications and virtual environments;

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post occupancy and facility performance evaluation; and social and cultural factors in design.

Urban and Built Environment Studies

Topics include --but not limited to: administrative and political factors contributing to the shaping of communities, cities and urban regions, community planning; sustainable urban conservation; environmental planning and eco development; housing policy, planning, and design; new urbanism; everyday urbanism; sustainable development; space syntax and GIS applications; and way-finding and signage systems.

Critical Essays on Architectural and Planning Projects

Essays that cover the above topics; critically discussing projects in use; after they have been designed, built and occupied. Articles are preferred to utilize the case study approach as a critical method in built environment research.

Reviews and Trigger Articles

In this section, non-refereed, thought provoking articles are published while book reviews, conference announcements of interest to ArchNet-IJAR readers are outlined and summarized including critical reviews of recent books. The intention of this section is to give room for more voices so that the debate goes beyond pure academic writing. Therefore, this section represents a means of rapidly disseminating innovative ideas or lessons learned from experience and practice. However, while following the same graphical format, submissions are reviewed by the chief editor and interested board members principally on the basis of usefulness and interest to ArchNet-IJAR readers. However, the section is not necessarily a regular section and it will be available based on the quality of submissions received.

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3. Research Methodology: Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed, robust, defensible and appropriate?

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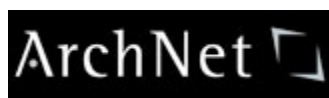
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GUEST EDITORIAL: COMPLEXITY, PATTERNS, AND BIOPHILIA

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Abstract

This is an introduction to the special issue of IJAR.

Keywords: complexity; patterns; biophilia.

When asked to suggest contributors for and edit a special issue of IJAR, I tried to think in terms of having maximal positive impact on the direction of architecture today. How could one group of writings really turn people's heads and inspire architects, students, and citizens towards a more human built environment? My long-term association with the work of Christopher Alexander naturally led me to try and educate people who are not yet familiar with his groundbreaking work. At the same time, those of us who have been inspired by Alexander have contributed our own body of results to the discipline. The present collection describes Alexander's work and related developments based on his human, sensitive, and scientific approach to architecture. And yet, much of it remains curiously outside the architectural and academic mainstream.

This is not the place to criticize the turn that architecture has taken in recent decades, but to try and remedy what most of my friends consider as an untenable situation. For the fascination with superficial visual novelty, flashy style, and engagement in an energy-wasteful architecture of consumption is leading the earth towards certain disaster. Voices arguing for a more sustainable, human, and ecological future are pleading for a less arrogant architecture for our times. Such humility combines traditional energy wisdom, inherited knowledge, and cultural values with the most recent scientific results. It has always been at the basis of Alexander's work: an approach and design philosophy that is more relevant now than ever.

I am fortunate to have many colleagues working in interesting topics in design, and I turned to them to put together this issue. The essays contained here are samples of original work being done outside the dominant architectural system, which are unaffected by power politics of global money interests tied to the worship of star architects. There are many other researchers and practitioners who are putting together an entirely new and healthier approach to architecture, and whose work is referred to in the present collection. This alternative approach to shaping the built environment is most relevant to the developing world, since that stands to lose most by adopting a philosophy of crazed consumption detached from all spiritual, scientific, and moral values. Consumption does not represent science. I emphasize the distinction between science, which seeks to understand phenomena, and technology, which can be applied for both good and bad purposes.

A few short words on the distinguished contributors to this volume follow.

Ramray Bhat is a biologist who has turned his attention to design and the structure of buildings and cities. His contribution summarizes an innovative biological basis of form generation, and nicely condenses results from Alexander's monumental book "The Nature of Order". From this fundamental synthesis between biology and design, a student can learn and develop what I hope are the elements of design for a truly sustainable future.

Michael Mehaffy is a close colleague of Christopher Alexander. He gives us a general blueprint for a sustainable city that cuts greenhouse emissions. But more than that, he digs deeply into the philosophical underpinnings of the analysis of sustainability, and reveals the surprising inadequacy of other similar blueprints that are based on faulty thinking. This is an

intellectual tour-de-force that changes the paradigm with which we think about design and sustainability.

Jan Michl tackles the problem with architectural education in the past several decades. Why are architects not prepared with the material that we are presenting here in this special issue? Why does this knowledge base seem so totally different from what are accepted as working design tools in the mainstream? Architectural education has been extremely biased, being focused for a long time towards one particular and rather poor design philosophy, and ignoring the problems we face today. Unless we realize the need for radical reform in educating our young architects, nothing is ever going to change for the better.

The essay by architectural historian Martin Horacek is a very down-to-earth examination of new museums in general, and the Acropolis Museum in Athens in particular. In an admirably balanced analysis, he presents both pro and con opinions of the Acropolis Museum (unlike my own previous essay on this topic, in which I condemn the Acropolis Museum in the harshest terms). Beyond talking about a single building, we have here a critical analysis of the procedure and mental traps that many cities and governments fall into when commissioning a new museum. The separate questions of reinforcing national identity and providing a tourist attraction are not automatically resolved by appealing to a star architect, contrary to what is widely accepted today.

Catherine Ryan and her collaborators are practitioners in an innovative firm, offering a superior product that takes into account the biophilic effect. This takes advantage of the evolved human response to a natural environment, utilizing both direct and intimate contact with nature, as well as shapes, spaces, and surfaces that possess the same geometries found in living organisms. All of us working in this topic know that Alexander's *Patterns* anticipated biophilic design, and it is very nice that this paper establishes a close link between Biophilic Design and new Design Patterns. The advantage of using *Patterns* is that they provide a guide and checklist for any architect wishing to embed the documented health and psychological benefits in their own work.

Urbanist Serge Salat and his collaborators study the city as a living organism, following Alexander's lead. A detailed and comprehensive comparison of three of our greatest Western cities, Paris, New York, and Barcelona, reveals their morphological patterns and links them closely in an interpretative framework. The result totally discredits the planning tools widely used since the end of the Second World War. A city that is designed according to modernist principles, which contradict the mathematical qualities of living cities, is neither sustainable nor resilient. And no amount of investment can make it so. These findings are crucial for emerging countries eager to adopt Western methods.

Philosopher and jurist James Kalb gives us an overview of Alexander's work, emphasizing its philosophical and transcendental aspects. The suffocating image-based design industry has made us lose the timeless connection between our societal values and what our built environment embodies. Or, in what could be even more frightening, our society has embraced an anti-human nihilistic movement. In any case, thinking outside contemporary architectural discourse should wake people up to unnoticed developments that actually shape humanity in an undesirable way for its own survival.

Jaap Dawson is an architect and teacher of architecture. His rather philosophical essay makes some key points about design and structure in a very enjoyable, indirect manner. Perhaps this is the way to communicate his message of humanity: if done so more directly, in words that a practicing architect would expect, the message might be resisted. And his message is a crucial one of what we have lost in the architecture of the past several decades. We have lost its human and spiritual aspects. These parables bring us closer to rediscovering that profound missing knowledge.

In conclusion, a reader might wonder how seriously to take this collection of essays introducing a radically distinct approach to design that includes so many non-architect authors. Well, the ecological crisis is also a crisis in morality that architects are ill prepared to solve. And if

innovation is truly welcome, then it is most often found in the periphery of any discipline. At its established center, the urge for innovation very frequently turns into running useless circles around practices that don't really change. People like to continue things just as they are. Thinking becomes locked into conventional models, in which deceptively apparent new ideas serve mostly to reinforce what is already in practice. Yet the present system is promoting inhuman design, with mostly superficial changes, as "innovation". That is a deception. It follows that a new direction in architecture is expected to come not from the inside, but from the outside. I have the honor as guest editor to present this special issue as a contribution to such a hopeful change.

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UNDERSTANDING COMPLEXITY THROUGH PATTERN LANGUAGES IN BIOLOGICAL AND MAN-MADE ARCHITECTURES Comparisons between Biological and Architectonic Patterns

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Abstract

In 1944, the celebrated physicist, Erwin Schrodinger, famously asked, "What is Life?" Neither Schrodinger nor generations of illustrious scientists after him have been able to satisfactorily answer this question. What is generally agreed upon, however, is that being alive is about being complex: forming, transforming, and maintaining a structural organization that consists of multiple constituents arranged in specific orders and patterns. The advances in the theory of complexity have come not just from biologists, but also from architects and urban theorists. In this essay, I discuss how theorists from both life and architectonic sciences have come to a similar conclusion: that patterned and organized form ensures proper function and, ultimately, life. I show how deviation from this principle in biology leads to cancer and death; in architecture, the deviation allows the takeover of mechanical and imagery-based building ideologies leading to dysfunctional and 'lifeless' building and public spaces.

Keywords: pattern formation; polarity; multiscalarity; cancer; architecture.

INTRODUCTION

The science of complexity is predicated on the following questions: why are some things in this world complicated and multi-constituent? Is there a method in this complicatedness? Does the complicatedness correlate directly with function? And lastly, is it even needed in the shorter or longer run? It is a problem that comes up in several disciplines: biology, architecture, material chemistry, and computer theory (Alexander, 2002a; Lineweaver, Davies, and Ruse, 2013). The questions that are framed by their respective practitioners are done so in vocabularies that are inherent to their respective fields. This masks the underlying common thread of logic running through these questions: how does any system or structure acquire or exhibit novel properties over a reasonable span of time? In biology, this problem relates to how an organism exhibits new behavior or begets a new organ, which it was never associated with in its evolutionary history (Newman, Forgacs, and Muller, 2006). In computer theory, one can ask what the minimum amount of steps is required for a system to learn a new function (such as predicting outputs for a certain kind of inputs) (Valiant, 2009). In chemistry, it would involve coming up with the conditions within which homogeneously mixed chemicals would start exhibiting novel spatial and temporal patterns, and waves (Mikhailov, 1990). In architecture, it involves formulating rules and arrangements to make a building habitable, resilient and harmonious with its surroundings (Salingaros & Mehaffy, 2006). The advantage in approaching complexity from a more interdisciplinary generic perspective lies in the ability to see beyond what individual disciplinary methodologies afford. Moreover, common principles and facts accrued in one field can readily be applied and tested in another field to verify if an underlying common logic extends to solutions as well.

In this essay, I will discuss how the problem of complexity is grappled with by practitioners of two disparate fields: biological morphogenesis and architecture (and urban planning). In the first section, I will show an uncanny similarity between some principles establishing pattern and

order in built and biological forms respectively. The second section deals with the consequence of the violation of these rules in biology. The third and final section deals with how these rules are bent or flouted in architecture.

FORM: A GEOMETER'S PROBLEM?

Architecture

If one is to undertake a serious systematic study of the lasting architectural patterns spanning diverse civilizations, it would not be difficult to come up with some structural rules and qualities that are integral to 'successful' buildings and built environments, even separated by swathes of time and space. By successful I mean an immediate, positive, and nourishing visceral appeal to the inhabitants or persons who experience the building first-hand. Research by architectural theorists trained in the physical sciences, such as Christopher Alexander and Nikos Salingaros, has unearthed mathematical principles of design that appear again and again in buildings that have stood the test of time, weather and, taste (Alexander, 2002b; Salingaros and Mehaffy, 2006). The architects building these buildings had neither the access to modern libraries or to the World-Wide Web, or even to crucial contemporary advances in geometry, such as nonlinear dynamics and fractal theory. The overall essence of these principles is to ensure that buildings are not just mechanical entities with a height, area, volume, windows, and doors. Buildings are very complex structures with many spatial scales determining their form and details, and the coherence of the structure has a communicative effect on human perception.

In order to discuss these geometrical qualities, I would like to first introduce the notion of distinct cooperating scales: architectonic and structural elements of a certain size, from the smallest detail going up to the size of the building or urban space itself (Alexander, Ishikawa, & Silverstein, 1977). The smallest scale is essential, and is defined by visual patterns through contrasting structural elements, ornaments, and colors (Figure 1). The largest scale establishes relations between distant elements in a manner that renders their arrangement ordered (rather than random). The relationship between these two scales contributes to the positive perception of a building's architecture (Mehrabian, 1976; Salingaros, 2000). Finally, the overall harmony links all the intermediate scales together through techniques that employ symmetries common in traditional design and architectures. Note, in particular, that there could be relationships even in the magnification ratio between one pair of adjacent scales and another pair (i.e. scaling invariance).

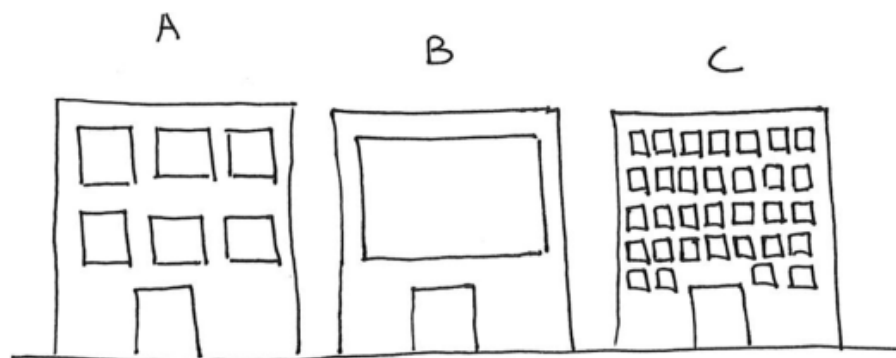


Figure 1: Cartoon showing three buildings with variation in the relationship between scales of pattern (Source: Author).

A. In building A, the windows are well spaced apart and bear a contrast with the spaces between them. They also bear a fixed ratio in dimensional scale with those of the entire building.

B. In Building B, the single large window results in loss of contrast.

C. In Building C, the multiple rows of small windows do retain a contrast with the spaced between them but their dimensional ratio with the dimensions of the building is very large leading to sensory chaos.

To illustrate the notion of scale with a simple example: let us seek to define the proportional relationship between windows and the space between the windows. These two elements set up a contrasting visual pattern to a building's exterior. Seeking coherence qualifies how the windows of a building (and the gaps between them) are oriented and sized with respect to each other. Finally, we need to define the boundaries of the ratio of the average size of the windows to the size of the building (Figure 1).

The underlying core principle is that these adjustments are based on empirical observations, and the analysis of those observations made into a canon of more intuitive than documented, design rules. This suggests that buildings and built environments that have stood the test of time, and appreciation, have common rules of pattern and organization in their substructures. In fact, it is entirely conceivable to envision the 'life' of a built structure as a quantifiable product of the intensity of visual information, due to contrasts set up by adjacent elements, and the harmony of the arrangement of elements across the dimensions of the building (Salingaros, 1997). This is not to imply that buildings are alive in the strictest biological sense, although even biologists have generally been hard pressed to provide a clear-cut definition of life. What this allows us, however, is to have a cogent idea of why and to what extent some built environments and buildings are more breathtaking, more beautiful, and more habitable than some others. It also gives us the freedom to compare, by a set of criteria, two or more buildings of distinct times, divergent cultures, and varied styles. More importantly, it also tells us that structure determines function and utility.

Let us pursue the multiscale issue one step further. The "life" of buildings is not just determined by the structural materials that go into it or how, for that matter, they are arranged. It is essential that the buildings themselves harmonize with the built and natural environment that surrounds them. A positive example of this is the Emoto apartment building in Tokyo. Negative examples would be the skyscrapers housing commercial offices surrounding, and dwarfing the Chinatown district of San Francisco (for further details, see last section). This leads us to the associated subject of urbanism, a detailed elaboration of which I will leave for a subsequent essay. Put briefly, the laws described above hold, in principle for how a building relates to its environment, with other buildings, with the surrounding nature, with roads, plazas, and other elements of organized habitation.

In fact, multiscale in building design, and the relationships of different scales to each other, is one of the fifteen structural features identified by the architect-philosopher Christopher Alexander that can sift between which building is "alive" and which is relatively "dead" (Alexander, 2002b). The other fourteen properties are 1. Strong centers (points in space) around which spaces can be organized and divided, contributing to wholeness and components which make up the whole 2. Boundaries that bound, and separate, centers and spaces 3. Alternating repetitions – periodically arranged centers that reinforce each other through their regularity 4. Positive space, which is created by curved structures, such as by spandrels 5. Good shape: a property defined by a coherently arranged set of multiple centers 6. Local symmetries, coherent geometrical patterns at lower scales and not on the highest scale 7. Deep interlock and ambiguity: enmeshing and interconnections between elements 8. Contrast 9. Gradients 10. Roughness: imperfections that are merely signs of human agency 11. Echoes: an attempt to create more than a single scale with the same structural element(s) 12. The Void: creation of an empty space that accentuates the order and solidity of the rest of the structure 13. Simplicity and inner calm: coherence (not symmetry) at the largest scale and finally 14. Not-separatedness, which measures the ability of the building to harmonize with its surroundings.

These fifteen properties can be considered to constitute the grammar of pattern language, an index of patterns for the construction of cities and towns down to individual buildings. The incorporation of these fifteen properties contributes to the function and sustainability of built forms.

Biology

What is more surprising is that these principles find echoes even in case of structures and environments that have not been sculpted by the collaboration of human hands and minds: the morphologies of living things. There is probably no solid organ in the body that does not bear some mark of organization and pattern. Our liver, skin, breast, and brain all consist of cells and non-cellular scaffolding elements in definite spatial arrangements.

For example, every single species of the animal kingdom that has limbs exhibits the very same geometrical pattern of bones within the limbs (Figure 2). Closest to the body is a single bone within the arm or thigh; following this are two bones within the forearm or shin and farthest from the body are a series of bones which form the fingers or toes. Not only is there a gradational increase in number of skeletal elements, there is a gradational decrease in element width. A second example is that of branched organs such as the lungs. Each major airway breaks into progressively smaller and thinner airways. At the smallest scale, for both these examples, one sees contrasting visual patterns (during development, fingers are separated by cells that do not form fingers but later die or form webbing; branches of airways are separated from each other by connective tissue). At the largest scale, one can envision the harmony of the arrangement: the bones of our body are all arranged along the same axis, parallel to each other, and the airways are oriented as to form a radiating centrifugal tree, without any centripetal motifs. The transformation of the largest to the smallest scale is never sudden, but through intermediate scales with progressive gradational shifts.

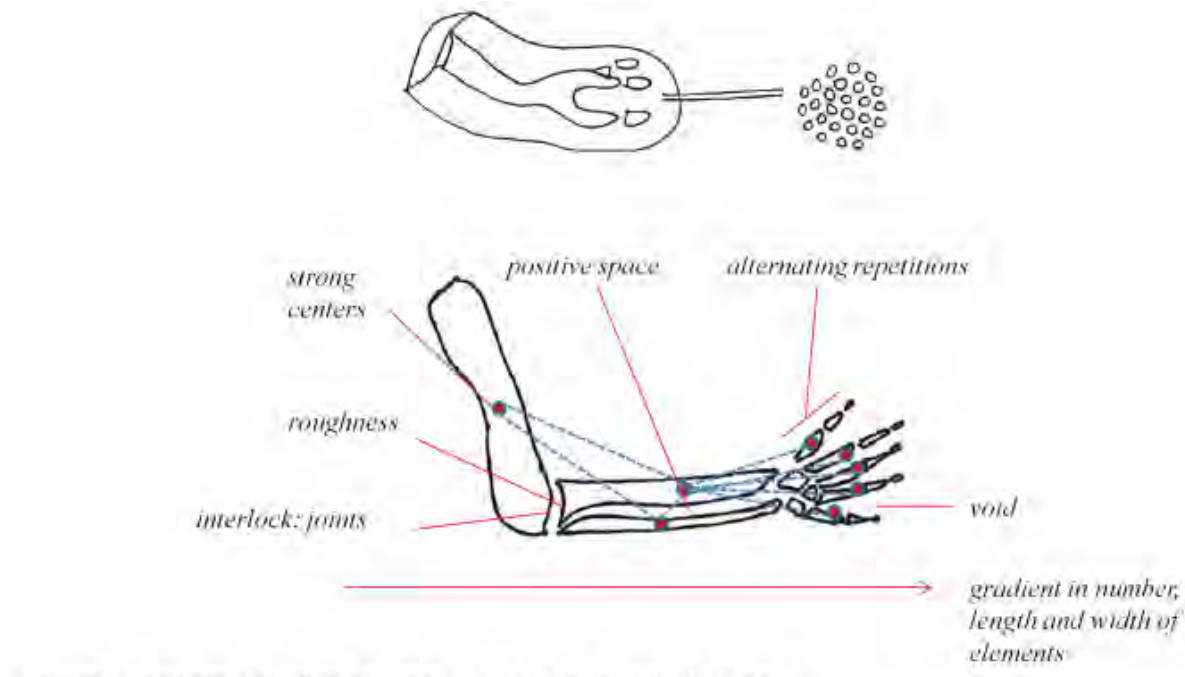


Figure 2: Cartoon depiction of the development of limb skeleton

Upper panel: Developing limb skeleton during chick embryogenesis: cells cultured from limbs at this stage form regularly spaced cartilage nodules suggesting that the ability to form coherent biological patterns is inherent to biological material and is manifested in changed conditions as well.

Lower Panel: Fully formed limb skeleton showing a significant subset of the fifteen structural rules for architectural life that have been proposed by Christopher Alexander (Source: Author).

In fact, when the cells of limbs in which the skeleton has not yet formed, are taken out and 'cultured' on a plastic plate, they organize themselves spontaneously into a pattern in which subsets of cells form spherical aggregates, known as condensations. Condensations are the

culture equivalents of digits and become nodules of cartilage (precursors of bone). Condensations are separated from each other by surrounding cells that do not become cartilage. Interestingly, the overall organization concurs in principle with the architectural laws: the spots, along with their surrounding non-spot cells, constitute contrasting elements and far away spots are similar to each other in terms of size and spacing (Newman and Bhat, 2007) (Figure 2).

It is also interesting how some of the descriptive terms are common in the respective fields of built environments and biological form. Thus when cells of our body gradually transform from a homogenous mass into an ordered one, the process is referred to as pattern formation. In an adult organ, the cells are not only patterned with respect to each other, but also have specific arrangements with respect to other non-cellular structures, such as the extracellular matrix (ECM), which is defined as the scaffolding of huge, often fibrillar macromolecules that acts as a substratum and façade of the cells. The composite superstructure is referred to as the tissue- or organ architecture (Bhat and Bissell, 2014)!

There is an increasing body of elegant literature that shows that, just as in-built architecture, the structure of the organ determines its functioning (Bissell, Hall, and Parry, 1982). Specifically, the functioning of genes coding for proteins that determine the activity of the cells is under the constant regulation of the cells' microenvironment. The latter decides whether a cell turns the right genes on and functions as part of the organ. For example, cells derived from the breast, if cultured on plastic, grow into a carpet like arrangement, showing absolutely none of the branching or gland-like structure or function that are characteristic to the organ. Give them their native microenvironment (ECM) and they organize into branching hollow tubes and can even start producing milk (Streuli et al., 1995)! Therefore, while we can keep cells alive by giving them their nutrition, organs come 'alive' only when the essential elements of tissue architecture, the microenvironment, is present.

If we were to analyze the structural characteristics of biological organs through the eyes of an architect, we would find that they bear an astounding level of congruence with principles of design that contribute to the beauty and resilience of man-made architectures. For example, the fifteen structural principles that I elaborate in the previous section are an exhaustive set of crucibles against which to test any given example of a biological architecture. Let us take two divergent examples of biological architecture introduced briefly above – the breast tissue and appendicular skeleton, and analyze them further.

The structural and functional units of the functioning adult breast organs are known as the terminal ductal lobular units (TDLU), so called because they lie at the end of the ducts which fuse together to form the channel that connects with the nipple. The TDLUs synthesize and secrete milk which passes through the ducts and comes out through the nipple. A cross-section through the TDLU gives a clear picture of its structure: a concentric ring of cuboidal cells (known as LEPs) surrounding the lumen, bounded on the outside by a ring of smaller rhomboidal cells (known as MEPs) which in turn are bounded by what is known as the basement membrane – a specific topological arrangement of ECM proteins that acts both as a scaffold and the signaling hub (Figure 3).

The TDLU shows sequential radial scales with the outermost sphere formed by the BM, followed by the MEPs followed finally by the LEPs. It has a strong center in the lumen which is reinforced by the centers of each other the spheres surrounding it. It has a strong thick boundary in the BM, which is an ECM superstructure as well as the MEPs, which, being the producers of the BM, reinforce the boundaries. Each TDLU is surrounded by several other TDLUs, all of which are connected by ducts that converge finally onto a single large duct that transmits the milk out. Hence, the TDLUs together form a repetitive motif. On the other hand, the entire mammary ductal tree forms by growing into, a positively shaped stromal environment which acts as a reservoir to contain a host of different cells and proteins that signal and reinforce the architecture of the TDLU. The LEPs within the TDLU are deeply interlocked with each other through intercellular bridges. While the whole glandular tree is randomly structured- no tree can match another perfectly, there are inbuilt local symmetries- the density of branch points is roughly the same and

so is the general direction within which the braches grow. The TDLUs and their ducts form strong contrasts with their surrounding stromal space. The BM in growing glands is made in a gradient-like fashion trailing the invading tip of the branches of the gland. The entire glandular structure manages to fill the space within which it grows in a rough undirected manner, but the branches form suitably to maximize its volume within the constricted space. And yet the principle of branching as a means to maximize volume is a simple yet powerful method.

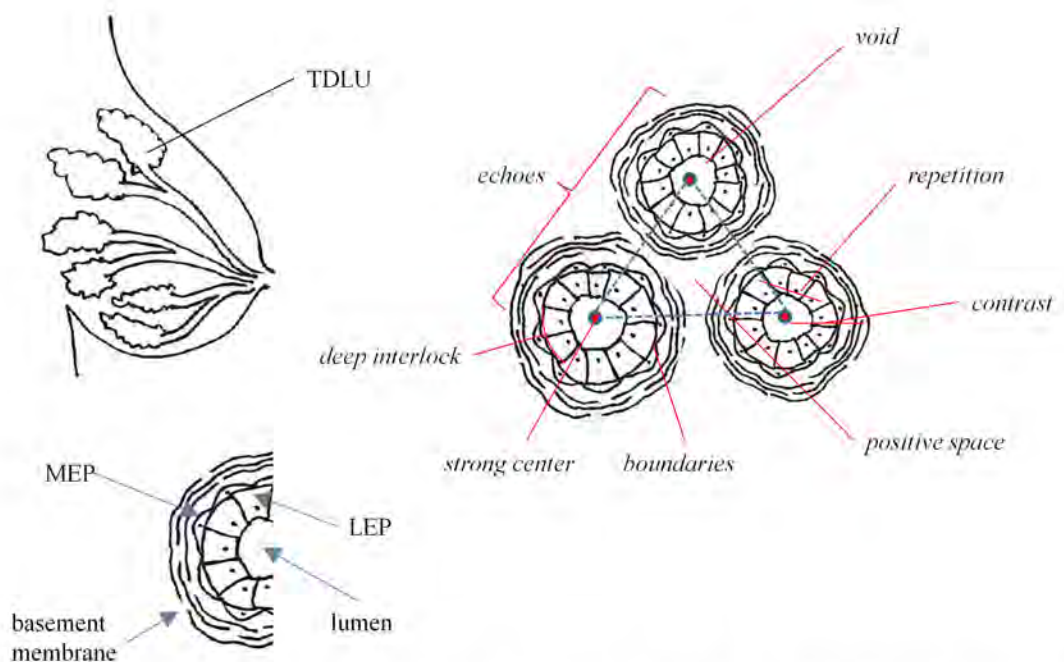


Figure 3: Cartoon depiction of the breast architecture showing TDLUs. The internal anatomy of the TDLUs consists of acini embedded in matrix. the acinar pattern shows a significant subset of the fifteen structural rules for architectural life that have been proposed by Christopher Alexander (Source: Author).

The appendicular skeleton shows sequential changes in spatial scale with the number of bones increasing and the size of the bones sequentially decreasing further away from the body (Figure 2). The effect of having tandem and parallel arrangement of bones creates strong centers that reinforce each other. The tandemness creates repeatedness. The bones are interlocked in joints to create a rigid though immensely mobile structure. The parallel bones also create contrast by creating positive inter-skeletal spaces between them, which allow for the muscles to attach and pull them in different directions. The bones are shaped in ways which make them asymmetric albeit the translational symmetry of the skeleton. The size and number of bones form a uniform gradient. The appendicular skeleton is built to be agile and flexible, while at the same time rigid enough to withstand extensive stress in the form of a Type III lever. The physics that is embedded in its architecture is thus complicated but an emergent property: the latter has a simplicity that deceives.

Anatomists and developmental biologists have also taken the structuralist route to analyzing biological form. One tissue-level property that encompasses a subset of the above-mentioned structural principles is that of polarity – the arrangement of cells and ECM in a linear or radial arrangement. Polarity is one of the fundamental characteristics of adult animal organs (Bissell, Radisky, Rizki, Weaver, & Petersen, 2002). Cells have polarity, which is reflected in the

difference in structure and function, especially of epithelial cells. However, tissues have a polarity that is autonomous of cell polarity. Let me illustrate this point with a specific example: that of mammary epithelial cells and the architecture of the breast. Investigation of structure-function relationship within the TDLU shows that the mere coming together of the components of the TDLU is not sufficient for it to function - they have to be present in the correct centripetal configuration – and it is this configuration that is known as tissue polarity. It is only when the tissue is polar that the TDLU starts functioning and producing milk.

If we were to describe polarity in a formal fashion (i.e., without describing the specific biological examples) in terms of the fifteen properties of living architectures that we have mentioned above, radial polarity is thus a combination of strong center, strong boundaries, positive space, good shape, local symmetry, deep interlock and ambiguity, contrast, roughness, and void. Linear polarity subsumes levels of scale, strong centers, good shape, gradient, deep interlock, and echoes. In specific biological contexts, as we show above, polar organs encapsulate even the rest of the fifteen properties. Polarity also maintains the homeostasis of the organ- in other words; it prevents the organ from dysfunction or breaking apart. It also imparts specificity to the organ – in other words, it is not so much the genes, not even so much the cells, but the configuration or architecture that is so immanent to the organ identity.

Polarity is not the only organizing principle of biological pattern formation. In a series of papers on the evolution and organization of biological matter, a set of agents, known as dynamical pattern modules (DPMs) have been identified, which organize homogeneous fields of cells into patterned tissues (Newman & Bhat, 2008, 2009). These agents are mediators of physical effects, specifically on the material properties of biological tissues and are associated with different proteins in different contexts. For example, one of the simplest DPMs, known as ADH, mediates cell-cell adhesion leading to the transformation of a collection of individual cells into a multicellular mass. Polarity is another DPM, using which a homogeneous cell population can organize itself into a centrifugally or linearly heterogeneous organ.

In summary, DPMs constitute a pattern language that is utilized by biological tissues to encode information, and by extension, complexity, in order to give rise to, and maintain, biological architecture. I have shown that there is a strong convergence between the pattern languages that gives rise to living biological tissues and organs on one hand and living buildings and built environments on the other. What are the consequences of violating these pattern languages?

THE LOSS OF BIOLOGICAL ORGANIZATION LEADS TO CANCER

We are thus naturally motivated to ask what happens when the organ architecture is disturbed due to some reason. The answer - cancer - would likely even surprise many biologists. Cancer is a deadly disease that afflicts and kills millions of people all over the world. The cause of cancer is often opined to be mutations of specific genes, elements that code for the proteins, the building blocks of biological form. This is biological reductionism at its most extreme. Abnormalities of the organ's microenvironment result in incorrect signals to the genes, including those that are responsible for tissue structure, ECM production, and even cellular health (Lochter and Bissell, 1995; Sonnenschein and Soto, 2008). The convergence of all these pathological signals is cancer. It is important to note that the gene mutations purported to bring about cancer are present in every single cell of the body and yet the individual is afflicted with only cancer of a particular organ. Cancer is therefore a disease of the organ architecture and not the genes.

Despite the fact that every organ is different and its cancerous state is also therefore unique, there are some properties common to the various types of cancers. The first is, of course, a breakdown in organization of the organ: boundaries between erstwhile well-separated cells are no longer honored. A characteristic 'superstructure-scaffold' that acts as the microenvironment for a large subset of cells (known as epithelia) is the basement membrane. Cancer results in breakdown of this superstructure and results in contact between cells that were not supposed to communicate with each other. The result is abnormal communications and signaling leading to loss of organ function (Bhat & Bissell, 2014).

On a larger scale, the symmetry of the organ undergoes drastic alterations. Hollow tubular organs become solid, soft tissue becomes hard, well-conserved shapes and geometries of the organs get distorted and subverted. In other words, organ and tissue polarity, which I have shown above to be integral to their formation, is completely lost. In the language of architecture, the strong center is lost, contrasts and gradients are obliterated, interlocks are broken down, local symmetries get wiped out, and boundaries are no longer respected (Figure 4).

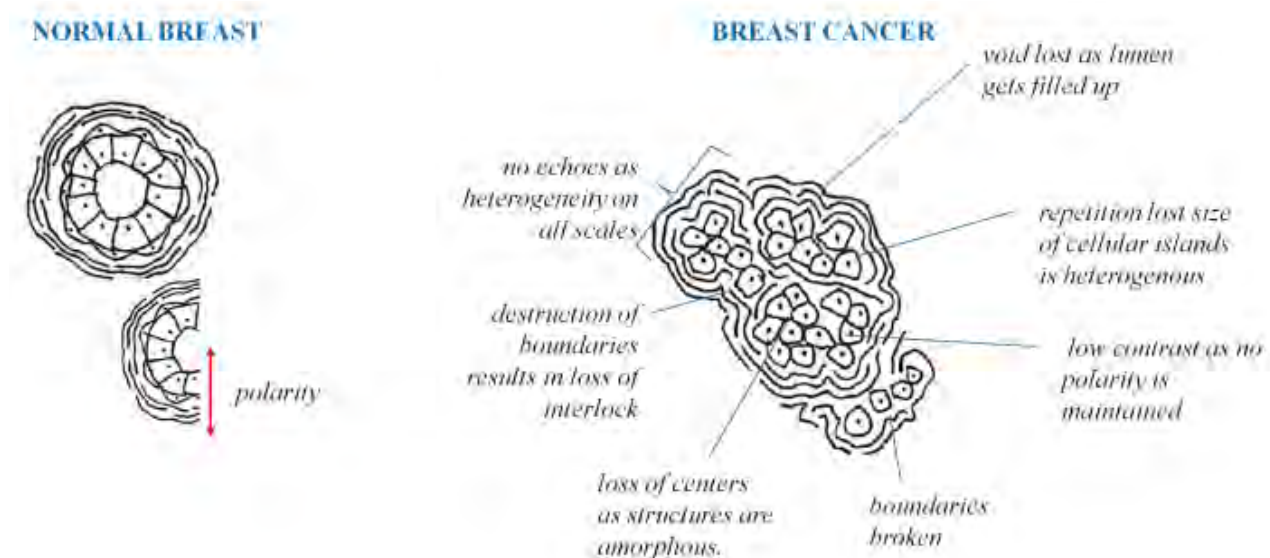


Figure 4: Cartoon depiction of normal breast architecture showing
Left Panel: polarity is composed of a subset of the structural rules of Christopher Alexander.
Right Panel: the tissue architecture of breast cancer where most of the structural rules maintaining organization and polarity are found to be violated (Source: Author).

Cancer is characterized by a loss of control over growth: there is an unbridled proliferation of cells of the organ and a loss of cell-cell contact. Therefore, positive spaces and voids get filled up and roughness gets smoothened. In an advanced state, cells invade and metastasize, i.e., they depart from their original locus travel to distant locales and start parasitizing, and proliferating within new tissues. In conclusion, we observe, in cancer, a breakdown in those the very design principles that we found overarching between man-made architectures and biological architectures.

CONSEQUENCES OF SUBVERSION OF ARCHITECTURAL PATTERN LANGUAGE

What of disordered structures in built environments? There are abundant examples of buildings built around us that violate the principles that have been alluded to in the first section. The subversion began at the turn of the century with the modernist school of architectural thought, but has been taken to an altogether new level by 'postmodernist fashionistas' (Krier, 1981; Salingaros and Alexander, 2004).

In fact, such urban morphologies not only deviate from the morphogenetic rules presented above, but also start exhibiting the properties shown by cancerous biological tissues. This is not just a matter of the overall shape, size, and topologies of the finished structure (or the lack of it). The first and foremost feature is the loss in identity and vernacularism (by the latter I mean a sensitivity to incorporate materials, themes, and geographical and historical influences from the locality). These properties are ubiquitous to traditional architectural styles and establish the harmony of the building with its surroundings. This characteristic is completely overridden in modernist monuments where choice of materials, more often than not, boils down to being

influenced by globalization, corporatist symbolism, and contemporaneous fashion trends. The almost universal glass-and-granite look of office buildings is a case in point. Buildings such as 30 St Mary Axe (London), the Neutrality Monument (Turkmenistan) and, Antilia (India) were built with an abject disregard to their surroundings generating considerable disharmony.

Like biological organs, every building is also specific: it has a function and the environment around it, its paths and its connections are structured uniquely to it. A house and its surroundings cannot be planned in the same way as say a downtown plaza or a school. Despite this, most modern buildings, whether they are residential or commercial, get built in the same way. A ride on the Amtrak into New York City shows gigantic cooperative residential towers in the Bronx followed by gigantic corporate mega towers in Manhattan. Postmodernist creations on the other hand, seem to wage a war against their interior and their utility. It is not possible, for example, to envision what the buildings stand for, or what happens inside it by surveying its exterior.

The second feature is one of loss in polarity, proposed above to be integral to the difference between normal and cancerous biological systems. Polarity in architecture defines the distinction between the inside and the outside. Modernist buildings with glass curtain walls have nullified this distinction. Instead of having windows that allow inhabitants to experience diurnal changes in light and fluctuations of the weather, and allowing a harmonious interaction between the interior and exterior, such buildings accentuate a sense of being exposed to the outside, without actually interacting with it. On the other hand, examples of brutalist school of architecture at many times often do away with the concept of windows in order to create an impression of magnificent size and imposition. In his seminal critique on the postmodern ideology, Fredric Jameson levels a similar accusation on examples of affiliated architectural examples: dysmorphic houses constructed by building over partly preserved shells of older houses, and gigantic metropolitan hotels fragment polarity by creating negative spaces and yearn to confuse, in accordance with their ideology, rather than to calm (Jameson, 1991). While adopting a vocabulary that jargonizes advancements in mathematics and complexity theory, the postmodernists ignore the concept that complexity is firstly a systems- and secondly a historical-property. The first means that it has to maintain links and associations of scales with its components and the second means it has to evolve out of a historical and historicist way of thinking. The first criterion is abandoned by postmodernists through their praxis; the second by definition never existed in their ideology. This renders the postmodern monuments and, especially, their subsequent deconstructivist successors, incoherent and amorphous, attenuating their complexity, their utility and, ultimately, their life of the buildings. To complete the epistemic loop, cancerous tissues are in the end, incoherent and disorganized masses of tissue with severed connectivities and lost function.

Lastly, like the most debilitating characteristic of cancer, i.e., metastasis, ill-designed buildings and built environments cannibalize their surrounding urban landscapes by growing, dwarfing, and pushing out smaller and traditionally built structures at the interfaces. A measure over time of the shrinkage of Chinatowns in the major metropolitan cities all over the world is an apt example of this urban pathology (Figure 5).

Built within the city limits, encroachment by commercial enterprises, and an exodus by its inhabitants for zoned ethno-suburbs have led to an implosion of these immensely alive urban neighborhoods vibrant with motifs, design traditions, and colors. A combination of globalization, postcolonial mimicry, and aspirational urges have left burgeoning cities in India, Pakistan, Bangladesh, China, and Brazil dotted with mega towers and zonings which parasitize on their surroundings through labor and energy demands creating even widening peripheries depleted of culture, diversity, and beauty.



Figure 5: Photographs of San Francisco Chinatown.

Upper photo panel: Grant Avenue the commercial nerve center of the ethnic enclave with its unique “Chinoiserie” architecture since when the Chinatown was rebuilt after the 1906 earthquake.

Lower photo panels: Commercial multi-storeyed buildings preside over the horizon of the Chinatown and are harbingers of its shrinkage and eventual disappearance. (Courtesy: Kusumita Rakshit)

CONCLUSION

In this essay, I have put across sets of principles that were not considered ‘mainstream’ in biology and architecture, but are increasingly gaining ground in the respective disciplines. I show that these principles may have different names, but bear a great deal of geometric similarity to each other. Examined closely, these sets of principles are crucial in their ability to give rise to spatial complexity in both biological and man-made architectures. Additionally, they are required for homeostasis (biology) and sustainability (architecture). Their loss leads to cancer in organs. An absence of these principles in architectonic methodologies, especially of the current era, underlies the reasons why some buildings, neighborhoods, and even cities start decaying and dying.

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COUNTING URBAN CARBON: Effective Modeling of Resource-Efficient Urban Design Decisions under Uncertain Conditions

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Abstract

Urban design decision support tools aimed at achieving desired outcomes – such as reduction of greenhouse gas emissions – must respond to the inherent complexity of urban systems, and the inherent uncertainties within measurement and inventory methods. Moreover, they must accommodate the epistemological limitations of all models, arising from their dynamic relationship with the often self-modifying phenomena they are intended to model. Drawing on methodologies from other fields, we present here the outline of a methodology that meets that requirement, exploiting the capacity for iteration, empirical evaluation, and collaborative refinement over time. We show how this methodology is suitable for application in a new generation of decision support tools for urban design.

Keywords: modeling methodologies; carbon reduction; greenhouse gas emissions.

INTRODUCTION

Perhaps no problem facing the human species today appears more daunting than the reduction of greenhouse gas emissions to mitigate the increasingly ominous threat of climate change. Yet it is also surely true that greenhouse gas emissions are only one aspect of a wider challenge of sustainable resource use for the future. Both topics raise deeper issues still about the ability of humans to act effectively in the face of inherently uncertain scientific knowledge about future events, and an often-associated (and increasingly problematic) atmosphere of political controversy.

It is encouraging to observe, however, that we humans have acted effectively on occasion to manage just such future events, under just such conditions. Examples include the elimination of chlorofluorocarbons to effectively mitigate the loss of atmospheric ozone, and the reduction of rates of cigarette smoking (at least in some countries) to achieve measurable improvements in human health.

However, the problem appears much more daunting when it comes to the reduction of greenhouse gas emissions (hereafter termed GHGs). First, it seems evident that there are many more economic and political disincentives against taking strong action, shared by many more interests – notably including developing countries, who often see such action as a serious threat to their own economic development goals.

More deeply, as we will discuss in this paper, there is a high degree of uncertainty arising from the sheer complexity of the systems that shape consumption and emissions – most notably, the urban systems in which we move, consume, waste, and otherwise generate most of the ultimate demand for resources.

One significant problem is that there are complexities and ambiguities in the way we measure emissions, as this paper will discuss. Moreover, there is inherent uncertainty and even randomness in the way these emissions will actually occur, which makes prediction a problematic, possibly even self-deceptive exercise (Taleb, 2005; Kahneman, 2012). In part this is because the systems themselves are not static but are self-modifying, posing a fundamental challenge to both science and policy (Mayumi and Giampietro, 2006).

At the same time, evidence suggests that there is an opportunity to achieve significant reductions, if these challenges can be met. As has been demonstrated, the role of urban systems and their form in affecting emissions constitutes a large, and largely under-exploited, set of factors (Mehaffy, 2013).

THE NEED FOR USEFUL MODELS IN SUPPORT OF DESIGN DECISIONS

This is the environment in which urban designers, charged with making design decisions that achieve greater resource efficiency and lower greenhouse gas emissions, must operate. As with all design, the goal is not merely to create some wholly new structure with desirable attributes, but – as the great design theorist Herbert Simon famously described it – to effect a course of action that successfully changes an existing state into a preferred one (Simon, 1962). This implies an ability, on the part of the designers, to explore a range of alternative design decisions and their likely outcomes, so as to judge their preferability. That is, it implies a capacity for usefully reliable prediction.

It is in this environment that scenario modeling has arisen as an urban design decision-support tool (Schoemaker, 2004; Mehaffy, 2013). In essence, a designer, or design team, prepares a series of design alternatives, which serve to outline the range of choices that are believed to be available for the design. The modeling process then provides a set of comparative predictive results of those choices, and thereby provides guidance in directing the design process. In so doing, the process works to solve an optimization problem with regard to a set of inter-dependent variables – such as greenhouse gas emissions, residential density, urban paving area and the like (Condon, Cavens and Miller, 2009).

A question immediately arises as to which variables are selected, and how the preferential condition is determined – and by whom. By definition, the designers are optimizing relative to normative definitions of “preferred states” that they themselves have accepted. For example, more reduction of greenhouse gas emissions is better, but perhaps not at the expense of an excessive level of residential density, which may be an “unpreferred state.”

But the next question must be, of course, on whose authority do they choose those normative definitions? This was the problem raised by urban design pioneer Kevin Lynch, writing in his book *Good City Form* (1984). He argued that such normative values are an inevitable part of all design, and what is critical is that they are transparent, critically examined, and subject to democratic process. The goal is not to have “the right model” of good city form in any objective, predetermined sense, but to have a model that has been openly and critically assessed, with the benefit of public scrutiny and evaluation.

A key strategy for doing so has been to employ scenario-modeling tools within so-called “public involvement” processes, where citizens and stakeholders have at least a theoretical opportunity to participate in shaping the normative values of the urban design modeling and decision-making process. Examples are so-called “envisioning” processes, where stakeholders are brought into a process of design scenario development and given choices about preferred outcomes, which are then analyzed with predictive modeling (Lemp et al., 2008). Subsequent iterations can refine the outcomes according to the preferences of those engaged in the stakeholder involvement process, as well as other required parameters of the outcome (e.g. legal and regulatory requirements).

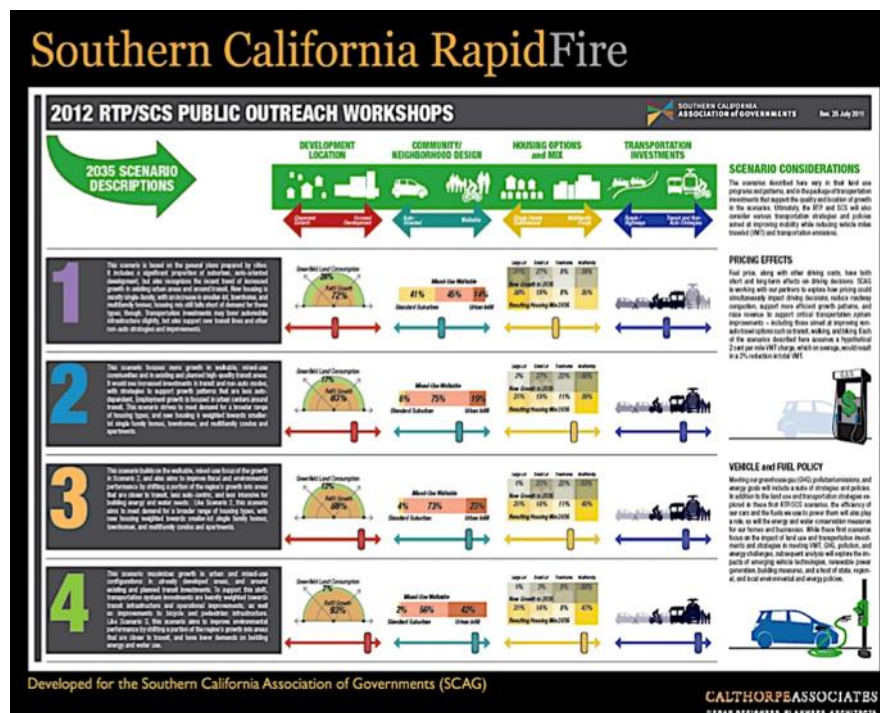


Figure 1: Scenario modeling has been developed on computer platforms using open-source methods, such as RapidFire, shown here, developed by Calthorpe Associates for use in California's greenhouse gas reduction planning work. In this user interface, stakeholders are able to choose their preferences within comparative scenarios, and then see the predicted results of their choices (Source: Calthorpe Associates).

It is important to emphasize that the achievement of a preferable state, as Simon described it, need not be accomplished entirely by one act, by one process, or even by one agent. Indeed, in practice this rarely happens. As Gigerenzer described it (2004) we are in an environment of “ecological rationality” and must rely in part upon “fast and frugal” heuristic decision-making methods. Progress will be achieved through successive iterations that often involve multiple parties, who can then learn from the results and refine the successive iterations to become more effective.

This means that in modeling of such design actions, what is necessary is to have generally reliable, but not necessarily precise, guides to actions that are likely to take us sufficiently in the preferred direction with each iteration, while avoiding the reversal of progress by any other factors. Through successive iterations we can get closer still, and at the same time, we can use the feedback we gain to hone the accuracy of our predictions as we progress. Through successive iterations and by many participants, these actions can be refined and made more effective over time: the process can “learn” and grow more effective. This is an aspect of design that mirrors phenomena in the natural world, as Simon (1962) and other planning and design theorists have described (e.g. Jacobs, 1961; Alexander, 1987).

Another fundamental challenge of modeling is the selection of data and the methodology by which the predictions are generated. As we will discuss in more detail below, the issue of political controversy and inaction in the realm of GHG reductions remains especially acute because the complexity and inherent uncertainty of the information obscures the set of decisions that would likely make progress possible, relative to other goals. Our models, often reliant upon large data sets and statistical inventories, are highly sensitive to small errors in initial assumptions – for example, incorrect selection of relevant factors to compare on an “apples to apples” basis (see e.g. Rypdal and Winiwarter, 2001). These errors become magnified to produce large-scale errors at worst, or inconclusive results at best (Cullen and Frey, 1999). Inconclusive or erroneous results are then cited by self-interested parties to support their policy arguments,

leading to greater confusion (Morgan and Henrion, 1990). The result is that there is very little progress, and a great deal of uncertainty, false hope, paralysis – and worse, false claims for failing methods. This undesirable cycle is self-reinforcing and self-accelerating.

We need reliable methods that can mitigate this problem. Luckily, promising methods have been developed within other fields that are available to apply to the problem of modeling in urban design, and greenhouse gas emissions specifically. (We note here similar implications for many other topics, but they are beyond the scope of this paper.) We discuss these promising methods below, after assessing the boundary issues of the problem.

CURRENT INVENTORY PROBLEMS

If we are seeking to develop a useful predictive model for design decision support, the first question is whether the data on which we rely to develop the model and to measure its effectiveness is accurate enough to provide the basis for usefully accurate measurement. In our case, the data in question is the inventory of greenhouse gas emissions by cities and by the constituents of cities, which furnish the evidence on which we can make meaningful predictions. To the extent the data is unreliable, our predictions will also likely become unreliable. In this regard, there are several well-recognized problems to take into account.

Many authors have documented inherent uncertainties with current greenhouse gas inventories, which may result in errors as high as 20% (Rypdal and Winiwarter, 2001). These errors are even more significant when distinctions are not kept clear between production-based and consumption-based values. Hoornweg et al. (2011) demonstrate that per-capita emissions can vary significantly for the same resident of a city or country depending on whether these are production- or consumption-based values. Such distinctions are often confused, or comparisons are not made between consistently defined values.

Satterthwaite (2008) presents evidence that the emissions generated by residents within cities are overstated in current methodologies, relative to residents of other regions. Moreover, he notes, it is important to tease out the different kinds of residents within cities and their consumption habits, in order to get an accurate understanding of emissions sources. Dodman (2009) makes a similar finding, showing that the factors accounting for emissions are complex and not well understood at present.

Jonas and Nilsson (2007) find that scientific uncertainties are inherent in greenhouse gas accounting, and that (particularly under treaties such as the Kyoto Protocol) a verification framework is essential, but to date does not exist. Lieberman et al. (2007) observe that recognizing high levels of uncertainty is necessary to improve inventories and manage risk in policy actions, such as carbon emissions trading schemes.

Many of these authors make the point that uncertainty cannot be removed, but it can be recognized and accounted for so as to produce more usefully reliable inventory measurements. Indeed, to that end the Intergovernmental Panel on Climate Change has produced practice guidance on uncertainty management in national inventories (IPCC, 2001). Rypdal and Flugsrud (2001) are among investigators who have developed methodologies to reduce or manage uncertainty in inventories. Moss and Schneider (2000) also have issued guidance to IPCC lead authors to reduce uncertainties through more consistent assessment and reporting procedures.

All of these investigators point out an inherent component of uncertainty in greenhouse gas data, illustrating the need for models that are sufficiently robust to be useful in spite of this uncertainty. What is critical, then, is that the basis for comparison is equivalent, and that it has a logical relation to the opportunities for reduction. For example, the allocation of GHG emissions per capita, and to the activities of individuals as they generate varying levels of demand, may provide better access to the behaviors that actually generate emissions in manufacturing, agriculture, energy generation and other sectors. Of course, it is in urban settings of varying kinds and intensities that most of these activities occur.

Deeper Epistemological Problems of Modeling

There is an even more profound problem for those seeking to develop models to guide design choices. It lies in the epistemological limits of all models, which we will discuss here in more detail. Following that discussion, we can examine some of the modeling methodologies that have been developed in part to respond to these limitations, and to provide the more robust capability that we seek.

First, we must recognize that a design model is, by definition, a prediction of what will happen in the future, when conditions in reality are sufficiently aligned with the parameters of the model. But the data on which the model relies for its development is, by its nature, from the present or the recent past. In relying upon previous data, we must apply our own theories – the predictive elements of our model about how the system will behave – to generate a prediction. If our model is not a simple extrapolation (which is rarely correct), then we must rely upon a more complex set of abstract ideas about the interaction of factors.

Of course, any such abstraction is precisely that – an abstraction, which is fundamentally “an omission of part of the truth,” in the memorable words of the philosopher and mathematician Alfred North Whitehead (1938). Our challenge is not to create a perfect copy of reality, but to apply such abstractions (including models) in a way that their corresponding features provide useful guides to the structure of the phenomenon of interest, without their omissions becoming problematic. This standard of usefulness must ultimately apply to all models.

However, Whitehead warned, we must be clear about what our abstractions can and cannot do, and the need to attain what he termed a “right adjustment of the process of abstraction.” Failure to do so may lead us to what he called “the fallacy of misplaced concreteness” – the mistaken assumption that aspects of our abstractions must correspond to aspects of reality. An example is the unfounded belief that the predictions of a theoretical model must hold true – a common problem in a number of professions today (Taleb, 2005; Kahneman, 2012).

Whitehead's work is part of an extensive literature on the epistemology of modeling, and the broader capabilities and limits of abstract systems – including language itself – whose cautionary lessons must form the foundation of the robust modeling methodology we seek. In particular the Twentieth Century brought important work in identifying the inherent incompleteness of information as a fundamental limitation of any such model.

Especially notable among this literature is the work on undecidability and incompleteness by the mathematician Kurt Gödel (1931). Gödel famously applied a brilliant analysis of symbolic logic to Whitehead's own logical system, presented in his masterwork *Principia Mathematica* (developed with his colleague Bertrand Russell, 1912). Somewhat ironically, in view of Whitehead's own later work, it was Whitehead and Russell's intention to create a *complete* logical system to represent all of mathematics. But Gödel proved, with unassailable logic, that it *must* be incomplete – and so too must any such formal system. The implication is that any referential system – that is, any system that refers by formal representation to some other system, including any model – must be incomplete. Furthermore, this incompleteness is not a trivial distinction, but it goes to the core of any referential system.

The philosopher Ludwig Wittgenstein (1953) made a similar observation about the nature of language itself. In his earlier work (1921) he had built on Russell's own work to develop a theory of the correspondence of linguistic acts to structures in the world, as maps correspond to the regions they represent (a “picture theory” of language, as he put it). His later work, however, recognized that there is no such simple mechanical coupling of a linguistic model to its subject; indeed, he formulated a “rule-following paradox” that showed, not unlike Gödel, that language could not be generated by a rigid set of rules of correspondence to reality. Rather, the linguistic system must function as a kind of “game”, or an analog system with its own internal rules, in which useful but quite loose correspondences may (or may not) occur. To think otherwise, Wittgenstein warned, is to fall victim to a kind of “bewitchment of intelligence,” of just the sort that language (and especially the misuse of language) is prone to encourage.

Unfortunately we can still see examples of Wittgenstein's "bewitchment of intelligence by means of language" and Whitehead's "fallacy of misplaced concreteness" in many modeling methodologies today – or what is just as unfortunate, in their uncritical application by over-specialized professionals. These faulty outputs become the uncritical basis for rigid, poorly optimized design decisions, with little scope for refinement and fine-grained support.

As the urban theorist Jane Jacobs (1961) pointed out, such models actually fail to account sufficiently for what she described as "the kind of problem a city is" – a problem that has the dynamic behaviors of living systems and their processes. Such systems cannot be entirely reduced to linear, single-variable analyses or statistical models – though these approaches have their limited place. However, she argued that their misuse by planning specialists damages the inherent capacity of these cities to self-organize in benign ways. The inevitable result is the grim damage that is readily observable in great cities of the 1960s, as she documented in her landmark work *The Death and Life of Great American Cities*.

Complexity and Self-Organization

Jacobs' analysis alluded to yet another fundamental problem with the modeling of complex phenomena like urban systems. It is that the phenomena we are modeling do not sit frozen, but have the unfortunate habit of self-modifying in response to dynamic events, and in unpredictable ways. That is, they are complex adaptive systems that are continuously evolving and, to some degree, self-organizing. While some of their features may remain relatively static, many of them – particularly those relating to socio-economic interactions – are exceedingly dynamic. Often they have "non-linear" characteristics, i.e. their behavior is not proportional to the quantitative factors that influence it. Clearly we must somehow account for this dynamism in any model as well.

The development of transportation modeling illustrates the nature of the problem. Earlier transportation models treated the actions of individual vehicles as simple and predictable elements that seek only to continue on their current path at the maximum possible rate. The errors of these models, and the failures of the systems constructed in response – particular the failure to alleviate traffic congestion for any but a short period – are now well documented (Supernak, 1983). Of course, human beings are decision-making agents in their own right, and they are able to decide to take alternative routes based upon dynamic conditions – or not to travel at all. One consequence of this dynamic environment is the phenomenon of induced demand: the more supply is increased; the more demand may grow in order to consume more of it (Noland, 2001).

The same limitation affects the systems that generate greenhouse gas emissions. As Mayumi and Giampietro (2006) pointed out, the socio-economic systems that are ultimately responsible for greenhouse gas emissions are themselves self-modifying, and because the number of variables is large, the ability to predict actual outcomes is greatly reduced.

Jacobs (1961) noted the importance of large numbers of variables in playing a role in the complexity of cities. But she argued that it is not only the number of variables, but the way they are interrelated within a structural characteristic she referred to as "organized complexity." She noted the progress made in the life sciences in understanding how the elements of a system modulate one another's behavior so as to form an "emergent" pattern.

In the subsequent decades, this progress accelerated notably, as problems in many fields were seen to be understandable as problems of complex adaptive and self-organizing systems. The progress was perhaps most dramatic in the field of biology and genetic processes. For example, Farmer et al. (1987) were able to show how so-called "network models" could explain the complex interactions of immune systems and other biological phenomena, and they applied the insights to other systems as well. Kauffman (1993) also showed that self-organization processes are capable of accounting for the evolution of complex biological structures. But self-organization was readily seen in other systems. Nicolis and Prigogine (1977) described the self-

organization of non-equilibrium chemical systems. Kauffman (1995) described broader insights from self-organization and complex adaptive systems.



Figure 2: Self-organization is seen in many natural systems including this bird flock. Each bird follows a local set of rules to adjust its position to the other adjacent birds, and the system “self-organizes” into an ordered structure. Similar phenomena have been extensively studied in urban systems and their economies (Source: Christoffer A Rasmussen).

A number of authors have also applied these lessons to urban systems since Jacobs. Salingaros (1998, 2005) described the “urban web” as an interactive network with dynamic and self-organizing aspects. Batty (2007, 2009) described the complex and fractal structure of cities, and proposed modeling methodologies to account for this structure. Allen (1997) described cities and regions as self-organizing systems, arising from the complex interactions of individual agents.

In these and related findings, the topic of self-organization poses profound epistemological limitations – but also opportunities (Kauffman, 1995). If we can understand the dynamics of these processes, we might well find ways of enhancing their desired results, and suppressing their undesired results. This indeed has been a fertile area of research. In fact, a number of modeling methodologies have been developed so as to account for and exploit these dynamics. We discuss several of them in more detail below, followed by a discussion of their relevance for carbon reduction urban design modeling more specifically.

METHODOLOGIES FOR MODELING UNDER UNCERTAIN CONDITIONS

Beginning in the middle of the Twentieth Century, a number of innovations in modeling methodology emerged to incorporate the epistemological insights of earlier decades. We survey several of the most relevant up to the present day, and draw conclusions for current work in development of urban design support modeling.

Improper Linear Models

Although linear models are often significantly inaccurate, they may still be more accurate than human judgment alone, including the judgments of highly trained professionals (Kahneman, 2011). This may be because, like all models, linear models combine inaccurate features with features that may be accurate enough to be useful in some decision-making contexts. The

question is not whether they have any inaccuracy – all models must, as Gödel demonstrated – but whether they nonetheless provide useful capabilities.

The usefulness of so-called “improper linear models” was made clear in a very highly cited paper by the psychologist Robyn Dawes, titled “The robust beauty of improper linear models in decision-making (1979). In it he demonstrated that, in certain contexts, “improper” models (that is, models in which the variables are not properly weighted in relation to one another) can be useful. These contexts are typically where data is limited and “noisy” (inaccurate) and where there may also be many variables of data. In such a case it may be more effective to simply aggregate the factors without giving them weight. In fact, the research shows very clearly that such models can be remarkably effective, and far more accurate than human judgment.

It is a remarkable fact that this is so. The reason, according to Dawes, is rooted in the subject of epistemological limits as we discussed previously. While models can suffer from inability to cope with complexity and dynamic self-organization, it appears that human judgment is even more prone to error. As later work by Kahneman (2012) showed, we make decisions with cognitive systems that are extremely vulnerable to biases and distortions. When it comes to phenomena like climate change, these biases can result in the familiar patterns of inaction and apparently irrational response. Improper linear models, for all their limitations, might well be superior to human judgment.

A rudimentary example of an improper linear model, according to this definition, is the urban sustainability rating system known as LEED-ND, or Leadership in Energy and Environmental Design for Neighborhood Development. The system uses a point system for scoring a range of urban sustainability metrics. It has been criticized, probably rightly on the merits, for ranking the points in an arbitrary way – “improperly” according to this definition (for example, in the critique of Sharifi and Murayama, 2013). Yet Dawes' work suggests that LEED-ND may well be a good interim model to use, at least until such time as better models are developed.

System Dynamics Modeling

The fundamental problem of dynamic interaction and feedback was recognized in the 1950s by Professor Jay Forrester of the Massachusetts Institute of Technology (1957, 1961). His methodology, called “system dynamics,” explicitly built in recognition of the effects of feedback and time delays with the behavior of systems, and the methodology sought to capture and predict the outcome of such interactions.

Forrester's stepwise, iterative modelling methodology can be described as follows:

- First, define the boundary of the phenomenon to be modeled, using existing boundaries as much as possible.
- Second, identify the most important “stocks” (metrics) and the flows (movements of quantities) that will change these stock levels.
- Third, identify inputs that will influence the flows.
- Fourth, identify the feedback loops in the flows and the inputs.
- Fifth, draw a “causal loop diagram” that links the stocks, flows and inputs.
- Sixth, write equations (or computer programs) that will calculate the flows.
- Seventh, estimate the parameters and initial conditions, using the best information available.
- Eighth, run the simulation of the model and analyze the results.
- Finally, if iterations are required, cycle back to the point of the next iteration.

Forrester's modeling methodology became popular in business management and industrial process engineering, notably as a tool to optimize quantities and delivery times. Initially a manual method, the process was computerized in software such as SIMPLE and DYNAMO, and it became an industry standard tool. The modeling was expanded into urban systems when Forrester was asked by Boston mayor John Collins to collaborate on a project at MIT, resulting in the book *Urban Dynamics* (1969).

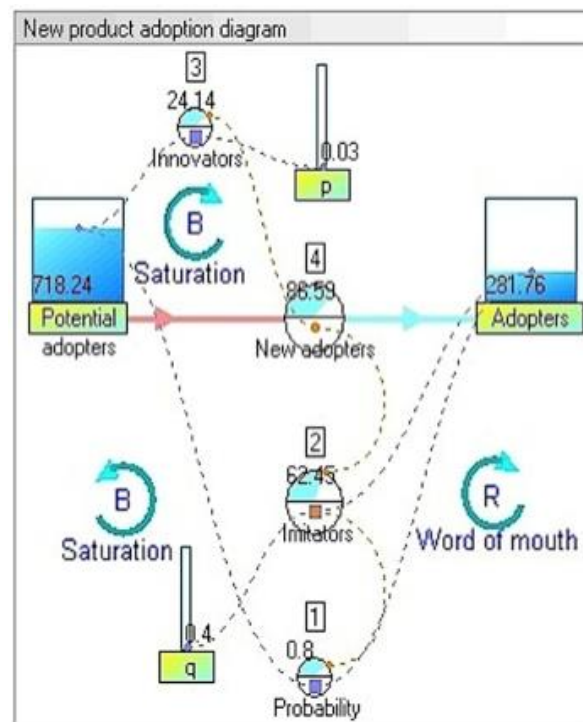


Figure 3: Diagram of a dynamic model of the interaction of factors in the adoption of a new product, as it is influenced by word of mouth, imitation, innovation, and other factors.
(Source: Patrouh/Wikimedia Commons, After Sterman, 2001).

Forrester was drawn into global systems modeling in his work for The Club of Rome's 1972 report *The Limits to Growth*. That work certainly focused public attention on the ecological parameters of socio-economic systems, and the implications of their limitations. But its notable inaccuracies of prediction (for example, it under-estimated ecological capacity) also did damage to the reputation of such large-scale models. In fact, the following year, a "requiem for large-scale models" was published in the *Journal of the American Institute of Planners* (Lee, 1973).

Other critics pointed out the value-laden assumptions in Forrester's modeling. Kadanoff (1971) published a critique of Forrester's book *Urban Dynamics*, making the argument that Forrester's choice of modeling elements shaped the outcome. Harris (1972) argued that single projections, including those proposed by Forrester, are extremely unreliable because their boundary definitions isolate the entity under study from its environment. He suggested that Forrester's modeling, while highly influential in business process planning, had little effect on urban planning practice.

Artificial Neural Networks and Bayesian Belief Networks

The recognition of limitations imposed by self-organizing phenomena has inspired a class of models that are able to self-organize on their own, and, in effect, "learn." Notable among these are "artificial neural networks," which seek to mimic the learning processes of neurons in biological systems (Rumelhart and McLelland, 1986). This approach to modeling is "connectionist" – that is, it relies upon the evolving set of connections between the elements of the model, which are not defined statically as in Forrester's system dynamics.

This work has begun to be applied to modeling, and to greenhouse gas modeling specifically. For example, Radojević et al. (2013) published a report on a project to forecast

greenhouse gas emissions in Serbia using artificial neural networks. However, much more remains to be done in this promising area.

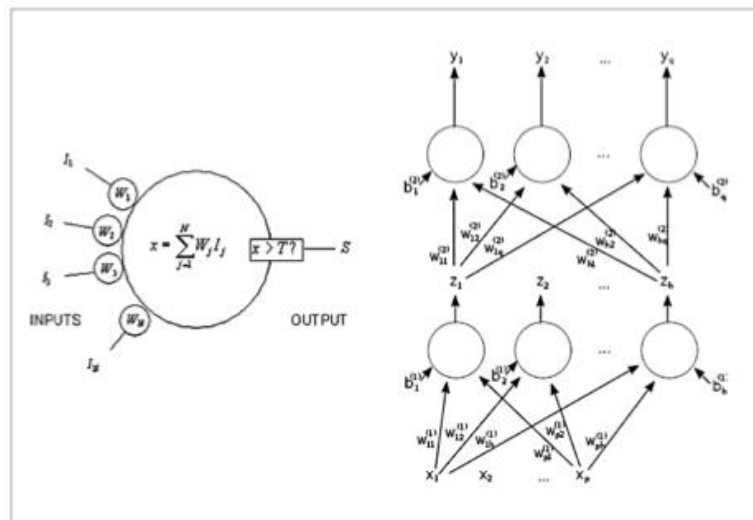


Figure 4: Artificial Neural Networks solve optimization problems by mimicking the way natural neurons work. Left, each neuron receives inputs from other neurons and decides whether to “fire” based on a threshold value. Right, the network of neurons is able to “learn” the pattern that produces the intended output. (Source: Left, after Ivan Galkin, U. Mass Lowell. Right, M.C. Strother).

Bayesian belief networks are similar in that they have the capacity to learn by identifying and evaluating inferences within a modeling environment of uncertainty. But they do so using so-called Bayesian probability, a statistical approach to uncertainty that does not work with “true-false” relationships, but with degrees of probability based on incomplete knowledge and belief. In such a model, a certain quantitative relationship between A and B might be probable to a certain degree (say, residential density and number of kilometers driven), and another relationship between B and C might also be probable to a certain degree (say, number of kilometers driven and types of automobiles owned), but with variable degrees of probability. The resulting network can model the total degree of likelihood for the condition in which A, B and C interact (say, how residential density relates to types of cars owned, and how both affect kilometers driven).

Bayesian belief network models have been used in ecological modeling and conservation (Marcot et al., 2006) and the effects of variable greenhouse gas emissions on sea ice and polar bear populations (Amstrup et al., 2010). A Bayesian Belief Network has also been used successfully to model land use decision behaviors (Aalders, 2008). Again, more remains to be developed in this promising field.

“Dynamic Structural Models”

Several fields, notably econometrics, apply the concept of a “dynamic structural model,” in which the behavior of an individual (a person or object) is predicted based upon a dynamic interaction of structural conditions and preferences (Aguirregabiria, 2011). In this sense, the individual person or object is embedded within a dynamic system and their behavior is understood as an interaction with the other factors.

In computer systems engineering and other related fields, the same term is used to describe an “object-based” modeling process. The systems that are modeled are not seen fundamentally as collections of discrete mechanical elements, but rather, as whole systems that are “decomposed” into smaller systemic wholes according to their functional sub-systems. These

elements of “dynamic structural models” are more readily able to retain the larger systems attributes that are essential in the generation or “instantiation” of new applications (IBM, 2014).

Pattern Languages

In software, one of the best known such object-based modeling systems is pattern language programming (Coplein and Schmidt, 1995). Pattern languages, developed by architect Christopher Alexander, have been used successfully as object-based models of software design since the early 1990s. In fact they are now ubiquitous within computing, and they form the basis of many common software systems (such as the Apple Mac OSX and the iPhone Cocoa language). Pattern languages have spread into many other domains as well, including human-computer interaction, service design, business administration, education, and many other fields. In some cases innovations in software design have led to innovations in other fields; a notable example is the development of the “Scrum” and “Agile” methodologies, which began in the software world and spread to become mainstream management methodologies (Beedle 1999; Mehaffy 2010).

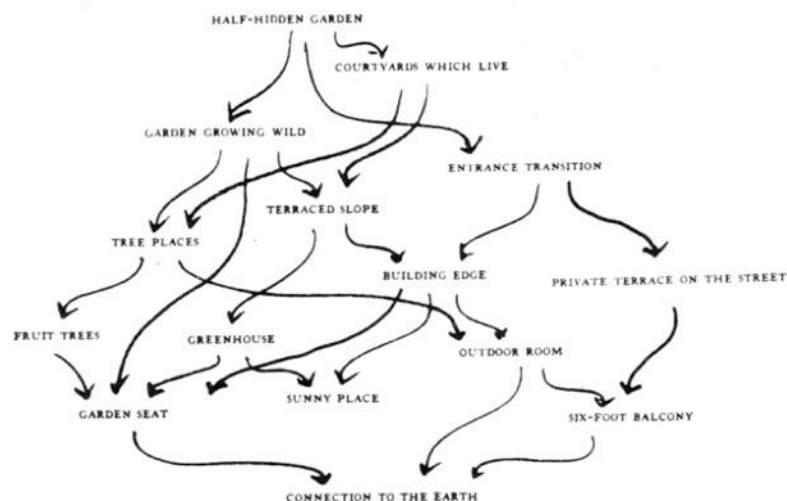


Figure 5: Pattern languages have been used in many fields of software and hardware design, following their invention in the field of architecture. The elements and their linkages form a web-network, which usefully mimics the web-network structure of design problems (Source: Christopher Alexander).

The reason that pattern languages, invented for architectural design, fit so well within the object-based approach of computer software is that they were explicitly developed as flexible, networked, language-like design models (Mehaffy, 2010). Their inventor, architect Christopher Alexander, was trained as a mathematician and physicist before earning the first Ph.D. in architecture at Harvard University. However, he spent time working on early generations of computer decomposition software. He also worked closely with leading cognitive psychologists at MIT, including George A. Miller, and his Ph.D. research included cybernetics, cognitive psychology, linguistics and philosophy.

Like Wittgenstein, Alexander became convinced that language was not a perfect decomposition of an orderly hierarchical reality, but more like a “game” with its own set of objects and rule-based interfaces, only loosely coupled to the world to which it referred. It had ambiguities, overlaps, and the complexity of web-networks – as did the phenomena it sought to describe. So, too, designs must not seek to be perfectly rigid hierarchical structures made up of collections of elements, but rather, they must be systems with language-like ambiguities (Alexander, 1965). The value of such a design model was in its ability to capture the same web-like structure of the world, and to be able to explore a wide range of design possibilities in a powerful and flexible way – not unlike the power and flexibility of natural languages.

One of the developers of pattern languages in software, Ward Cunningham, took this capability a step farther. He developed a flexible new tool for collaboration, using pages as hyperlinked objects or patterns. His invention, Wiki, is also now a ubiquitous tool, leading to the development of Wikipedia and thousands of other corporate and private wikis (Mehaffy, 2010).

Another key capacity of pattern languages is that, like natural languages, they are shared and evolved by a community of users. For Cunningham, this capability was an essential strength of Wiki, and was clearly a critical ingredient of the success of Wikipedia. Cunningham is now working on a new generation of wikis that will, in addition, have the capacity of data management and manipulation, as well as a more distributed, “federated” structure (Mehaffy, 2013; Cunningham and Mehaffy, 2013).

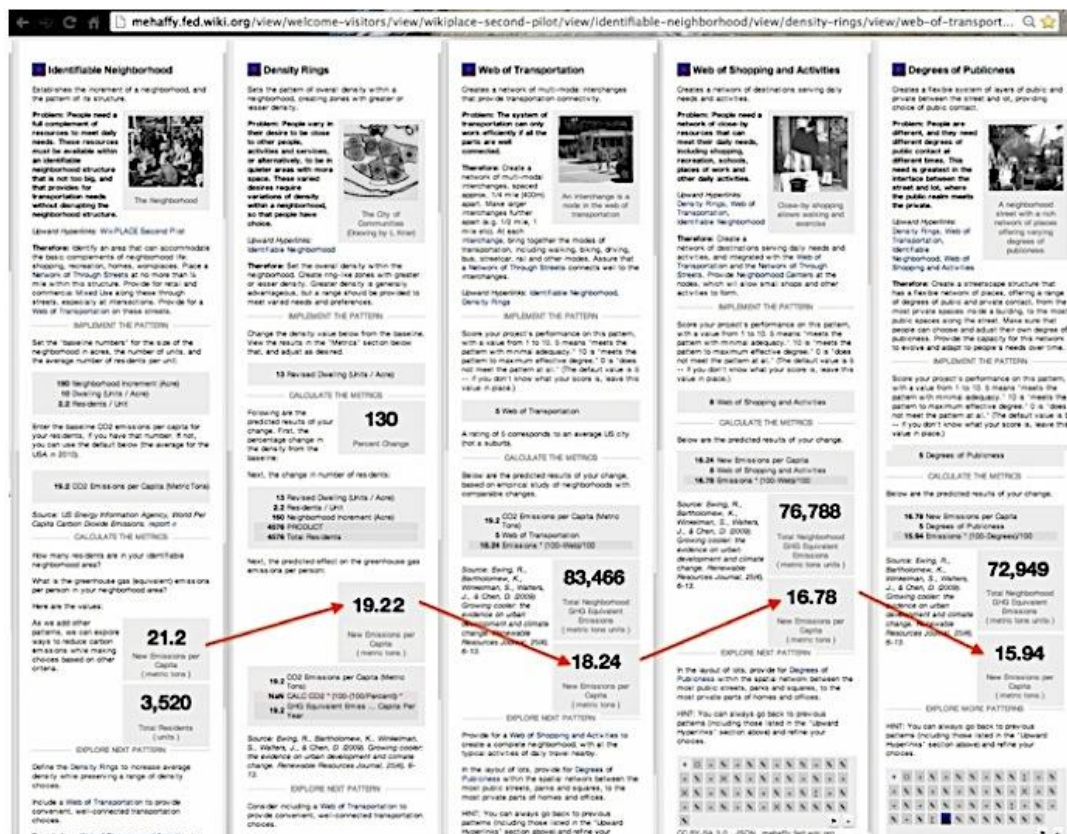


Figure 6: An early test version of a wiki-based pattern language modeling system that is capable of modeling and calculating the magnitude of “externalities” such as greenhouse gas emissions, called “WikiPLACE” (“Wiki-based Pattern Language Adaptive Calculator of Externalities”). It is under development as part of a quantitative wiki system now in development by Wiki inventor Ward Cunningham. Users choose “patterns” that interact with other patterns to produce an optimized output. By modifying the patterns, users can develop and test scenarios.

(Source: Cunningham and Mehaffy, 2013).

CONCLUSION

Building on the advances of these existing methodologies in other fields, we can now state the requirements of an effective modeling methodology for resource-efficient urban decision decisions, working under the uncertain conditions with which we must cope:

1. **Such a methodology will be iterative.** It will not be applied in a single iteration to any degree of effectiveness, but will improve with successive iterations.

2. **It will be able to regularly make comparisons with empirical results and adjust its predictive data accordingly.** The iterations will be of little benefit if they do not allow a periodic comparison with empirical results so as to verify or refine the model.
3. **It will utilize the iterative participation of a community of users in an “open-source” format.** In this way the improvements can be distributed across a larger community, and the cycle of improvements can be accelerated.
4. **It will include the most readily identifiable factors, and add other factors as they can be established accurately.** The accurate weighting of the factors is less important than their inclusion within the model as it goes through iterative refinement and empirical adjustment.
5. **It will account for the dynamic interactions between factors, without becoming overly complicated.** The best way to do that is to use a more flexible, web-networked, language-like approach, rather than a mechanical approach to constructing components within a linear or reductionist scheme.
6. **It will draw on the best available data – but it will also compensate for the inherent uncertainties of the data.** This means using methods to draw inferences (such as Bayesian methods) and other compensations. It will also mean that the result is treated as provisional and incomplete, but nonetheless, a useful basis for incremental improvement.

It will be noted that the previously discussed modeling methodologies do contain some or all of the features specified above, to varying degrees. But an opportunity now appears to combine the varying benefits of different approaches into a next-generation methodology, as outlined here. For example, in what ways might pattern languages be able to function as artificial neural networks, capable of learning in problem solving – particularly with the open-source capabilities of a Wiki community? What capacity might such a technology offer for developing more effective design models, and more effective problem-solving capability for complex contemporary challenges?

Such a synthesis methodology therefore suggests the possibility of a promising new kind of design technology – or perhaps an existing technology, given useful new capabilities.

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A CASE AGAINST THE MODERNIST REGIME IN DESIGN EDUCATION

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Abstract

The article argues that the present dominance of the modernist design idiom, and the general aesthetic inferiority of existing non-modernist stylistic alternatives, is a consequence of the fact that design schools have for decades banished non-modernist visual idioms from their curricula. The author discusses original arguments for the single-style / single taste modernist regime of contemporary design schools, and contends that the modernist vision of a single unified style, which prompted the banishment, was rooted in a backward-looking effort to imitate the aesthetic unity of pre-industrial, aristocratic epochs. Against the received view of modernism as an expression of modernity, the author argues that the modernists were, on the contrary, intent on suppressing the key novel feature of the modern time: its pluralism in general and its aesthetic diversity in particular. It is further asserted that the design philosophy behind the modernist regime was largely self-serving, aimed at securing the modernists an educational and aesthetic monopoly. The author pleads for transforming the modernist design education into a modern one, where a pluralism of aesthetic idioms and positions replaces the current one-style-fits-all approach.

Keywords: design history; design pedagogy; modernist design theory; stylistic diversity; modernism, historicism, styles

DESIGN SCHOOLS NEGLECT THE DIVERSITY OF AESTHETIC PREFERENCES IN CONTEMPORARY MARKETS

There is no doubt that the modernist visual idiom has been a striking success – so much so, in fact, that the word *design* has now come to stand for a definite visual style. Terms such as *design sofas*, *design fireplaces*, *design apartments*, *design boutiques*, and many other design-branded things, obviously refer to the modernist minimalist aesthetic the media and public have come to associate with the word design. But this identification of design with a particular stylistic idiom is not only a sign of the success of this idiom, but also, at least to my understanding, a sign of a major problem. I contend that the focal points of the problem are contemporary design and architecture schools.

Let me add that this text relates mainly to the world of three-dimensional design, and not so much to graphic design or textile design where the situation has never been so dominated by one idiom only. It does touch upon architectural design as well, though architecture is not its main focus. And although I have in mind European design schools in general, I am aware I may be speaking from a limited North European perspective. So please judge for yourself and in your own context the validity and topicality of what follows.

I submit that the magisterial position of the modernist visual idiom, which turned the term design into a synonym for modernist minimalism, cannot be explained by the usual claim that the idiom proved fit in many contexts. Rather, it has a lot to do with the fact that an absolute majority of designers and architects, who graduated from the modernist design schools since the 1950s, have been neither willing nor able to design in any other stylistic idiom practiced during the same period. The ubiquity of the modernist esthetic is, in other words, largely a result of restricting design education to the modernist idiom alone. This modernist restriction, or rather the modernist educational monopoly, is the problem I want to discuss.

I mentioned other stylistic idioms. Probably you would object that non-modernist idioms, such as the present day versions of stylistic historicisms, the anthropomorphic, zoomorphic, and other kinds of figurative design, as well as various decorative and ornamental schemes, are nothing more than fringe phenomena, not worth taking seriously. But wait: if we see designers and architects as members of professions vitally connected to the mechanism of supply and demand, what are we to make of the fact that things dressed in non-modernist styles are still very popular, and that they, in fact, have never really disappeared? Although almost entirely ignored by both design and architectural historians, these non-modernist idioms have existed all the time alongside the modernist aesthetic, and have done so for one simple reason: there has always been demand for them. And they have always been in demand because they have given pleasure to many people. As design teachers, we may deplore the fact, but that does not make it go away. Whether we like it or not, we have been living in an age of stylistic pluralism.

But even if some of you would acknowledge that various non-modernist stylistic idioms are popular, you would probably point out that those idioms, as embodied in concrete products, are, aesthetically speaking, mostly mediocre or worse, compared to the majority of modernist objects. Regrettably, it is true. But again: is that lower aesthetic quality a sign of an intrinsic inferiority of these non-modernist idioms as such? Or is it rather the consequence of the refusal of design schools to offer instructions to those who would choose to meet this kind of demand, and design in one of the non-modernist idioms? Those who practice the non-modernist visual design usually have no design education, and it shows. Schooled designers, on the other hand, receive no practical knowledge of any non-modernist formal languages. In addition, they are equipped with a strong bias against practicing of that kind of idioms. Extremely few of them are able to overcome that prejudice, knowing or suspecting they would risk excommunication from their own professional community.

Once you start thinking of it, it is certainly odd that design schools have largely ignored the full scope of aesthetic demands in society, and that for several generations only one particular type of aesthetic, to the exclusions of all others, was chosen to be imparted. To limit the scope of instruction to a single aesthetic idiom would surely be less baffling and much less problematic in private design and architecture schools, which naturally follow aesthetic orientations of their owners. But an overwhelming majority of design schools are state-run, public institutions, financed via taxes exacted from all citizens – not only from the modernist buffs. Besides, the governments which finance architecture and design schools are neither autocratic nor totalitarian or authoritarian regimes. They belong to modern democratic states, where the plurality of political, cultural, and religious positions, as well as the resulting diversity of lifestyles in the populations, is accommodated as a matter of principle.

One would then expect that, being run by modern democratic governments, the design schools would feel obliged to cater not only to the idiom popular with designers, architects, and art people themselves, but also to other categories of existing stylistic and taste preferences popular among those who do not happen to be, or not aspire to be, designers or architects, or design historians or art critics. This is, however, not the case. I would therefore argue that the schools have for years failed to do their job properly. As a consequence, we keep letting down huge numbers of ordinary, non-art people, who live outside our little ghetto-like art world. Why this apartheid-like approach to design training? How come all state run design and architecture schools practice a single-idiom / single taste aesthetic monopoly? How did we get there?

MODERNISM IN ARCHITECTURE AND DESIGN WAS AN ANTI-MODERN, BACKWARD-LOOKING IDEOLOGY

The dominant reason for this state of affairs is that modernism is, by its very nature, a monopolist ideology. The majority of present day design schools still seem to be wedded to a more than one hundred year-old modernist vision of a single style. Since the end of the 19th century, modernists argued that in contrast to previous epochs where each epoch had supposedly produced its own typical stylistic idiom (Classicism and Gothic would be the chief examples), the present time,

although enormously different from all previous epochs, had failed to bring about a style of its own. Designers and architects were purportedly reduced to repeating the idioms of the past, recycling both Western and exotic historical idioms (Horáček, 2014). According to modernists, it was imperative to bring about the still absent aesthetic unity to which the modern epoch was supposedly entitled.

Now, in their effort to create a new “authentically modern” idiom out of the means of the present, modernists claimed to have turned their backs on the past. But have they really? True, they ceased using both the *form language* and *pattern language* (Salingaros & Mehaffy, 2006) of historical styles of the past. But their goal, an aesthetically unified modern epoch, had nothing to do with modernity. It was born out of a profoundly backward-looking vision (Kellow, 2006:ii, iii). Modernist architects and designers wanted to recreate the present in the image of past epochs. They insisted that their own period have the same stylistic unity that, according to the discipline of art history, characterized the pre-modern, feudal epochs prior to the Industrial Revolution. But the stylistic unity of those past epochs, to the extent there was any, was a by-product of very small elite power groups, such as royal courts, aristocracy or the church, having, on account of their wealth, a decisive say in all things aesthetic, with hardly any input from the rest of the society. This explains the enormous attraction of the modernist idea that the Modern Epoch was obliged to have a new style all of its own. Modernists, arguing that they had worked on behalf of the Modern Epoch allegedly longing after its own authentic expression, set up themselves as the new elite group, aiming to secure the same aesthetic unity as the pre-modern period purportedly had. This was to be achieved through their monopoly decision power in all things aesthetic.

To exemplify the past-dependent modernist vision of a single, unified, modern idiom, let me quote four passages from four leading 20th century modernists.

The Swiss architect Hannes Meyer expressed succinctly, though unwittingly, this backward-looking aim of modernism in his article “Die neue Welt” (“The new world”) from mid-1920s when he wrote:

Each age demands its own form. It is our mission to give our new world a new shape with the means of today. But our knowledge of the past is a burden that weighs upon us, and inherent in our advanced education are impediments tragically barring our new paths. The unqualified affirmation of the present age presupposes a ruthless denial of the past (Meyer, 1975:107).

The supreme modernist ambition, as the quotation reminds us, was to do at present what craftsmen, designers and architects of the past supposedly had always focused on: to generate an authentic expression of their own epochs, entirely independent of previous stylistic idioms.

Several years later two American architectural writers, Henry-Russell Hitchcock and Philip Johnson, employees of the Museum of Modern Art in New York, formulated the past-dependent modernist ideal with even more clarity when they stated:

Now that it is possible to emulate the great styles of the past in their essence without imitating their surface, the problem of establishing one dominant style, which the nineteenth century set itself in terms of alternative revivals, is coming to a solution (Hitchcock & Johnson, 1932:19).

The German architect Walter Gropius claimed in 1935 that:

It is now becoming widely recognized that although the outward forms of the New Architecture differ fundamentally in an organic sense from the old, they are not the personal whims of a handful of architects avid for innovation at all costs, but simply the inevitable logical product of the intellectual, social and technical conditions of our age (Gropius, 1935:18).

And in 1964, after discussing the educational aims of the Bauhaus, Gropius stated his continued hope, that “we could gradually develop an art form that expresses the times, [an art form] such as existed in strong cultures of the past” (Neumann, 1970:19).

In 1967 the Danish designer and critic Poul Henningsen discussed in his article “Skal vi oppgi nutiden?” (“Are we to renounce the present?; Henningsen, 1967:170) the two new restaurants built and furnished in a peasant hut style, erected on each side of the new motorway leading out of Copenhagen. He claimed that although cozy and popular, both restaurants were “devoid of architectural quality”. His only support for that claim was that in the future (he mentioned explicitly year 2100, i.e. in some 130 years hence) these two buildings had allegedly no chance of ending up in an architectural museum, as representatives of what the Danes of the 1960s had achieved. Henningsen takes it here completely for granted that the architectural quality of a building consists in its future museum potential, as a representative of its historical period, rather than in pleasing its users. Quotations of this sort could fill several pages. Now, who were really the captives of history: the 19th century historicists, or rather the 20th century modernists? (Michl, 2014)

Not surprisingly, this effort to create a single, unified style was to collide with the real nature of the modern epoch, i.e. its essentially pluralist make-up. When the new religious, political and economic liberties of the late 18th and 19th century unleashed the brain powers of gifted common men, and led to what came to be called the Industrial Revolution, (Bernstein, 2005) the ensuing growth in the standard of living made the emerging stylistic diversity more and more manifest (Bell, 1979).

The early modernist architects and designers, in their search of clues of the authentically modern visual idiom, had misread the new, unprecedented utilitarian forms and shapes of the modern industrial means of production, interpreting them as signs of the novel “functional” style. To put it metaphorically, they were spellbound by a pointing index finger, while paying no attention to what the index finger was pointing to. What they failed to see was the rising standard of living the new machines and industrial constructions were slowly bringing about. Now, with the rising wealth (that the index finger really was pointing to) many more people than before, both the expanding middle class and the growing working classes, began – through their buying power in the market – to have a say in how things were to look. While buyers and users themselves greatly enjoyed this new empowerment, an increasing number of architects, designers and art people came to see the growing stylistic diversity as a Babel-like confusion. In their nostalgic obsession with the idea of aesthetic unity of the preceding aristocratic epochs, the modernist proponents completely missed what was truly epoch-making in the new industrial development: they failed to see the dawn of a radical diversity of lifestyles, and of plurality of aesthetic styles, vagues and trends that was emerging with it (Rittel & Webber, 1973).

MODERNIST SCHOOLS KEEP SPIRITING AWAY THE MODERN DIVERSITY

After the Second World War, the new one-idiom-only design and architecture pedagogy, modeled on the 1920s’ Bauhaus curriculum, was, with some delays, successfully implemented in practically all industrialized countries. Walter Gropius promoted already in the mid-1930s, in his book *The New Architecture and the Bauhaus*, the Bauhaus pedagogy as the model for any future design education (Gropius, 1935), on the account of its proclaimed position as a spearhead of the historically inevitable development. Gropius’ comrade, the Swiss architecture and design historian and theorist Sigfried Giedion, attempted shortly after the Second World War to promote (unsuccessfully) a worldwide reform of architecture and design education on the Bauhaus lines via the newly established United Nations Educational, Scientific and Cultural Organization (UNESCO) in Paris (Giedion, 1949). The subsequent modernist monopolization of design education was undoubtedly helped both by the violent status quo dislocations that came in the wake of the WWII, and by the widely advertised claims that the new modernist aesthetic was *the* historically necessary idiom the Modern Man had been waiting for. The general acceptance of the latter claim may explain why there has hardly been any research interest in following the concrete steps that led to the establishment of the modernist education monopoly.

This education monopoly came to be seen as the key to eradicating the modern stylistic diversity and to replacing it with a single, all-embracing modernist idiom. In this effort, two

different measures can be distinguished. One was to impart, sustain and reinforce in the student the belief that there is a single, true, and only moral expression of the modern epoch. Students, who, to begin with, were largely open-minded about the modern diversity of stylistic positions, were taught to respect only one taste culture. It was the culture identical with the less-is-more aesthetic preferences of their teachers, who considered themselves representatives of the aesthetic truth of the epoch. Students were induced to see the current non-modernist styles in contemporary use as ridiculous, inane, and even morally repugnant. The deal was that in repudiating pluralism, the students too would enter the elite (i.e. the avant-garde), and partake in giving collective birth to the aesthetic truth of the time.

The other ubiquitous feature was the promotion of the so called critical attitude to market economy. Although we all sometimes find the working of the supply and demand mechanisms personally objectionable, the wholesale modernist cultivation of a negative view of the market has been hardly more than a self-serving measure: it aimed at denigrating and rejecting this prime generator of aesthetic pluralism. As suggested earlier, the market economy, by empowering not only the tastes of the rich and powerful elites, but also an increasing number of emerging taste cultures, kept undermining the modernist project of a single style of the epoch. Market mechanism can be seen as a permanent ballot, or a referendum, about what at any time is in demand, based on consumer responses to inventive experiments of businesses (Gilder, 1981, ch. 4). Modernists wanted to do away with this ballot system because it kept providing non-modernist idioms at the expense of their own, allegedly historically necessary style. It was therefore considered imperative to weaken or preferably eradicate the market mechanisms. In this context it is not surprising that most of inter-war modernists were strongly attracted to various forms of socialist, collectivist ideas, as socialism promised to abolish the market system through monopolizing all means of production in the hands of the government. In the eyes of the modernists, this represented high hopes for realizing their vision of an all-embracing aesthetic expression of the epoch.

All this, the single style / single taste pedagogy, imbued with the concept of design as an aesthetic truth, coupled with imparting a strongly negative attitude to stylistic diversity and to market economy, were measures devised to bring about the modernist goal of an “authentic” visual expression of the new epoch. When contemporary design schools still cling to teaching a single aesthetic idiom, i.e. to ignoring the diversity of market demands, they in effect still gear their students, for five or six long years, to simulating a non-existent aesthetic unity in face of the modern epoch’s unredeemable stylistic diversity. This may sound like too absurd a procedure to be true, but how else can one understand the modernist education monopoly still firmly in place?

THE MODERNIST MONOPOLY IMPOVERISHES OUR AESTHETIC ENVIRONMENT

Some generations ago, the modernists devised a novel, fresh, matter-of-fact, naked-like stylistic idiom, an elementarist kind of aesthetic, until then largely missing among the established tradition-based visual signs of prestige, status and wealth. Developed in the 1920s, and largely based on the achievements of post-cubist abstract painters and sculptors, the new idiom was for quite some time enriching the aesthetic alternatives open to consumers at the time when diverse non-modernist stylistic competence still reigned supreme.

Today, with modernism for decades completely dominating design education, the erstwhile liberator has turned into a new autocrat. The problem is that perpetuating the modernist aesthetic monopoly keeps impoverishing the aesthetic means that could have been available at the designer’s hand. This in consequence impoverishes our aesthetic environment. The minimalist idiom itself, although admittedly refined and sophisticated as an aesthetic, seems to most people to be able to communicate their present day wealth – wealth in a broad sense of that term – mainly in one particular manner: through sophisticated signs of fictitious poverty.

One difficulty with this inversion is that its enjoyment is usually limited to well-to-do people with abundant cultural capital (Bourdieu, 1984). The inversion might be amusing if it was consciously intended and played with, but is it? As long as designers see their idiom in terms of

aesthetic truth, the results tend to be rather humorless. Humor in design seems to be a product of keen awareness that one deals in visual conventions rather than in aesthetic truths. Since humor and wit are related to a measure of skepticism, they do not go well with the ideologies of truth and authenticity. This may be one reason why general public often perceives the modernist design objects as dull, and the modernist architecture as contrived and arrogant. It certainly does not help that the modernist abstract idiom is almost exclusively self-referential.

As schools refuse to teach, cultivate, refine and fine-tune any non-modernist aesthetic strategies, and thus limit innovation possibilities to the minimalist style alone, they indirectly encourage only one kind of innovative direction: further away from heteronomy and more and more towards autonomy, i.e. closer and closer to “free art”, appealing more and more to art insiders only. If such a direction looks like a *cul de sac*, what else to blame than the single idiom monopoly of the design and architecture schools?

That the modernist victory was bound to end up like that is hardly surprising, taking into account that the rationale of the modernist design theory was predominantly strategic: it was about winning a war. It aimed, in the first place, to deride, disgrace, and disqualify the very idea of historicist and eclectic, i.e. pluralist, approach to design (Wright, 1931; Adam, 1988, 2008), and, second, to promote modernists’ own strikingly new visual idioms as historically inevitable, and therefore as the only legitimate aesthetic expression. In other words, the key modernist tenets – such as the claims that the new epoch demands its own aesthetic expression, or that functions contain their own preordained aesthetic solutions (as the form-follows-function slogan suggested) – did indeed an effective demolition job, and secured the modernists the coveted monopoly position. Nevertheless, as practicable, day-to-day design guidelines, the tenets proved entirely empty. To the modernist designers, their own theory was only helpful as a pep talk (Michl, 1995).

STATE FINANCING TENDS TO CEMENT THE ONE STYLE MONOPOLY

That the design and architecture schools go on offering a single visual idiom in a modern world of increasingly pluralist and aesthetically diverse societies, is after all not very surprising. The schools, run by the governmental departments, have always been financed by the taxpayers’ money. As there is no financial linkage to the market outside the schools’ walls, the schools experience no financial loss because of the mismatch between their supply and the demand out there. This may explain why the state schools have no incentive to abandon the entrenched monopoly of the modernist aesthetic, and to start relating to diverse kinds of markets outside the school walls. After all, who would want to rock the boat when the departmental money comes streaming in anyway?

But has not the monopoly situation changed? It seems that nobody explicitly promotes the modernist vision any longer. Two-three decades ago there was the short-lived movement of post-modernism, which, somewhat naively, attempted to replace modernism altogether. Before, during, and after post-modernism, scores of bright architects, designers, theorists and critics had been pointing out various problems with modernism, as well as developing alternatives to the modernist design theory (Muthesius, 1964[1927]; Barnes & Reinecke, 1938; Ames Jr., 1949; Mumford, 1964; Pye, 1964; Norberg-Schulz, 1977[1966]; Jencks, 1969; Jones, 1969; Tzonis, 1972; Allsopp, 1974; Brolin, 1976; Posener, 1976; Watkin, 1977; Blake, 1977; Pye, 1978; Bonta, 1979; Scruton, 1979; Hubbard, 1980; Jencks, 1980; Wolfe, 1981; Herdeg, 1983; Jones, 1983; Zeisel, 1984; Brolin, 1985; Rybczynski, 1986; Norman, 1988; Lawson, 1990; Petroski, 1992; Blake, 1993; Ackerman, 1994; Krier, 1998; Brolin, 2000; Watkin, 2001; Lawson, 2004; Lewis, 2004; Norman, 2004; Salingaros & Alexander, 2004;; Silber, 2007; Millais, 2009; Salingaros, 2013). As a consequence, reality has made inroads into the educational practice of design schools.

In the schools of design, we nowadays speak about product semantics, and emotional design, and we teach students the marketing aspects of design. All this can be seen as signs of departure from the previous monopolist modernism. But still: product semantics discussions are mostly limited to the modernist abstract aesthetic, as if visual culture commenced only in the

1920s with the abstract-art-derived aesthetic, and the Bauhaus. The notion of emotional design is often discussed as if non-modernist design or pre-modern idioms have never existed. Marketing courses run in parallel with the standard "critical" platitudes about the consumer society still at home in other courses. The schools still largely keep to their one-style-fits-all modernist ideal. And the users who prefer some sort of non-modernist, traditionalist look of things, still tend to be treated as if they were somewhat retarded. The modernist design ideology seems to be fully internalized now, running imperceptibly in the background like the air-conditioning system of the school's infrastructure.

In contrast to design schools, situation is positively different in the field of contemporary non-modernist architectural theory or practice. Here one can find vibrant, free-standing, but interconnected groups of vocal practicing architects and theorists, both in Europe and in the US, dissociated from the established schools of architecture. Besides penetrating and lucid criticism of the modernist ideology (Adam, 1988, 1991, 2003; Salingaros, 2002; Salingaros & Alexander 2004; Mehaffy, 2003; Kellow, 2006) there have been proposed explicit theoretical alternatives to the modernist design theory and pedagogy (Alexander, 1977, 1979, 2002a, 2002b, 2004; Krier, 1998, 2008; Salama & Wilkinson, 2007; Salingaros, 2005, 2006, 2013). Also, a fairly great number of remarkable buildings in non-modernist visual idioms have been built in the past 30 years or so: please, google names of contemporary non-modernists such as Robert Adam, Leon or Rob Krier, Demetri Porphyrios, Robert A. M. Stern, or Quinlan Terry (more at intbau.org).

A HOPE AFTER ALL?

Is there any chance that the established schools of architecture and design would include in their curriculum other aesthetic idioms, in addition to the modernist one? Well, realistically speaking, the chances are close to zero. In my experience, the standard answer to the sort of critique presented here – that design schools offer one stylistic idiom only, while modern epoch is distinguished by its stylistic diversity – is namely this: *We do not teach one idiom only – in fact we teach no idiom at all. What we do teach are methods.* This kind of response suggests that the central tenet of modernism is still believed to be true: the modernist forms are still thought of as by-products of objective factors, rather than as results of conscious imparting of a visual idiom. Admittedly, to insist on this traditional modernist self-understanding is a reasonable position to take. To admit that schools do teach a definite stylistic idiom leads immediately to the question of why exactly that idiom, and why only one and not more than one. So the most effective way to prevent this kind of profoundly unsettling questions is to deny that the schools have any stylistic agenda at all, and to keep insisting that the focus is on the methods. Sad to say, it seems that the modernist design schools are constitutionally unable to face reality inside their own walls. To admit that they, just as all schools before them, impart established aesthetic conventions, would wreak havoc with their whole identity. The schools therefore appear to be unreformable.

Unreformable, that is, unless we succeed in opening the eyes of our students – some of them future teachers – for the reality both inside and outside of the established schools. To that end we should make clear to these teachers-to-be the gist of our criticism: that modernists, in spite of their novel visual idiom, never came with any new design method – that the postulated radical distinction between the historicist and modernist design process has never materialized; that the modernist injunction to start from "functions" or from "problems at hand" means in practice starting from yesterday's forms, yesterday's solutions and yesterday's idioms; and that in this sense, the modernists – both past and present – worked exactly like the historicists before them did, simply because there has never been any other way of solving problems than by starting from yesterday (Lawson, 1990, 2004; Michl, 2002; Petroski, 1992). In other words, we should teach the students to see the modernist aesthetic not as an "authentic expression" of the modern epoch, but as something very different: as a strikingly new and innovative *contribution* to the stylistic diversity of the modern time. The schools should therefore embrace this modern stylistic diversity, and not only the modernist idiom – i.e. the most recent manifestation of that diversity. In other words, we should try to persuade the students that offering an aesthetically

pluralist curriculum would abolish the only thing that is wrong with the modernist idiom: its intolerant, monopolist pretensions. The abolition of the modernist regime, we should emphasize, would clear the way for truly *modern* schools of design and architecture, as against the old *modernist* ones.

NOTE: The text above was originally presented as an invited lecture at the conference of Cumulus / The International Association of Universities and Colleges of Art, Design and Media, in Bratislava, Slovakia, on October 12, 2007, under the title “Am I just seeing things – or is the modernist apartheid regime still in place?” The present text is partly reformulated, somewhat expanded, and equipped with bibliography.

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MUSEUM OF ART VERSUS THE CITY AS A WORK OF ART A Case of the New Acropolis Museum in Athens

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Abstract

This study is concerned with the New Acropolis Museum, which was opened in June 2009 in Athens. The New Acropolis Museum, out of all of the world's new museum structures of the past century, has dramatically intensified the issue of the relationship between parts and the whole, between the building and its integration into the setting, between the museum function and the historical city, which is a protected heritage site, one treated as a museum exhibit. With the New Acropolis Museum as an example, the study would like to highlight the complexity and the ambiguity of the present-day relationship between the heritage protection, the museumisation of art and the design of our environment. The particular attention is focused on the vivid debate about the building and the distinguishing the differences between traditionalist and modernist views of architecture manifested in this debate. These differences are deeper rooted than many people have been willing to admit.

Keywords: theory of architecture; museology; architectural conservation; traditionalism; modernism; the Acropolis Museum; Athens.

INTRODUCTION

At the beginning of the third millennium, museums certainly rank among the most prestigious architectonic themes. Unlike any other building type, the museum has retained its privilege to be a piece of *art*. Apartments, offices and shops, athletic facilities, cinemas and other entertainment facilities, even town halls and churches – all of these were able to be placed into the simplest aluminum or concrete boxes, thrown about open landscapes, while new buildings for museums were always given special attention and care. Because the construction of museums is so closely observed and so often commented upon, during these discussions opposing desires and conceptions of artistic values of architecture are exposed, to an extent and clarity which is unusual elsewhere.

This study is concerned with the New Acropolis Museum, which was opened in June 2009 in Athens. The building became the new, and controversial, feature dominating the cityscape. In its dimensions and shape, it challenges the key icon of the historical centre of Athens – the Parthenon temple on the holy mount of the Acropolis. The New Acropolis Museum, out of all of the world's new museum structures of the past century, has dramatically intensified the issue of the relationship between parts and the whole, between the building and its integration into the setting, between the museum and the historical city, which is a protected heritage site, one treated as a museum exhibit. The story of the museum invites to an examination of the ambiguous relationship of the art museum institution and its architecture toward the urban structure which serves as its backdrop and which is itself regarded as an artwork. With the New Acropolis Museum as an example, the study would like to highlight the complexity and the ambiguity of the present-day relationship between the heritage protection, the museumisation of art and the design of our environment. The particular attention is focused on the vivid debate about the building and the distinguishing the differences between traditionalist and modernist views of architecture manifested in this debate. As we will see, these differences are unfortunately deeper rooted than many people have been willing to admit.

THE NEW ACROPOLIS MUSEUM IN ATHENS

Here are the facts: the Acropolis Museum was founded in 1865 with the goal of housing and exhibiting the archaeological finds from the Acropolis, its slopes and foothills. The museum building, situated directly on the Acropolis, was rebuilt in the 1950s by the Greek architect Patroklos Karantinos in an unobtrusive modernist style. Its capacity was soon exhausted. There was a call for new spaces, also caused by another motive, this time a political one – a hope for the return of what have come to be called the Elgin Marbles. The British, who have been exhibiting these sculptural fragments from the Acropolis in London since 1817, had so far refused the requests of the Greeks for their return, claiming that Greece was missing an appropriate space in which to exhibit them.

Thus in 1974 the Greek prime minister, Constantinos Karamanlis, called for the construction of a new, larger, and more impressive museum. Its required size would rule out placement directly at the Acropolis; however the building should be connected visually with the hill. The Makrygianni parcel was suggested, an extensive trapezoidal plot used by the military, with various constructions along the southeast foot of the Acropolis (a hospital, barracks, churches, several family homes and apartment houses from the XIXth century and the interwar period of the XXth century) (Loukaki, 2008, pp. 284–287). It was not until the fourth competition for the project, which took place in 2000, that a design led to actual construction. The new museum was supposed to be opened in 2004, the year in which the Olympic Games took place in Athens. Similar to the architecture of the athletic stadiums planned for the games, the architecture of the museum was supposed to express the progress and the dynamism of Greek society and of the metropolis. In both cases thus a futuristic design was proposed. Only avant-garde, mostly deconstruction-oriented *star* architects were approached – and the Swiss-born American architect Bernard Tschumi was selected.



Figure 1: Bernard Tschumi – Michael Photiadis, the New Acropolis Museum, Athens, 2000–2009. In the foreground behind the big trees there is the pair of houses once intended for demolition (Source: Author, 2009).

Tschumi joined up with Greek architect Michael Photiadis. They designed a colossal building in the centre of the parcel, made up of an irregular two-storey prism on the trapezoidal plot, on which a rectangular block is placed with orientation copying that of the Parthenon and with similar dimensions to the temple. A smaller trapezoidal, two-terrace sandwich is connected with the basic body, narrowing to point in the direction of the Acropolis [Fig. 1]. The lower terrace, with a cut opening looking out onto the archaeological excavations, functions as the entrance to the museum [Fig. 2]; the top terrace is used as a café with a view. The entire structure is raised above the terrain on pillars, set into the foundation so as to reduce damage to the excavations and also so that the structure could better withstand earthquakes. The museum was opened to visitors on 20 June 2009. It expected to attract about two million visitors yearly and to significantly increase the tourist trade, which employs roughly one-fifth of the country's inhabitants (McGrath, 2009). In fact, approximately 1.3 million visitors came in 2010 and then again in 2011. Although the estimate was higher, the museum became the most popular tourist spot in Greece, even frequently visited than the Acropolis hill (The new Acropolis Museum, 2011).



Figure 2: New Acropolis Museum, entrance, with view of uncovered excavations (Source: Author, 2009).

Simplicity and transparency characterize both the ground plan of the museum, and also the exhibition concept and the materials used (exposed concrete, corrugated metal, and glass in huge, undivided spaces). A ramp and a moving staircase lead the visitor from the ground floor with services to the first floor with exhibitions of pre-Classical and Classical artifacts in one continuous space, circling the perimeter of the building and segmented only by the rhythm of concrete load-carrying columns and neutral pedestals. The path culminates in the second storey, where there is a replica of the Parthenon entablatures, with sculptures which are original (owned by the museum), or plaster casts (from those in the British Museum, occasionally from other world collections). The plaster casts are presented as a temporary solution, until the originals are returned. The entire glassed façade makes possible the visual confrontation of the exhibits with

their original environment. At night the illumination transforms the museum into a gigantic antique shop display window.

Out of the existing buildings on the parcel the former military hospital (in Byzantine style, from 1834) was preserved, also one small church and a part of another church, three one-storey Classicist homes facing the street and two three-storey apartment houses from circa 1930. Another 25 buildings were dispossessed and demolished and the plot was surrounded by a wall about 1.5 meters high, topped with a metal fence. The above-mentioned two apartment houses, with marble Classicist and Art Deco façades with sculptural and mosaic decorations (D. Areopagitou street, nos. 17 and 19), partly obscure the higher part of the museum. Their preservation was a condition agreed to by the Central Archaeological Commission regarding construction of the new museum. However in 2007, when the basic building structure was in place, the Greek Ministry of Culture struck the buildings off the list of cultural monuments in view of the fact that they were blocking the view from the museum to the Acropolis. An initiative launched by one of the owners showed that the buildings only partly obscured the view from the museum restaurant on the first storey, not the view from the higher floor with the exhibition of the Parthenon [Fig. 3]. A petition for saving the buildings, with the help of the internet, garnered 48,000 signatures from Greece and abroad, and also the support of international heritage conservation agencies (ICOMOS, INTBAU) and the International Union of Architects. In 2009 the Greek High Court of Appeals declared the Ministry of Culture decree to remove the protected status of the apartment buildings invalid. A citizens' initiative strives for an architectonic cultivation of the rear façades of the houses, now within view of the museum, and eventually covering them with greenery; a prominent architect of vertical gardens, Patrick Blanc (CaixaForum in Madrid, Musée du quai Branly in Paris), was mentioned in the discussions (Campbell, 2007; Kitsos, 2007–2008; A Monument in Danger, 2009). The revealed sidewall of the house at no. 17 is used by the museum as billboard space to promote its events. The construction was subsidized by the European Union; costs came to EUR 129 million.



Figure 3: New Acropolis Museum: view from the highest floor of the exhibition onto the Acropolis. In the center of the frame there are the rear areas of the houses once intended for demolition (Source: Author, 2009).

OPINIONS

How does the author explain his work, and what do the critics and the public think about it? The project provoked intense and contradictory reactions. Many archaeologists, architects and laymen criticized the form of the building and the proposed demolitions on the site. What about the architect? *"I always say that I did not want to imitate Phidias, but to think like Pythagoras,"* said Bernard Tschumi on the New Acropolis Museum.

Architecture is the 'materialisation' of a concept. It is always very much about a logic, as well as the simplicity and the clarity of the expression. So if La Villette and this building have something in common, it is the clarity of the concept. It is never about fancy shapes... In a way this case is the opposite of Bilbao. (Stathaki, 2008) [Fig. 4]

As opposed to the Guggenheim Museum in Bilbao, which, after Tschumi, did not have to take a given structure into consideration, in Athens it was necessary *"to establish a dialog with... th[at] masterpiece of ancient architecture"* – i.e., to the Parthenon. This meant above all to permit the viewer visual contact between the exhibits and their original placement on the hill, and to evoke the lighting in which the sculptures were originally perceived. Thus the highest level of the structure is oriented in accordance to the temple, and is all glass, so that the sculptures receive the sun's rays in the same intensity and color range as if they were in place on the metopes and entablatures of the Parthenon. The architect does not say much regarding the exterior: *"We had to consider the sensitive archaeological excavations, the presence of the contemporary city and its street grid."* (Tschumi, 2009) The architect was not engaged in the controversies and the one hundred and four judicial proceedings which were brought about by citizens' initiatives and archaeologists concerned with the future of the site: *"We stood at the side, protected by Professor Pandermalis. (...) I had no doubt that the design was the right one; that it was possible to build something at the site in a beautiful manner"* (Atkinson, 2009). Dimitrios Pandermalis, Professor Emeritus of Archaeology at Aristotle University, and Museum Director, became the defender of the project. The result was after him successful:

The design was chosen for its simple, clear, and beautiful solution that is in accord with the beauty and classical simplicity of the Museum's unique exhibits and that ensures a museological and architectural experience that is relevant today and for the foreseeable future (Atkinson, 2009).



Figure 4: Bilbao, on the right the Guggenheim Museum designed by Frank Gehry, 1993–1997 (Source: Author, 2010).

The New Acropolis Museum is one of the largest museum projects of the first decade of the XXIst century, and as such was carefully scrutinized and held in the spotlight of the media, even during its construction phase (Werner, 2006). Professional critics were divided into three camps. The first expressed unequivocal appreciation. According to Nicolai Ouroussoff (*The New York Times*) the museum was “a building that is both an enlightening meditation on the Parthenon and a mesmerizing work in its own right” (Ouroussoff, 2007). The popular British critic Jonathan Glancey declared the museum “a geometrical marvel dedicated to the celebration of antiquity” (Glancey, 2007). Perhaps the greatest praise given to it was by the critic in *Sculpture* magazine: “A building of such singing grace, that calls attention to its contents rather than itself, is like a gift from the gods.” (Durell, 2009) The museum became one of six finalists of the 2011 Mies van der Rohe Award (selected from 343 entries), a prestigious prize awarded by the European Union for the best European work of architecture in the past two years.

In addition to those critics who definitely liked the building, there were those critics who admired the interior, but were taken aback by the exterior. According to Hugh Pearman, an influential critic on modern architecture, the museum was “good inside, disappointing outside”. Pearman was not afraid to base his argument on his own experiences:

From outside, these do not create the spark, the lift of the soul, that great public buildings achieve. (...) I walked round it time after time and never got a sense of visual coherence. It's big, it's fairly clumsy ... lacking a level of detail. (Pearman, 2009) [Fig. 5]



Figure 5: New Acropolis Museum: rear façade (Source: Author, 2009).

The museum “evokes *High Modernist commercial American buildings of the 1970s*”, wrote Suzanne Stephens in the *Architectural Record*. According to her, “*Tschumi rightly resisted pressure to use the Parthenon’s Classical vocabulary*”, but he did not maintain the whole – there were some blind spots: “*The Herculean columns ... create an odd lack of coherence between pieces and parts, proportions and scale.*” And some sloppy work carried out in the exposed concrete detracted from the whole (Stephens, 2009).

Finally, according to a third group, the building represented a fiasco, primarily for the reason that the architect chosen, whose consistent deconstructivist attitude foreclosed any successful solution to the problem of building on this historically important site. According to these critics, the client was to blame, that is the museum management and the Greek government. Alexandra Stara, in *The Architecture Review*, confronting Tschumi’s rhetoric with his result, found empty sophism:

As with la Villette, the abstract geometric constructs that generated the project have little effect on the actual experience. The geometry of the Acropolis suggests a precise understanding of architecture as experienced event, as movement and measure of temporal rhythms – its drawings tell you little of its reality and meaning. With the New Acropolis Museum it is almost exactly the opposite.

The scale was not properly solved, nor the interior space (the entryway evokes “*a used-car dealership*”), nor the details and the materials used.

But Tschumi is Tschumi, with a considerable oeuvre, both written and built, that makes his position on architecture abundantly clear. The real question is what were the great and good of this glorious city hoping to achieve when they sat down with him (and long before him) to develop this project, and how can they still stand before us, before this very building, and rehash the same sophistry about light and clarity and you-name-it, as if they have never seen well-made architecture in their lives, and as if this isn’t all happening in the shadow of a certain Acropolis. (Stara, 2009)

The acerbity of this criticism is also surprising because *The Architectural Review* is a journal otherwise inclined toward (neo)avant-garde architecture. The desired qualities (especially the consistent preference for *quality of experience* as opposed to the *concept*, and the absence of temporal relativism in the comparison between the museum and the original Acropolis) bring the reviewer close to the arguments of Nikos Salingaros, the leading figure of contemporary traditionally-oriented theory of architecture. According to him, as well, Tschumi “*did what he does*”; while the Greeks showed how easily one could fall prey to political manipulation, and how easily they sacrificed the authentic values of their art in favor of trendy, imported affectation. The project was supported by the government without heed to right-wing or left-wing orientation; the citizens believed in the futile hope of the return of the Elgin Marbles; lovers of modernist art hoped one powerful gesture would improve the fame of Athens, lacking an interesting new building; advocates of the demolition of the original buildings wanted to show the world that the nation was marching forward into a future without nostalgia for the past. Greece however in all this showed that it remains “*still part of the Third World*”. Obviously from the commentaries on the catastrophic economic situation of the country at that time, Salingaros was not the only person of Greek origin living abroad who considered his countrymen naïve and irresponsible. Not even the inhabitants of the two buildings which were threatened protested when the Church of St. George was demolished on the parcel. They defended their passivity by higher public interest. Salingaros also underlined his thesis on the incompatibility of deconstructivist and minimalist architecture with permanent, sustainable development and a healthy lifestyle; he pointed to one argument in Tschumi’s written, declarative attempt (in the text *Architecture and Disjunction*, 1994) to transform the feelings of “*schizophrenia*” and “*madness*” into architecture (Salingaros, 2007; Salingaros, 2004, pp. 149–155, 170–171).

CLASH

The exploration of the relationship between museum architecture and the cityscape on the basis of this controversy can be broken down into the following five parts:

1.

Athens is one of the cities which has its period of most important historic significance behind it. A certain part of the population of such cities, both educated and common, is frustrated by this situation and welcomes radical steps, promising quick reinforcement, or even renaissance, of its former fame. The cultural sphere seems to be the arena for more realistic hope in success than the economic or political spheres, upon which local initiatives have a minimal influence in the globalized world. It proves that spectacular museum buildings can bring about the desired effect.

The monument assets of cities are by their nature limited and visually stabilized. This stability is – usually by the same group of inhabitants mentioned above – perceived negatively, as proof of stagnation. The strategy, when the standard new building by its qualities saturates the need for change by the locals, and at the same time increases credit and creates an attractive goal for visitors, is used minimally. While *the picturesque old town* asserts itself as a product on the marketplace with cultural attractions, a picturesque new town does this rarely, usually just when holiday visitors are taken into account from the start (such as Port Grimaud in the south of France, 1963–2009) [Fig. 6]. However, the main reason is that constructing a town tissue to be as attractive as old towns requires the complex cooperation of town management, private firms, citizens and artists – which in the last half-century has been rare. A single action – such as a launching a large museum – thus represents a relatively simpler way to achieve the two desired goals, which are to reduce the feeling of stagnation for locals, and to be attractive to strangers. Cultural content for a project receives more support among the educated circles, which otherwise would rather distance themselves from the principle of tourism and its economic benefits.



Figure 6: François Spoerry, Port Grimaud, France, 1963–2009 (Source: Author, 2011).

2.

The city center of Athens belongs to the first historical areas in the world relatively strictly protected because of its architectural heritage. Under the rule of the Bavarian Wittelsbach dynasty in Greece (1832–1862) and thanks to German architects, a preserved zone of an archaeological park was established around the Acropolis and the Agora. The new, tightly regulated building in Classicist style, increased the feeling of the city as a total work of art, considered one of the most beautiful in Europe (Tung, 2001). However, the Greeks, who during the previous Turkish rule could not own property, fought against the regulations and considered them an expression of German imperialism. With the expulsion of the Germans they ceased to take care of the new development. Especially in the waves of immigrants after the First and Second World Wars, Athens underwent land speculating and building which was not officially sanctioned. Mainly in the 1950s and 1960s, a large portion of the Classicist buildings were demolished and replaced mostly by modernist buildings some five storeys higher in average over the one- or two-storey houses of the XIXth century [Fig. 7].



Figure 7: Athens, nineteenth-century landmarks surrounded by twentieth-century urban development (Source: Author, 2009).

On the other hand, thanks to the American archaeologists from the American School of Classical Studies, the archaeological park was expanded onto part of the earlier built-up plots of the Agora. Moreover, a reconstruction of the Stoa of Attalos (1953–1956, John Travlos project) was built as a museum and depository for the excavations at the Agora (Thompson, 1992) [Fig. 8]. The complex of the Acropolis, Agora and Philopappos Hill today represents the largest urban pedestrian zone in Europe, where there are fragments of Classical buildings and Byzantine churches presented as a collection of monuments, basically acting as a *picturesque* park of the

XVIIIth century. The rest of Athens is made up mostly of artistically inferior buildings; a small portion is valuable individually. Nevertheless, it has kept its traditional street layout, which makes the city coherent as a whole.



Figure 8: The Agora from the slopes of the Acropolis: on the right the Church of the Holy Apostles from the eleventh century reconstructed by John Travlos in 1956, and the Stoa of Attalos reconstructed by John Travlos in 1953–1956 (Source: Author, 2009).

Basically the *historical city center* is understood as a separate zone with a specific functional content, oscillating between a downtown and a museum *in situ*. In Athens the museum function has prevailed. It has increased the feeling of stasis in relationship to this place and the need for a radical gesture of innovation, paradoxically again connected to the museological function. The institution of the museum as a collection is the result of the same way of thinking as is a conservation area – the modernist idea of zoning, i.e. the idea that it is possible, or even necessary, to concentrate in one place objects of one particular type, in this case pieces of *art*, aesthetically and historically valuable artifacts. For them a special zone is created – with the contemporarily acknowledged status that outside this zone such objects may not be. The French art theorist Antoine Chrysostôme Quatremère de Quincy at the turn of the XVIIIth and XIXth centuries expressed his opinion that artistic artifacts should be transported from their original locations and put into museums in those cases when being left *in situ* would damage them (for instance in the case of the Elgin Marbles being taken to London), otherwise he was opposed. He was concerned that in an artificial environment the works would lose their meaning. Quatremère preferred art *in situ*, integrated into ordinary life. For example, regarding the Roman Campagna he stated that “*the landscape itself is a museum*” (Sherman, 1994).

3.

Quatremère also wrote on *art history*, that arranging artifacts into chronological order was a method leading to the anesthesia of art itself (Sherman, 1994). Modernist architectural historiography, adds the contemporary British architectural historian David Watkin, encouraged

the replacement of lovely old buildings with unattractive new ones, and defended their appearance by the theory of developmental inevitability of a style not yet seen, a *true* and *contemporary* style (Watkin, 2001, pp. 148–149). Its rhetoric often used the notion of “*dialogue*” in the meaning of dialog of epochs (let us compare it with the statements of Bernard Tschumi and Nicolai Ouroussoff quoted above). Robert Jan van Pelt, the American historian and philosopher of architecture, in observing the architectonic transformations of Chicago, pointed out the destructive role of architectural historiography: “*My involvement in the local citizen-based preservation effort revealed to me the destructive role orthodox architectural history plays in our cities.*” (Pelt, 1991)

Architectural historians have defended the Athens project. It is difficult to find them mentioning any destructive intention. On the other hand, it should be relatively easy to demonstrate why the new museum building is in disharmony with its surroundings. The building lacks an adaptive design, a hierarchical structure of scale, patterns in common with its neighboring buildings (Salingaros, 2008; Horáček, 2013) [Fig. 9]. The whole conception is deliberately opposite to context and the existing complexity of a historical setting. The patterns that lead to cooperation were ignored in order to make a building stand out instead of blending in. Biophilic elements of traditional architecture in the surroundings are undone by the industrial anti-biophilic forms of the project. Why all that? As Nikos Salingaros answered, because of the modernist paradigm, not for any basic need – it’s just an image and a specific will to form, an intolerant one of the surroundings and the culture and history of the place.



Figure 9: An anti-pattern: the New Acropolis Museum against the former military hospital (Source: Author, 2009).

What does this so-called modernist paradigm include? The emphasis on the *contemporariness* of the outcome was mentioned. It is coming from the obsession with chronology – each year (month, day?) one must have one's own style, so that everyone the next year (month, day?) could distinguish when this or that thing was made. It is a sort of historicism turned on its head: while the traditional supporter of historicism in architecture (let us say in the XIXth century) borrowed from forms already discovered (because their period identification was less important for him), modernist historicism places the emphasis on the first period of existence of a phenomenon. Thanks to modernist historicism of art historians, authors of disharmonious artefacts were integrated into the *history of art*. The American urban historian Donald Olsen wrote in his famous book *The City as a Work of Art*: “*The antihistoricist practice ... is based on philosophically historicist assumptions.*” (Olsen, 1986, p. 308; Michl, 2013) The Czech conservationist Břetislav Štorm mocked “*the art-history science*” in his essay on *Art and Art History*:

It can be said without exaggeration that ... dating is the only joy in the ascetic life of art historians. Such joy and pride gushes from the paragraph where the scholar in question arrives at the correct date... It is a certain kind of spiritual sport. (Štorm, 1941)

Let us leave it an open question, how much the fixation on time is connected to the religious orientation, or more precisely, to the absence of its Christian form.

4.

The emphasis on *concept* (which temporally precedes the design and its realization, and which cannot be seen) differentiates the logic of supporters of the New Acropolis Museum from the logic of opponents. The latter group considers what is basic is that which can be seen, or respectively that which they must, willy nilly, look at (above all, the façades). The authoritative idealism of the initiates is thus confronted with the aesthetic pragmatism of the public. Part of the former is also consideration of buildings as models on the drafting board. Supporters do not mind that a building facing busy pedestrian zone is missing any interesting detail at the critical eye level, for they are delighted with the building's ground plan.

Adversaries and advocates of the project did not manage to find common ground and it is unlikely they ever will. Both groups are working with very different ideas of successful architecture, using different terminology, modes of interpretation, and *styles* for processing and evaluating information. Traditionalists and modernists assume here their typical positions. The former do not care about the concept unless it leads to a harmonious result, while the latter praise the intellectual gesture and the audacity of the project and regard evaluation based on the façade's appearance as superficial and populist. Traditionalists demand elegantly structured space (a building seamlessly filling the empty space); the modernists demand clearly visualized time (an expression of the *Zeitgeist*). Emotional factors enter the game and rationality loses its last chance for success: collective frustration and the hope of overcoming it; faith in the redressing of historic wrongs; closing the gap with the West.

Professional criticism follows a similar duality. Modernist critics (often also historians) see themselves primarily as interpreters of the architect's (allegedly original) conception. Conversely, non-modernist critics imagine themselves as well-educated visitors whose refined taste comes from knowledge of the historical canon.

5.

In any case, in Athens two museological concepts collided: the museum of buildings (a protected heritage site), and the museum of transferred artifacts. The non-adaptive design of the new building disintegrates and obscures the aesthetic relations between individual parts of the city, which in and of itself constitutes a kind of contextual exhibition and is simultaneously a complex work of art – *civic art*. Modernist thinking abandoned this idea of a city, just like modernist

museology abandoned the idea of contextual exhibitions in order to intensify the aesthetic effect of individual artifacts, in the name of some metaphysical truth and not in favor of the educative function of the environment.

However, just as creating a contextual exhibition in a museum does not cease to be *creating* – writing a textbook on the truth, in no way a copy or an image of truth itself – neither does the town monument reservation show *how it really was*. The case of Athens is striking. Classical Athens was beyond a holy mount and the public space densely and unrestrainedly built up (Tung, 2001, pp. 249–250), not as it is presented to tourists today – quite paradoxically – in the manner of a Le Corbusier's city in greenery. Those interested in history of places are constrained from the start. Their knowledge and understanding are shaped by the contemporary constellation of aesthetic and political preferences. This decides how the past is presented – and consequently what image of that past will be evoked in the viewer.

German, American and Greek archaeologists and architects in the XIXth and XXth centuries created a new artwork from the ruins of ancient Athens and their imitations. Athens' archaeological park fulfills the assessment of a museum and at the same time living, or contemporary, art. The fact that Athenians supporting Tschumi's new building do not perceive this could support arguments for their naiveté and manipulability. Nevertheless, the diligent researcher is rather forced to question: what exactly has changed in their perception? Athenians abolished their city as a total work of art roughly half a century ago. Now they have disrupted an image of the archaeological park; they supplemented it by an aquarium for its sculptural details. There is no question that the valuable originals would be damaged if left to remain in the open air. The problem is that their replacement home visually collides with their original home. It is as if one erected a concrete orang-utan run in the middle of the Indonesian jungle [Fig. 10].



Figure 10: Athens from the Philopappos Hill: on the left the Acropolis, on the right the New Acropolis Museum (Source: Author, 2009).

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BIOPHILIC DESIGN PATTERNS

Emerging Nature-Based Parameters for Health and Well-Being in the Built Environment

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Abstract

*This paper carries forth the conceptual framework for biophilic design that was first laid out by Cramer and Browning in *Biophilic Design* (2008), which established three categories meant to help define biophilic buildings – Nature in the Space, Natural Analogues and Nature of the Space – and a preliminary list of “biophilic conditions”. New research and insights from the neurosciences, endocrinology and other fields have since helped evolve the scientific basis for biophilic design. This paper begins to articulate this growing body of research and emerging design parameters in architectural terms, so that we may draw connections between fields of study, highlight potential avenues for future research, evolve our understanding of biophilic design patterns, and capture the positive psychophysiological and cognitive benefits afforded by biophilia in our design interventions.*

Keywords: biophilia; biophilic design; pattern language; prospect-refuge theory; mystery; complexity and order; thermal comfort

INTRODUCTION

Biophilia is the deep-seated need of humans to connect with nature. It helps explain why crackling fires and crashing waves captivate us; why a view to nature can enhance our creativity; why shadows and heights instill fascination and fear; and why gardening and strolling through a park have restorative healing effects. Biophilia, as a hypothesis, may also help explain why some urban parks and buildings are preferred over others. For decades research scientists and design practitioners have been working to define aspects of nature that most impact our satisfaction with the built environment. But how do we move from research to application in a manner that effectively enhances health and well-being, and how should efficacy be measured?

As new evidence emerges, the relationships between nature, science and the built environment are becoming easier to understand old wisdom and new opportunities. The scope of this paper, however, limits its perspective to identifying universal issues, rather than situational or sector-specific issues within health and the built environment. This is due to the huge volume of research appropriate to each industry sector that would be required to validate such a paper and would likely be enough content to formulate a book or even several volumes. This paper therefore presents 3 categories and 14 patterns of biophilic design in a manner reflective of the nature-health relationships most prominent in the built environment. We focus on the patterns for which evidence has shown, at least to some degree, to impact our cognitive capacity to enhance and maintain a healthy, life experience through a connection with nature.

The design patterns have been developed from empirical evidence and interdisciplinary analysis of more than 500 peer-reviewed articles and books. The patterns have a wide range of applications for both interior and exterior environments, and are meant to be flexible and adaptive, allowing for project-appropriate implementation. From a designer's perspective, biophilic design patterns have the potential to re-position the environmental quality conversation

to give the individual's needs equal consideration alongside conventional parameters for building performance that have historically excluded health and well-being.

The intent of this paper is to serve as a catalyst for discussing biophilic design implementation; establishing more robust quantitative and qualitative parameters, where appropriate; identifying where greater research is needed; identifying potential methods and tools to account for variables and to measure or track efficacy. This all, so that we may better capture the benefits afforded by biophilia in our design interventions.

METHOD

The incorporation of nature into the human environment can be found in the earliest man-made structures, and cultures around the world have found ways to bring nature into homes and public spaces. It has been poetically expressed for millennia and scientifically explored for decades. As such, biophilic design is not a new phenomenon; rather, it is the codification of human intuition for what makes a space a good place for humans.

Good biophilic design draws from nature in a manner that is equally inspirational and restorative without disturbing the functionality of the space to which it is integral. How that balance is achieved may differ for particular user groups, building types, or geographical regions, but the science that informs the quality or condition of a healthy space remains relatively universal human response. To articulate what this means for the built environment, our methodology for defining 14 patterns is discussed here in terms of (1) familiar precedents for patterns in the design community, (2) three nature-health relationships, and (3) three nature-design relationships.

Pattern As Precedent

The descriptive term 'pattern' is being used for three reasons: To propose a clear and standardized terminology for biophilic design; to avoid confusion with multiple terms (metric, attribute, condition, characteristic, typology, etc.) that have been used to explain biophilia; and to maximize accessibility for designers and planners by upholding familiar terminology.

The use of spatial patterns is inspired by the precedents of *A Pattern Language* (Alexander, Ishikawa, Silverstein et al., 1977), *Designing with People in Mind* (R. Kaplan, S. Kaplan, & Ryan, 1998) and *Patterns of Home* (Jacobson, Silverstein & Winslow, 2002). Alexander et al. (1977) brings clarity to this intent with his explanation that patterns "...describe a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice."

Alexander's work built on the tradition of pattern books used by designers and builders from the eighteenth century onward, but his work focused on the psychological benefits of patterns and included descriptions of the three dimensional spatial experience, rather than the aesthetic focus of previous pattern books. These fourteen patterns of biophilic design focus on psychological, physiological and cognitive benefits.

A Framework For Biophilic Design

Nature-health relationships in the built environment: There are three overarching health responses in biophilia that help explain how individuals interact with their environment: cognitive, physiological and psychological. Much of the evidence for biophilia can be linked to research in one or more of these response areas. The baseline condition for each of these responses also influences how our environment impacts us and to what degree.

Health responses are of specific interest to the designer, because they influence how an individual might experience their design, and to planners and policy makers, because they influence public health and equitable access to nature and its benefits.

Nature-design relationships in the built environment: Current theories state that contemporary landscape preferences are a result of human evolution, reflecting the innate

landscape qualities that enhanced survival for humanity through time. These evolutionary theories include the biophilia hypothesis (Wilson, 1993; 1984), the savanna hypothesis (Orians & Heerwagen, 1992), the habitat theory and prospect-refuge theory (Appleton, 1975), and the preference matrix (R. Kaplan & Kaplan, 1989). More recently, Heerwagen (2006) laid out a framework for “features and attributes of buildings linked to well being needs and experiences” reflecting these relationships in human-centric terms; and according to Cramer and Browning (2008), human-nature relationships tend to fall into three broad experience categories: nature in the space, natural analogues, or nature of the space.

Nature in the Space describes the presence and diversity of plant life, water bodies, animal species, and other elements from nature within the built environment. Seven patterns related to these interactions have been identified: [1] Visual connection with nature, [2] Non-visual connection with nature, [3] Non-rhythmic sensory stimuli, [4] Access to thermal and airflow variability, [5] Presence of water, [6] Dynamic and diffuse light, and [7] Connection with natural systems.

Natural Analogues are objects, materials, colors, shapes, patterns and algorithms that evoke nature. Broadly speaking, analogues can be characterized in architecture and design as representational artwork, ornamentation, biomorphic forms and natural materials. Three Natural Analogue patterns have been identified: [8] Biomorphic forms and patterns, [9] Material connection with nature and [10] Complexity and order.

Nature of the Space refers to different spatial configurations and associated psychological and physiological responses they engender. Four Nature of the Space patterns have been identified: [11] Prospect, [12] Refuge, [13] Mystery and [14] Risk/Peril.

While informed by science, biophilic design patterns are not formulas; they are meant to inform, guide and assist in the design process and should be thought of as another tool in the designer’s toolkit. The purpose of defining these patterns is to articulate connections between aspects of the built and natural environments and how individuals react to and benefit from them.

RESULTS

The results of this compilation of research are discussed here for six of the fourteen patterns: [1] Visual connection with nature [2] Non-visual connection with nature, [4] Access to thermal and airflow variability, [5] Presence of water, [10] Complexity and order, [11] Prospect and [13] Mystery. Emerging design parameters are highlighted.

This collected evidence leads us to deduce that good biophilic design could have a number of positive impacts. Some of these include enhance productivity and performance and have a positive impact on attention restoration and stress reduction (e.g., van den Berg et al., 2007); increase positive emotions and reduce negative emotions (e.g., Hartig et al., 1991); relaxation of the brain, ocular muscles and lenses; as well as lowering of diastolic blood pressure and stress hormone (i.e., cortisol) levels in the blood stream (e.g., Steg, 2007; Park et al., 2009).

Pattern 1: Visual Connection With Nature

A VISUAL CONNECTION WITH NATURE is characterized as a view to living systems and natural processes.

The VISUAL CONNECTION WITH NATURE pattern is derived from data on (1) visual preference and responses to views to nature showing reduced stress, more positive emotional functioning, and improved concentration and recovery rates, and (2) adaptation to windowless spaces showing that people intuitively add nature content, and respond positively to simulated nature (although not as strongly as to real nature).

There is evidence for stress reduction related to both experiencing real nature and seeing images of nature (e.g., Grahn & Stigsdotter, 2010; Bloomer, 2008; Kahn, Friedman, Gill et al., 2008; Hartig et al., 2003), that natural environments are generally preferred over built environments (e.g., van den Berg, Koole & van der Wulp, 2003; Hartig, 1993; R. Kaplan &

Kaplan, 1989; Knopf, 1987; Ulrich, 1983), and that access to biodiversity may be more beneficial to our psychological health than access to land area (Fuller, Irvine, Devine-Wright et al., 2007).

Visual preference research by Orians and Heerwagen (1992) indicated that universally the preferred view is looking down a slope to a scene that includes copses of shade trees, flowering plants, calm non-threatening animals, indications of human habitation, and bodies of clean water.

A study by van den Berg et al. (2003) observed participants with high levels of stress had higher preferences for natural environments and lower preferences for urban built environments. This is supported by research from Biederman and Vessel (2006) which concluded that (a) viewing scenes of nature stimulates a larger portion of the visual cortex than non-nature scenes and triggers more pleasure receptors in the brain; and that (b) repeated viewing of real nature, unlike non-nature, does not significantly diminish the viewer's level of interest over time.

Barton and Pretty (2010) argued that positive impact on mood and self-esteem occurs most significantly in the first 5 minutes of exercise within a green space; whereas, Brown, Barton and Gladwell (2013) report that viewing nature for 10 minutes prior to experiencing a mental stressor stimulated heart rate variability and parasympathetic activity (i.e., regulation of internal organs and glands that support digestion and other activities that occur when the body is at rest), while Tsunetsugu and Miyazaki (2005) showed that viewing a forest scene for 20 minutes after a mental stressor returned cerebral blood flow and brain activity to a relaxed state.

According to Fuller, et al. (2007), the psychological benefits of nature increase with higher levels of biodiversity. The same study stated that an increase in these benefits came with an increase in biodiversity and not with an increase in natural vegetative area.

The inclusion of real nature is often difficult to achieve in the built environment. Friedman, Freier and Kahn (2004) hypothesized that simulated nature could have the same physiological benefits as exposure to real natural elements or environments; this was later invalidated by Kahn et al. (2008) who, in a study tracking the heart rate recovery from low-level stress of participants working in an office environment, concluded that a glass window with a nature view was, on average, 1.6 times more restorative than each of the other two conditions a) a plasma screen with high-definition video of the same nature view, and b) a blank wall. The physiological recovery was also greater with increased window viewing time, and while participants looked at the window and plasma screen approximately the same number of times, duration of viewing times was significantly greater for the real window (median = 622.0 seconds) than the plasma (median = 491.5s) or blank wall (median = 55.5s).

This body of research suggests that visual connections to even small instances of nature can be restorative; an important finding given the limitations on and demands for space within urban and interior settings. We can identify emerging design parameters:

- Visual connections with nature can reduce stress, and improve mood and self-esteem (van den Berg et al., 2003; Biederman & Vessel, 2006; Fuller et al., 2007; Kahn et al., 2008; Barton & Pretty, 2010)
- Prioritize real nature over simulated nature, which is better than no nature (Kahn et al., 2008)
- Prioritize biodiversity over acreage (Fuller et al., 2007)
- Prioritize or enable exercise opportunities that are in proximity to green space (Barton & Pretty, 2010)
- Support exposure to nature for at least 5-20 minutes per day (Tsunetsugu et al., 2013; Barton & Pretty, 2010)

Pattern 2: Non-visual Connection With Nature

NON-VISUAL CONNECTION WITH NATURE is characterized by auditory, haptic, olfactory, or gustatory stimuli that engender a positive reference to nature.

The NON-VISUAL CONNECTION WITH NATURE pattern is derived from data on reductions in systolic blood pressure and stress hormones (Park, Tsunetsugu, Kasetani et al., 2009; Hartig, Evans, Jamner et al., 2003; Orsega-Smith, Mowen, Payne et al., 2004; Ulrich,

Simons, Losito et al., 1991), cognitive performance and exposure to sound and vibration (Mehta, Zhu & Cheema, 2012; Ljungberg, Neely, & Lundström, 2004), and perceived improvements in mental health and tranquility as a result of non-visual sensory interactions with non-threatening nature (Tsunetsugu, Park, & Miyazaki, 2010; Kim, Ren, & Fielding, 2007; Stigsdotter & Grahn, 2003; Li, Kobayashi, Inagaki et al., 2012).

Research by Alvarsson et al. (2010) suggested that nature sounds, when compared to urban noise, allow for physiological and psychological restoration to occur up to 37% faster after exposure to a psychological stressor. Further support is provided by Mehta et al. (2012), who documented that moderate (70 decibels) ambient noise had a greater positive impact on creative performance than did exposure to low (50 decibels) or high (>85 decibels) ambient noise.

In a study relating aromatherapy and post-anesthesia care, Kim et al. (2007) reported 45% less morphine and 56% fewer analgesics used among patients who underwent aromatherapy after surgery. A study by Li et al. (2012) also found that phytoncides (essential oils from trees) had a positive effect on human immune function both in vitro and in vivo.

Hunter et al. (2010) argue that experiencing visual and non-visual stimuli simultaneously changes where in the brain the non-visual senses are interpreted; whereby, if both stimuli are connections with nature, a larger portion of the brain becomes excited and the combined psychophysiological response is more impactful than two responses in isolation. Hunter et al. (2010) also observed that vehicle traffic and ocean waves can have a very similar sound pattern. In an experiment using a synthesized sound that replicated this sound pattern, participants processed the sounds in different portions of the brain depending on whether they were watching a video of waves or of traffic. The sound was considered pleasurable and enhanced the experience when experienced with the video of waves, and not when experienced with traffic.

From this body of work, we can identify emerging parameters:

- Small or momentary interventions with non-visual sensory stimuli can have a positive health impact (Li et al., 2012; Alvarsson et al., 2010; Kim et al., 2007).
- Prioritize nature sounds over urban sounds to engender physiological and psychological restoration (Alvarsson et al., 2010).
- Use moderate ambient noise based on nature sounds to enhance creative performance (Mehta et al., 2012).
- To maximize potential positive health responses, design for visual and non-visual connections with nature to be experienced simultaneously (Hunter et al., 2010).

Pattern 4: Access To Thermal And Airflow Variability

ACCESS TO THERMAL AND AIRFLOW VARIABILITY can be characterized as ambient qualities – air temperature, relative humidity, airflow across the skin, and the radiant temperature of surrounding surfaces – that in combination prompt feelings of comfort similar to those experienced in nature.

The ACCESS TO THERMAL AND AIRFLOW VARIABILITY pattern has evolved from research measuring the effects of natural ventilation, its resulting thermal variability, and worker comfort, well-being and productivity (Heerwagen, 2006; Tham & Willem, 2005; Wigö, 2005; Heschong, 1979), physiology and perception of temporal and spatial alliesthesia (pleasure) (Parkinson, de Dear & Candido, 2012; Zhang, Arens, Huizenga & Han, 2010; Arens, Zhang & Huizenga, 2006; Zhang, 2003; de Dear & Brager, 2002), Attention Restoration Theory and impact of nature in motion on concentration (Hartig et al., 2003; Hartig et al., 1991; R. Kaplan & Kaplan, 1989) and, generally speaking, a growing discontent with the conventional approach to thermal design, which focuses on trying to achieve a narrow target area of temperature, humidity and air flow while minimizing variability (e.g., de Dear, Brager & Cooper, 1997).

Heerwagen (2006) explained that evidence has shown that people like moderate levels of sensory variability in the environment, including variation in light, sound and temperatures, (e.g., Humphrey, 1980; Platt, 1961), and that an environment devoid of sensory stimulation and variability can lead to boredom and passivity (e.g., Schooler, 1984; Cooper, 1968).

Early studies in alliesthesia indicate that pleasant thermal sensations are better perceived when one's initial body state is warm or cold, not neutral (e.g., Mower, 1976), which corroborates more recent studies (e.g., Arens et al., 2006) reporting that a temporary over-cooling of a small portion of the body when hot, or over-heating when cold, even without really impacting the body's overall core temperature, is perceived as highly comfortable.

According to Attention Restoration Theory, elements of "soft fascination" such as light breezes or other natural movements can improve concentration (Heerwagen & Gregory, 2008; S. Kaplan, 1995). This is supported by the work of Wigö (2005), which reported that changes in ventilation velocity can have a positive impact on comfort, with no negative impact on cognitive function, while also offering the possibility of a slight increase in the ability to access short term memory; and research by Elzeyadi (2012), which showed that a gradient of thermal conditions within a classroom can lead to better student performance.

From this body of work, we can identify emerging parameters:

- Incorporate airflow and thermal variability to improve user comfort. But, how much variability and what velocities and frequencies are best for upholding a positive health impact (Wigö, 2005)?
- Temporal and spatial alliesthesia – conditioning the individual (e.g, hands, feet) rather than the space – may be more effective than conventional tactics (i.e., thermal uniformity) for achieving thermal comfort and satisfaction (Parkinson et al., 2012; Zhang et al., 2010; Arens et al., 2006; Zhang, 2003; de Dear & Brager, 2002; Mower, 1976).
- Provide features that allow users to easily adapt and modify their perceived thermal conditions of their environment will increase the range of acceptable temperatures by two degrees Celsius above and below the conventional parameters for thermal comfort (Nicol & Humphreys, 2002).

Pattern 5: Presence Of Water

PRESENCE OF WATER is a condition that enhances the experience of a space through the seeing, hearing or touching of water.

The PRESENCE OF WATER pattern has evolved from research on visual preference for and positive emotional responses to environments containing water elements (Windhager, 2011; Barton & Pretty, 2010; White, Smith, Humphreys et al., 2010; Karmanov & Hamel, 2008; Biederman & Vessel, 2006; Orians & Heerwagen, 1993; Ruso & Atzwanger, 2003; Ulrich, 1983); reduced stress, increased feelings of tranquility, lower heart rate and blood pressure, and recovered skin conductance from exposure to water features (Alvarsson, Wiens, & Nilsson, 2010; Pheasant, Fisher, Watts et al., 2010; Biederman & Vessel, 2006); improved concentration and memory restoration induced by complex, naturally fluctuating visual stimuli (Alvarsson et al., 2010; Biederman & Vessel, 2006); and enhanced perception and psychological and physiological responsiveness when multiple senses are stimulated simultaneously (Alvarsson et al., 2010; Hunter et al., 2010).

Visual preference research by Orians and Heerwagen (1993) indicates that a preferred view contains bodies of clean water. Research by Jahncke et al. (2011), Karmanov and Hamel (2008) and White et al. (2010) exhibited that natural scenes without a water body, and urban scenes with water elements, exhibit near equal health benefits to participants; whereas, experiences of unnatural or urban scenes generally engender less pleasurable or restorative effects. This is further supported by Alvarsson et al. (2010) and Pheasant et al. (2010), who showed that auditory access and perceived or potential tactile access to water reduced stress in participants; and by Barton and Pretty (2010), who concluded that activities conducted in green spaces with the presence of water generated greater improvements in both self-esteem and mood than green environments without the presence of water.

Emerging parameters:

- Water should be perceived as clean (Orians and Heerwagen, 1992).

- Prioritize a multi-sensory water experience (Alvarsson et al., 2010; Hunter et al., 2010; Pheasant et al., 2010).
- Prioritize naturally fluctuating water movement over predictable movement or stagnancy (Alvarsson et al., 2010; Biederman & Vessel, 2006).

Pattern 10: Complexity And Order

COMPLEXITY AND ORDER is characterized by the presence of rich sensory information that is configured with a coherent spatial hierarchy, similar to the occurrence of design in nature. In architecture and landscape, the experience is interpreted by S. Kaplan (1988:48) as “how much is ‘going on’ in a particular scene, how much there is to look at”.

The COMPLEXITY AND ORDER pattern is derived from research on fractal geometries and preferred views (Salingaros, 2012; Hägerhäll, Laike, Taylor et al., 2008; Hägerhäll, Purcella, & Taylor, 2004; Taylor, 2006); the perceptual and physiological stress responses to the complexity of fractals in nature, art and architecture (Salingaros, 2012; Joye, 2007; Taylor, 2006; S. Kaplan, 1988); and the predictability of the occurrence of design flows and patterns in nature (Bejan & Zane, 2012).

A familiar challenge in the built environment is in identifying the balance between an information rich environment that is interesting and restorative, and one with an information surplus that is overwhelming and stressful. Empirical evidence for the associative relationships between the patterns, structures, flows and rhythms – that provide, support and organize information – and human perception and physiological health, is most evidently revealed in studies of the occurrence of fractal patterns and dimensions.

The research of Joye (2007), Taylor (2006) and others has repeatedly correlated fractal geometries in nature with those in art and architecture, but as expounded by Salingaros (2012), there are opposing opinions over which fractal dimension is optimal for engendering a positive health response, whether an optimal ratio exists – the preferred fractal dimension is potentially quite broad ($D=1.3-1.8$) depending on the application – or if such an optimal ratio is even important to identify as a design metric or guideline.

An alternative perspective is to assess hierarchy of iterations of fractal geometry. Nested fractal designs expressed as a third iteration of the base design (i.e., with scaling factor of 3) are more likely to achieve a level of complexity that conveys reduces stress (Salingaros, 2012). The third iteration as a design quality is lost in much of modern architecture, which tends to limit complexity to the second iteration.

While mid-range fractal dimensions may be preferred, at either end of the spectrum, Hägerhäll et al. (2008), Taylor (2006) and others have reported that high-dimensional fractal artwork and overly complex environments can result in psychological stress and even nausea. According to J. H. Heerwagen and R. S. Ulrich, occupants in a U.S. Navy office in Mississippi reported nausea, headaches and dizziness, symptoms frequently associated with poor indoor air quality or poor ventilation. It was determined that the interaction of multiple wall paper patterns, complex patterns in carpets and moiré patterns in seating fabrics caused surfaces to appear to move as occupants walked through the space and therefore caused extreme visual perception problems (Heerwagen, personal communication, March 2014).

Empirical data on the health impacts of viewing or otherwise experiencing instances of COMPLEXITY AND ORDER is limited, but from this body of research a few emerging parameters:

- Fractal structures with iterations of three will be more impactful than a limiting design to two iterations (e.g., Salingaros, 2012).
- Fractal geometries with a mid-range dimensional ratio (broadly speaking, $D=1.3-1.8$) are generated in nature with relative profundity and should be more readily applied to architecture and design.
- Use fractal geometries in artwork (from realism to abstract); in building materials (e.g., wood grain, stone) for exposed structure elements, interior finishes, or components of the

façade; in the building skyline; and in species selection for landscape views (Joye, 2007; S. Kaplan, 1988).

- Establish a balance between complexity and order (Kellert, 2008).

Pattern 11: Prospect

PROSPECT is a spatial condition characterized by the presence of an unimpeded view over a distance for surveillance and planning.

The PROSPECT pattern is derived from visual preference research and spatial habitat responses, as well as cultural anthropology, evolutionary psychology (e.g., Heerwagen & Orians, 1993) and architectural analysis (e.g., Dosen & Ostwald, 2013; Hildebrand, 1991; Appleton, 1975). Health benefits are suggested to include reduced stress (Grahn & Stigsdotter, 2010); reduced boredom, irritation, fatigue, (Clearwater & Coss, 1991), and perceived vulnerability (Petherick, 2000; Wang & Taylor, 2006); as well as improved comfort (Herzog & Bryce, 2007).

According to Heerwagen and Orians (1993), preference for a prospect condition is strongest when it includes a savannah-like ecosystem with a water body and evidence of human activity or habitation. Petherick (2000) argues that good prospect reduces an individual's fear and stress responses, particularly when alone or in new or unfamiliar environments; and Herzog and Bryce (2007) concluded that distant prospect (>100 feet, >30 meters) is preferred over shorter focal lengths (<20 feet, 6 meter) because it provides a greater sense of awareness and comfort.

For interior spaces or dense urban spaces, prospect is the ability to see from one space to another, and is strengthened when there are clear distinctions and the opportunity to see through multiple spaces (Hildebrand, 1991), but there are potentially endless combinations for applying characteristics of prospect (Dosen & Ostwald, 2013).

Emerging parameters:

- Provide minimum focal lengths of ≥ 20 feet (6 meters), preferably 100 feet (Herzog & Bryce, 2007).
- Incorporate an information-rich prospect view by designing with or around an existing or planned savannah-like ecosystem, body of water, and evidence of human activity or habitation (Heerwagen & Orians, 1993).
- Limit opaque partitions (e.g., workplace conditions, landscape hedges) to 42 inches in height.

Pattern 13: Mystery

MYSTERY is a spatial condition characterized by the promise of more information manifested by the presence of partially obscured views or other sensory stimuli that fascinate and entice the individual to travel deeper into the environment (Herzog & Bryce, 2007; Ikemi, 2005; R. Kaplan & Kaplan, 1989).

The MYSTERY pattern is framed by R. Kaplan and S. Kaplan's (1989) proclamation that people have two basic needs in environments: to understand and to explore. Herzog and Bryce (2007) also clarify that these 'needs' are to occur "from one's current position" in order to engender a sense of mystery.

The characteristics of the pattern are derived from visual preference and perceived danger (Herzog & Bryce, 2007; Herzog & Kropscott, 2004; Nasar, & Fisher, 1993); and supported by research on pleasure responses to anticipatory situations (Salimpoor, Benovoy, Larcher et al., 2011; Ikemi, 2005; Blood & Zatorre, 2001).

Mystery engenders a strong pleasure response within the brain that may be a similar mechanism to that of anticipation (Biederman, 2011), which Blood and Zatorre (2001) and Salimpoor et al. (2011) hypothesize is an explanation for why listening to music is so pleasurable – in that we are guessing what may be around the corner. A quality mystery condition does not engender a fear response; the conditions that differentiate between fear and pleasure center around the visual depth of field. Research by Herzog and Bryce (2007) exhibited that an

obscured view with limited visual access can lead to unpleasant surprises, whereas a greater visual access, with a medium (≥ 20 ft) to high (≥ 100 ft) depth of field is preferred.

A study by Ikemi (2005) exhibited that a good mystery condition obscures the boundaries and a portion of the forward plane of the subject object, room, building, outdoor space, or other information source, thereby enticing the user to explore the space, to see more of the partially obscured subject. Emerging parameters:

- Views are medium (≥ 20 ft) to high (≥ 100 ft) depth of field (Herzog & Bryce, 2007)
- At least one edge of the focal object is obscured, preferably two edges (Ikemi, 2005)

DISCUSSION AND FUTURE DIRECTIONS

This review highlights some emerging design parameters for implementing biophilia, yet there is still a need for understanding where numeric metrics are necessary for designing for positive health impacts, and where qualitative attributes are more appropriate. Frequency and duration of exposure to these patterns of biophilic design, as well as persistence of health impact are key topics for additional research. Similarly, repetition – how often a pattern can be experienced and continue to elicit a response – and scope and scale – what is the intervention trying to achieve and how big the physical intervention needs to be to elicit a response – are also points of consideration for additional research.

Frequency and duration of experience: Planners, architects and designers want to understand how often the biophilic experience is needed (Elzeyadi, 2012), and what the minimal or optimal duration of an experience is needed to engender a positive psychological or physiological response (Brown, Barton & Gladwell, 2013; Barton & Pretty, 2010; Tsunetsugu & Miyazaki, 2005).

Persistence of health response: The body of evidence cited here is a sampling of the work conducted that has established a basis for our understanding of nature-design and nature-health relationships. However, as far as the authors are aware, little if any empirical evidence exists showing whether, and for how long, positive health responses persist after a biophilic intervention is experienced. From a designer's perspective, for example, understanding how long a positive physiological response persists once a fractal pattern is no longer observed (Hägerhäll et al., 2004), might influence where in a space it is placed, such as to maximize frequency and duration, or to ensure exposure to the greatest number of people possible.

Repetition of experience: A common concern with architects is whether a biophilic experience, particularly the Mystery pattern, is likely to become attenuated as an individual becomes familiar with the environment. One perspective is to incorporate design elements that vary or change over time (i.e., refreshing the promise for new information), such as through cycling spatial content, providing variability in light (diurnal or electric) and shadows, or seasonal patterns (e.g., vegetation, fragrances, etc). Understanding whether change and variation is important to overcome attenuation and maintain a positive health impact could potentially influence design complexity from the conceptual stage through to operation and maintenance.

Scope and scale of intervention: Understanding whether there is a quantity or percentage of objects in a view shed that must be at a specific fractal ratio to engender an adequate positive health response (Hägerhäll et al., 2004) could inform a range of design decisions, for example, plant selection for landscapes and gardens, interior finishes, and building orientation for maximum value views. Additionally, interest among planners and designers is growing to engage in a more sensory-rich experience with the built environment; therefore, it would help to understand whether mechanisms of perceptual pleasure be identified for our non-visual systems, particularly auditory (Hunter et al., 2010; Biederman & Vessel, 2006), and how much greater the health impact becomes when the experience of water, for example, is either multi-sensory or physically bigger.

Other directions include a broadening the scope to integrate with building systems by asking, for example, whether acoustic properties of a space can be enhanced by integrating water sounds to diffuse excessive noise to contribute to both increased worker productivity and mitigation of speech privacy issues.

Research that establishes relationships between multiple patterns, such as between prospect and refuge (e.g., Dosen & Ostwald, 2103; Ljungberg et al., 2004), or visual and non-visual connections with nature (e.g., Hunter et al., 2010), and especially patterns from two different categories (i.e., Nature in the Space, Natural analogues, Nature of the Space), tends to be contextually informative from a design implementation perspective. The work of Dosen and Ostwald (2103), Ljungberg et al. (2004), and Hunter et al. (2010) also brings us to question which other pattern relationships are being studied, and what additional opportunities are there for integrative research and design.

CONCLUSION

Establishing distinct patterns is not an attempt to create cookie-cutter solutions for human-centric design, but rather to provide a framework through which any variable, with the appropriate care, could be adapted with locally appropriate and user-centered biophilic design. Appropriate solutions will result from understanding what suits the unique programmatic needs of a space and its intended user group (R. Kaplan et al., 1998). There also needs to be an understanding of whether this holds true across ecosystem types and varying definitions of “nature”, how much nature is needed to define a condition, and which factors contribute to positive health effects that persist over time.

The body of literature cited here is part of a nascent effort to gather evidence recording health responses to nature experiences. Some aspects of biophilia are inherently difficult to quantify, and due to the relative infancy of the field of biophilic design, we recognize there is a significant need for additional research.

Tracking and measuring efficacy of biophilic patterns and parameters or metrics can be challenging. This is due to the high number of variables, shifting baselines, the unpredictability of the built and natural environments, as well as the highly invasive nature of some data collection techniques. Factors such as genetics, diet, level of exercise and socio-economic status each impact baselines for measuring and mitigating stress (Bilotta & Evans, 2007). What qualifies as ‘nature’ is in a state of perpetual flux across cultures and generations, making it difficult to establish a baseline from which to build supporting evidence (Barton & Pretty, 2010; Kahn, 2009; Hägerhäll et al., 2008; Kahn et al., 2008; Steg et al., 2007; van den Berg & Konijnendijk, 2007).

As this review of evidence shows, the built environment can have a positive, neutral or negative effect on an individual, and responses may differ with the user’s health baseline; the frequency and duration of the experience; socio-cultural norms and expectations; the user’s experience up to that point; and how the individual perceives and processes the experience.

While this breadth of research continues to evolve, definitions, metrics (Lercher, 2003) and guidelines are needed for planning (Tsunetsugu et al., 2013) and design implementation (Dosen & Ostwald, 2013), monitoring and validation of efficacy. Widespread accessibility to and implementation of biophilic design patterns could help re-focus the design process on the individual, while capturing the economic benefits of nature in the built environment (Terrapin Bright Green, 2012; Heerwagen, 2006). As more of the world’s population shifts to urban settings, the need for biophilic design will become more important.

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BREAKING SYMMETRIES AND EMERGING SCALING URBAN STRUCTURES A Morphological Tale of 3 Cities: Paris, New York and Barcelona

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Abstract

The challenge of a science of cities is to understand the links between urban morphogenesis, efficiency and resilience. Mathematical regularities emerge in resilient cities, coming from the scale-free properties of complex systems that present the same level of complexity across their different scales. They take the form of inverse power laws that are the « signature » of complexity. In living cities, these mathematical regularities derive from historical layering over millennia (Paris) or from intense market forces (New York). In complex, living and resilient cities, the distribution of elements and connections does not obey Gaussian laws but scale-free inverse power laws. Understanding the universality of this structure which also characterizes natural phenomena and living systems, and which has been violated by modernist city planning, would allow planning more efficient and resilient cities. The paper shows how initial breaks of symmetry fostered the emergence of scale-free structures in Paris and New York, with long-range time correlations, and how a break of symmetry in the spatial layout created a highly differentiated socio-economic structure in Barcelona.

Keywords: urban morphology; symmetries; scaling

THE CHALLENGE OF A NEW SCIENCE OF CITIES

The challenge of a new science of cities is to understand the links between urban morphogenesis, efficiency and resilience. It is also to understand the relationships between self-organization and planning. The large number and diversity of agents operating simultaneously in a city suggest that cities are a multi-fractal emergent phenomenon. On the other hand, planning plays an important role in the city, leaving long standing traces, and could be thought of as an external perturbation, as if it were foreign to the self-organized development of a city. Fractal geometry and complex systems theories reveal mathematical regularities maintained through the seemingly chaotic process of urban change. Fractal geometry has contributed to climate modeling, to study turbulent flows, to analyze brain waves and seismic movements as well as to understand the distribution of galaxies. It has also transformed finance by revealing a hidden complex order in the seemingly chaotic fluctuation of prices. It should transform the study and planning of cities. Historical cities display a multi-fractal structure layering and interlocking different fractal structures belonging to different morphological periods; the fractal and scaling parameters display high local variations (singularities) which are organized in different fractal sets (isohölder) described by a spectrum of fractal dimensions (Hausdorff spectrum).

In other words, are averages (average density, average GDP, average energy intensity or GHG emissions) meaningful in urban studies? In a Gaussian world they are meaningful because 68% of the values are at one standard deviation from the average. Quite the opposite, a Paretian world is extremely unequal: a few extremely high values are juxtaposed to a “long tail” of very low values.

TWO DIFFERENT KINDS OF SYMMETRY: MODERNIST PLANNING TRANSLATION SYMMETRY VERSUS HISTORICAL SCALING SYMMETRY

We know that symmetry plays a fundamental role in physical phenomena. Symmetries are certain properties of laws of physics that are conserved when a system undergoes a given geometric transformation. Equations in physics are, for example, invariant by translation in space and time. When we look for the most fundamental nature of physical interactions, we always find properties of symmetry. Emmy Noether was the first to discover that fundamental symmetries are at the origin of physical laws, such as energy conservation and the constant of motion. From this perspective, fractal geometry corresponds to a form of symmetry that is dilatation symmetry or scale invariance. It is found in countless natural phenomena and in living organisms whose evolution favored fractal structures because of the efficiency and resilience they offer.

Le Corbusier's modernism relies only on translation symmetries, repeating the same oversized objects in a highly simplified space with only one scale.

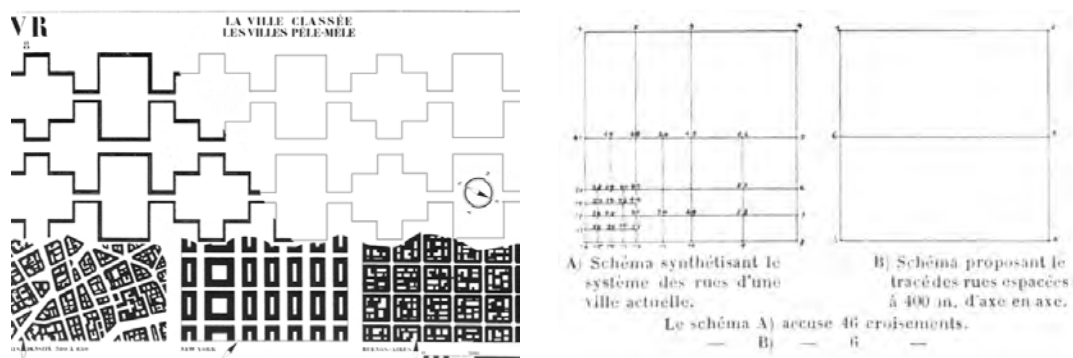


Figure 1: Drawings from Le Corbusier's *Urbanisme* (Corbusier 1922): *la ville classée* et *la ville pêle-mêle*. Le Corbusier proposed to remove all the small and intermediary scales of the urban structure (Source: Authors).

Le Corbusier removes from the Radiant City all the smaller and intermediary scales of the historical city to replace them by a giant scale duplicated by translational symmetry. Le Corbusier compares the sizing and inner complexity of Paris, New York and Buenos Aires urban blocks with the highly simplified and repetitive type of the Radiant City. He also shows an abstracted version of the scaling of the historical street patterns with 46 intersections on a square 400 meters side, that is 163 intersections/km² taking into account edges effect, i.e. the density of intersections of Paris and Manhattan. Le Corbusier's scheme of historical cities leads to a linear density of 20km/km² (22km/km² for present Paris intra-muros). Le Corbusier scheme is clearly an attack on the connective properties of the historical urban fabric in order to replace them by the car-oriented new paradigm: his proposed superblock scheme with only 6 intersections, leading to 18 intersections/km² and a the linear density of roads of 8km/km². Contemporary Chinese planners have reduced further this linear density to 4 to 3km/km².

Quite the opposite, from their multicellular growth over long periods of time historical cities have developed a scaling symmetry. In scale-free systems, inverse power laws act as a link between scales: the frequency of an element of size x is proportional to the inverse of its size at a scaling exponent m characteristic of the scaling properties of the system. There are few big elements, a medium number of medium-scale elements and a very large number (a "long tail") of small-scale elements. The relative frequency of each type is determined by the scaling parameter of the inverse power law.

In the Nolli-Piranesi plan of Roma of 1748, the hollow connective spaces are streets, outside squares but also interior of palace courtyards and churches. Studies have calculated the fractal scaling parameters of these types of urban fabric both for street patterns and for built forms (Frankhauser 1994).

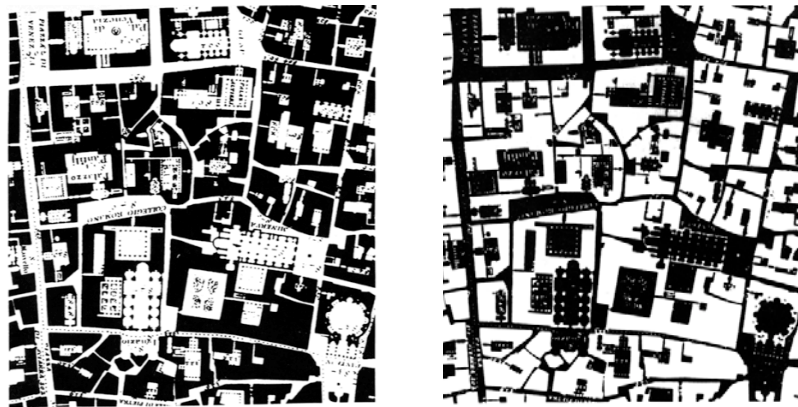


Figure 2 : Detail of Nolli-Piranesi map of Roma (Source: Tice and Steiner 2013).

WHERE DOES URBAN SCALING HIERARCHY COME FROM?

Like all living organisms, cities are evolutionary open systems. They are shaped and constantly transformed by social and political struggle, and by market forces. Their complexity is an emergent phenomenon based on equilibrium between bottom-up interactions of a great multiplicity of competing agents and top-down planning interventions. Too much competition may lead to anarchy while too much planning may constrain the system evolution. Urban systems constantly exchange people, ideas, goods, energy and matter with their environment. Open systems like cities cannot be described using classical thermodynamics, as developed in the 19th century by Boltzmann. To understand them, we have to turn to the more recent work of Ilya Prigogine on the theory of dissipative structures, far-from-equilibrium thermodynamics, and self-organizing systems where breaks of symmetry create scale-free patterns.

Breaking symmetries and the emergence of scale-free structures

Emergence requires first a fine grain structure, a high number of connections and a vast combinatorial space of configurations. Second, emergence requires breaks of symmetry in streets metric and topological properties, in division of land into plots. Avenues in Manhattan for example are 13 times more continuous and connective than streets not only because avenues are longer and wider than streets, but above all because they connect 155 streets while streets connect only 11 avenues. Blocks sizes in Manhattan are not square but elongated, which reinforces the previous break of symmetry.

Why is scaling hierarchy a key factor of urban sustainability and resilience?

Historical cities, like Paris with its 2000 years long history, were slowly transformed by incremental phenomena of destruction and reconstruction of the urban fabric. Structures that were not resilient enough were eliminated. And so historical cities have come down to us with extraordinary capacities of efficiency and resilience. In a process of spontaneous self-organization to adapt their forms to fluctuations in their environment, historical cities acquired the capacity to absorb fluctuations by reinforcing their structure and order, and becoming more complex.

Resilience may be defined as the ability of a system to evolve while keeping embedded in its structure the memory of its previous states. Transformation increases the number of scales without destroying the previous existing scales. It reinforces the scaling structure by enlarging it toward higher scales (Haussmann in Paris), by diversifying an original highly symmetrical state into a scaling structure (New York evolution under market forces), by intensifying it towards smaller scales (Tokyo or Kyoto plot fragmentation). In all cases the result of living evolutionary processes is reinforcing scaling structures. Quite the opposite, modernist top down planned cities that have no scaling structure like Le Corbusier Radiant City or like China's new urban

developments (made of the endless repetition of highly simplified giant identical types) cannot evolve in time.

Resilience is not an urban quality that can be reached by a strategy at only one scale. It is rather a property that emerges from the relationships between scales. What matters more than the nature of urban elements is the structure of urban connections. In a multiply connected, living organic structure, the smaller components can be changed without affecting the overall structure. Building the whole from the parts in an organic way leaves room for evolution. Starting from the whole creates structures that cannot evolve. Modifying the urban whole once it has been established from a technical blueprint involves destroying a great many components on very different scales. In a bottom up city evolving through a myriad of micro processes, it is, to the contrary, easy to modify smaller components (Salingaros 2008). The more structured and complex the city, the more readily it can absorb the perturbations to which it is subjected, without letting them upset the stability of its structure. It is in assimilating the fluctuations and tensions that complexity grows.

Scaling hierarchy and market fluctuations

Scaling urban structures are more adaptive to economic instability and market fluctuations. They display a fine grain platting (subdivision of land into plots), with a great variety of sizes, some large plots and a long tail of small plots. The platting can be easily reconfigured, subdivided like in Tokyo or consolidated like in Manhattan. The variety of plot sizes provides investment opportunities for every budget and every investor, which creates a diversified market with a multiplicity of actors that increase the complexity of the urban system. The scale-free diversity of actors increases the number of potential interactions and supports businesses, innovation and creativity at all scales.

Scaling hierarchy and social diversity and integration

The American-type suburbia or the South African townships made of repetition of small elements (large villas in rich suburbia, matchboxes surrounded by shacks in townships) have not enough initial complexity to evolve into scaling structures. This lack of spatial and formal scaling locks the urban development into a fragmented metropolis with no social mix and prevents the emergence of socio-economic scaling. A feedback loop is then created where the absence of socio-economic scaling prevents the emergence of spatial scaling.

Scaling hierarchy and accessibility

A scale-free distribution of amenities ensures a general accessibility. In Paris intra-muros, scale free distributions enhance accessibility with a long tail of small elements. The distribution of parks, for example, is scale free with a small frequency of big parks (17 parks bigger than 7 ha), a medium frequency of medium size parks (65 parks between 1 and 7 ha), a high frequency of small public gardens (300 public gardens less than 1ha including 260 less than half ha). Healthcare, shops, leisure are also distributed within the urban fabric according to inverse power laws.

Manhattan original Commissioner's plan comprised only 4 large parks while contemporary Manhattan has more than 300 parks. Manhattan today presents the same scaling hierarchy of its public parks as Paris. It ensures a general accessibility at less than 10 minutes' walk. The scaling parameter is higher in Manhattan than in Paris, which reflects a steeper hierarchy and more inequality between big and large in Manhattan than in Paris. Manhattan plan originally comprised only a few large public parks. Under market forces, they were abandoned in favor of the creation of more numerous smaller parks in order to increase the land market value of the city.

Scaling hierarchy and connectivity

In complex subway systems like in London, the number of connecting lines in metro stations (that is the degree of the nodes in the graph of the subway system) and their flows of passengers

follow inverse power laws. Complex street patterns have also scaling properties (Bourdic and Salat 2012).

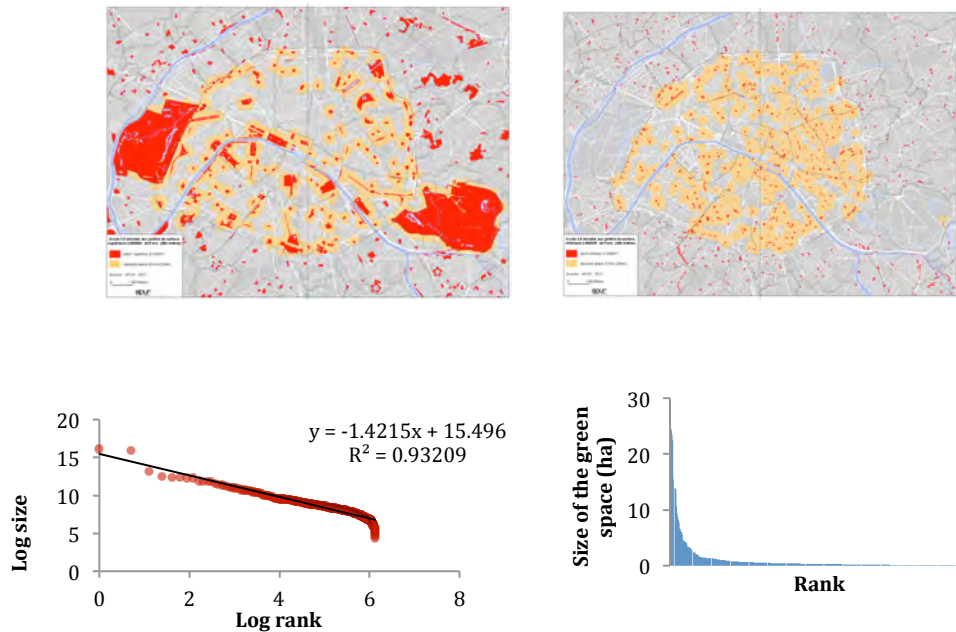


Figure 3: 300m accessibility to large public parks (more than 5000 m2) in Paris 300m accessibility to the long tail of small public parks (less than 5000 m2) (top), and Rank-size distribution of green spaces in Paris: The long tail of 260 public gardens less than half ha ensure general accessibility. (Source: Urban Morphology and Complex Systems Institute).

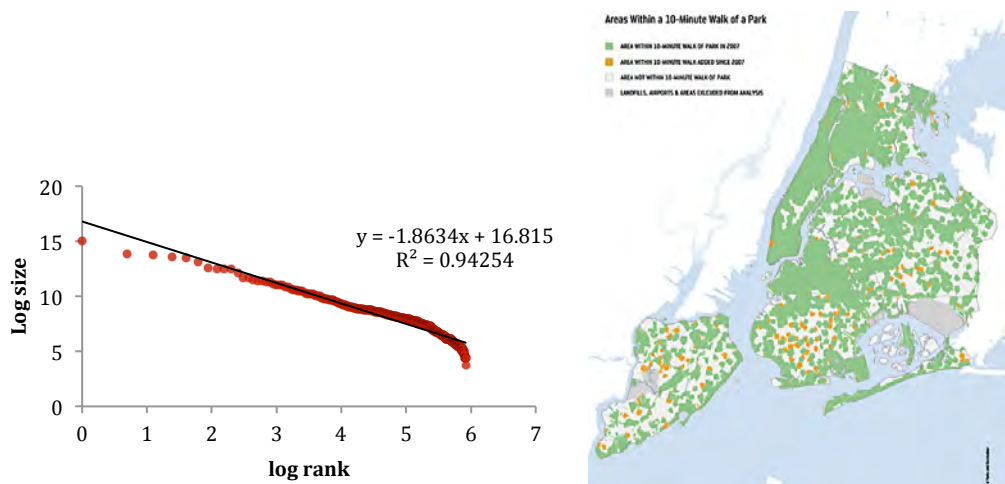


Figure 4: 10min walk accessibility to green spaces in New York City (bottom) and scaling properties of the distribution (top) (Source: Urban Morphology and Complex Systems Institute)

The scaling properties of different sub-systems in complex cities are coherent one with the other. The map above shows the frequency of buses in Paris along main streets over-layered on the map of public gardens. Streets are scaling, frequency of transit is scaling, gardens are scaling. Buses ensure accessibility to the larger amenities along main transit lines while the long tail of smaller streets ensures accessibility to smaller amenities. The different scales are well integrated.

URBAN EVOLUTION IN PARIS HAS CREATED A MULTI-FRACTAL FINE GRAIN PLATTING STRUCTURE EMBEDDING THE MEMORY OF 2000 YEARS OF HISTORY

Paris is not a city planned from the beginning. It is complex, connected, and highly differentiated while being integrated. Its urban form results from a balance between political and social power struggles, and market forces. The land division into parcels has maintained the historical continuity of the most ancient parts of the city (and now the most modern, vibrant and bustling of economic activity).

Paris land was, from the early Middle Ages and until the French Revolution, a multicellular city with intense competition between the cells. This fragmentation of land and power came from the feudal system. The land was divided between many Lordships. The Lords gradually granted to individuals settled on their land tenures on which they perceived an annual fee, the "cens" - hence the name "censive" for Paris Lordships. This property tax recognized the eminent property of the Lord on the land, the tenant having to settle for the useful property of the plot. This eminent property gave a number of rights to Lords: land rights such as the perception of the "cens" or transfer duties, but sometimes political rights such as rights on roads or high, middle and low justice. The Lordship fact was therefore an essential element of Ancient Regime urban life, a framework within which social life took place. The Lords started to divide their domains into plots and develop the land from rural to urban as early as the beginning of the 13th century, a process that started in New York only at the beginning of 19th century. Contrary to Manhattan, where the land division occurred within a unified global Euclidean grid covering the whole island, in Paris this process occurred within the fragmentation of powers of the feudal structure. It was an intense competition both for wealth and power in a highly fragmented society where the king controlled only a very reduced part of the capital.

The medieval land subdivision is the result of the city multicellular growth from successive subdivisions of noble and ecclesiastical censives. The successive morphogenetic ruptures of the medieval fortified walls created asymmetries still strongly visible in the platting five to six centuries later in the Napoleonic cadastre Vasserot of 1810-1836. In the early thirteenth century the abbey towns inside Paris did not really fit into an accomplished urban landscape. The towns inside Paris were formed very slowly. They filled up the gaps in the urban area, with heterogeneous structures at very different paces. The masters of the land (the bishop, the Convent, any particular noble or bourgeois) divided their remaining land into a number of units of roughly equal dimensions, regularly arranged along one or several streets. The Lords could receive higher profit and increased their influence and power because the new developments were targeted against the old cores, and provided economic and social benefits to new communities of men coming from elsewhere. The new developments were significant advantages in the struggle between the Lords of the land: canons against bishop, against Cathedral abbey, abbeys between them. Paris plot size pattern is a legacy of this medieval period, not of Antiquity: while the Roman period city is clearly focused on the left bank, the main urban center has developed on the right bank from the Middle Ages.

The geometric characteristics of past and present plot layers allow analyzing the urban morphogenesis: surface, elongation index (ratio length/width), index of rectangularity (the surface of the plot considered in relation to the minimum bounding rectangular box and the convex envelope associated with it). Overall, pre-industrial plots are in a range between 12m² and 300m², with plots most often between 50 and 100m². Highlighting below 300m² plots on the Napoleonic period Vasserot plan (1810-1836) confirms the high plot density on the more urbanized right bank compared to the more rural left bank. Per hectare there were on average 11 plots on the right bank against 8 on the left bank.

The plot analysis reveals 2 major perpendicular morphogenetic axes. The major orientation is between 60 and 74° with respect to east. It alone represents 36% of the total of segments. It relies on two morphogenetic axes (that can generate and transmit forms): the alignment formed by rue Saint-Martin and Saint-Jacques, and the Seine. Archaeologists have identified this orientation as dominant in the Roman period. The morphogenetic axis of ancient Lutèce was

based on a regular orthogonal grid aligned on rue Saint- Martin – rue Saint- Jacques, which is partly the cardo of the ancient foundation and builds on former islands formerly present in the course of the Seine. This orientation also dominates the network of streets that existed at the end of the fourteenth century. The Middle Ages have played a key role in the resilience of Roman period main orientation and its dissemination on the right bank. This Roman and Medieval axis still structures the most innovative economy in Paris.



Figure 5: Extracting on the 1810-1836 cadastral plan only the smaller plots (below 300m²) reveals a fractal pattern oriented according to the 2 morphogenetic axes of Antiquity and the Middle Ages (left). The orientations of the segments of plots in Vasserot map (1810-1836) as well as of the archaeological structures of Paris (1810-1836) (right) (Source: Noizet, Bove, and Costa 2013).

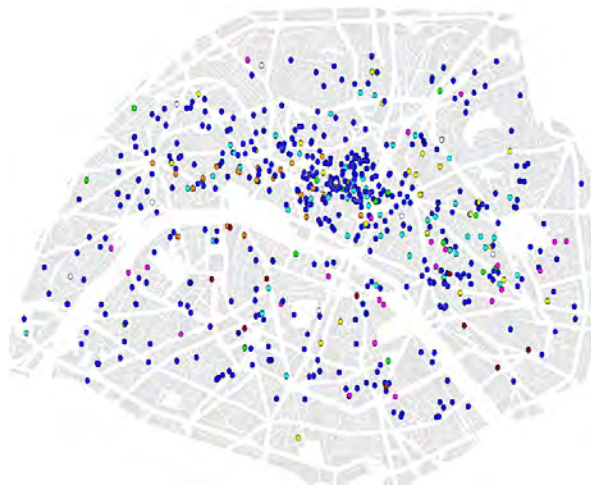


Figure 6: Map of the digital economy in Paris (localization of the ecosystem of start ups). (Source: Urban Morphology and Complex Systems Institute).

Minute breaks of symmetry in the urban fabric have been transmitted through centuries by long-term correlations. Platting geometry (size, orientation) is a time travel machine in layered urban strata. It embeds the memory of the city at extreme micro scales. As an example, we can analyze the consequences on the platting geometry of the opening dates of gates in Philippe Auguste wall (1190-1215). When Philippe Auguste decided to build a wall, the king made clear his desire to see the whole enclosed area occupied by houses of new residents. Abbeys then conceded large censives to bourgeois who undertook the subdivision and installation of men. The Knights Templars decided to develop their censives in Le Marais still sparsely populated. Rue du Temple crossed the wall through Porte du Temple, one of the original gates. Rue Vieille-du-Temple was

opened very early, before 1203. Rue du Chaume was opened only in 1288. The analysis of plots in Vasserot plan (1810-1836) reveals a morphological hierarchy with 20.3 plots per ha for rue du Temple, 15.5 plots per ha for rue Vieille-du-Temple, 11.3 plots per ha for rue du Chaume. The piercing of wall gates has been so structuring on the micro scale of the urban structure that 6 centuries after, at the beginning of 19th century, the spatial hierarchy of 13th century is still visible.

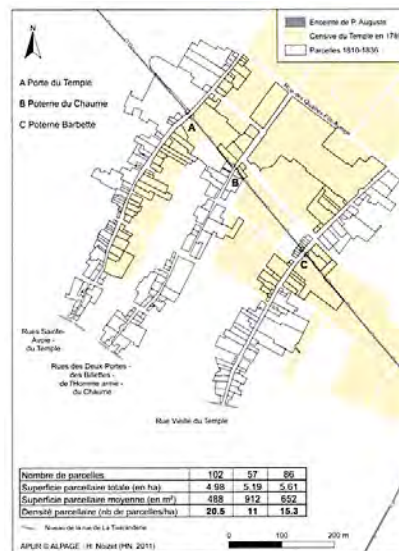


Figure 7: Platting at the beginning of 19th century (1810-1836) along 3 roads opened in the 13th centuries. Local scale breaks of symmetry have been transmitted throughout 6 centuries. (Source: Noizet, Bove, and Costa 2013).

From this long term history with long-range temporal correlations emerged a multi-fractal urban structure, with local singularities and breaks of symmetry reflecting the stratification and imbrication of different morphological periods. Scaling hierarchy of plot sizes is the “signature” of complexity.



Figure 8: Scaling hierarchy of plots' area along a structuring axis of Medieval Paris: rue Mouffetard. The largest plot is 760 m². (Source: Urban Morphology and Complex Systems Institute).

The evolution of Paris results from the superimposition of continuous, local growth processes and punctual changes operating at large spatial scales. The most important quantitative signatures of Haussmann planning are the spatial reorganization of centrality and the modification of the block shape distribution

(Barthelemy and Flammini 2008). In Paris intra-muros, Haussmann new boulevards (the “cuts”) reinforced the scaling structure of Paris street patterns by integrating the existing city into a larger scale-free structure.

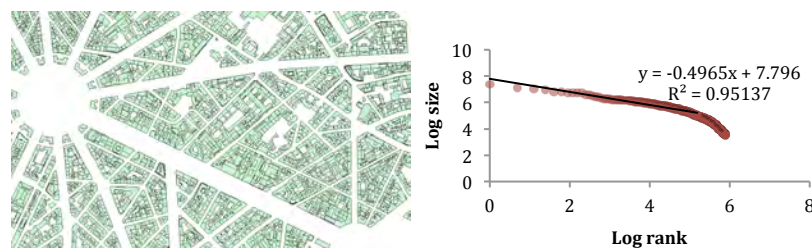


Figure 9: Quartier de l'Etoile. Plot scaling hierarchy in Haussmannian neighborhood developed 7 centuries after rue Mouffetard. The largest plot is 1600m². With much larger plots the scaling parameter remains almost identical. The city dilatation conserves the scaling hierarchy.
(Source: Urban Morphology and Complex Systems Institute).

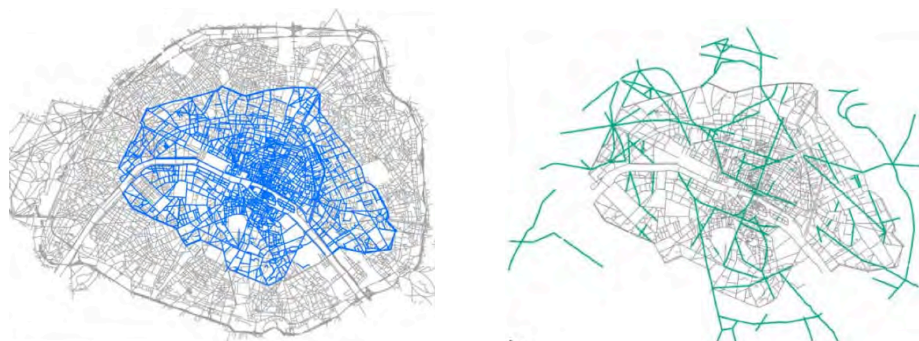


Figure 10: Map of Paris in 1789 superimposed on the map of current 2010 Paris (Source: Authors).

Map of Haussmann's modifications: The grey lines represent the road network in 1836 (Plan Vasserot), the green lines represent Haussmann's modifications. Recent studies (Barthelemy et al. 2013) have demonstrated that Haussmann's interventions did not change the structural properties of Paris street network, except the reorganization of betweenness centrality. The usual network measures display a smooth behavior. The network has scaled up while keeping its fundamental characteristics. First basic measures include the evolution of the number of nodes N , edges E , and total length L_{tot} of the networks (restricted to the area corresponding to 1789). These indicators display a clear acceleration during the Haussmann period (1836–1888). The number of nodes increased from about 3000 in 1836 to about 6000 in 1888 and the total length increased from about 400 km to almost 700 km, all this in about 50 years. This node increase corresponds essentially to an important increase in the population. The number of nodes N is proportional to the population P and that the corresponding increase rate is of order $dN/dP < 0.0021$ (Barthelemy et al. 2013). Barthelemy and al. have plotted various indicators such as the number of edges and the total length versus the number of nodes taken as a time clock. The results display a smooth behavior. In particular, E is a linear function of N , demonstrating that the average degree is essentially constant and equal to 3 since 1789. The total length versus N also displays a smooth behavior consistent with a perturbed lattice.

These results on the smooth behavior of 19th century evolution confirm our findings on the scale-free continuous evolution of Paris street pattern. The frequency of streets of different widths in Paris (created during different morphological periods, Haussmann period being the latest large scale intervention) follows an inverse power law. In the long tail of narrow streets we find the streets 8 meters wide opened in the 13th century like Rue du Chaume between rue du

Temple and Rue Vieille du Temple.

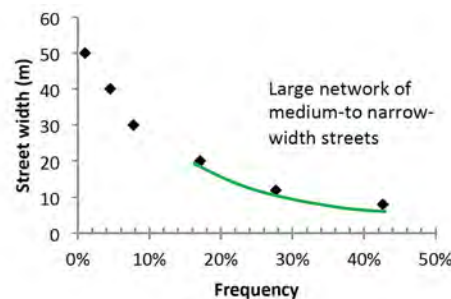


Figure 11: Scale-free distribution of street widths in Paris (Source: Bourdic and Salat 2012).

THE EMERGENCE OF A SCALE FREE PLATTING IN MANHATTAN UNDER MARKET FORCES

When discovered by Hudson in 1609, Mannahatta (« The Island with many hills ») had more ecological communities per acre than Yellowstone, more native plant species than Yosemite, and more birds than the Great Smoky Mountains National Park. Extreme ecological diversity has been replaced today by extreme human diversity. Before the grid, New York City grew organically. Concentrated at the Southern tip of the island was a knot of short streets, some dating back to the Dutch settlement of New Amsterdam, shaped by local conditions and lacking a unifying order. Most of the island was a patchwork of farms and meadows, ponds and marshes, laced with meandering country roads and providing ample ground for expansion. Towards the end of the American Revolution in 1776, the fundamentals of Manhattan, were almost unchanged since 2 centuries ago, except a town of 32, 000 inhabitants at the bottom of the island. After the American Revolution, the new and cash-strapped American city government looked to profit from its underperforming domain (about 2 square miles of rocky, hilly undesirable land in the middle of the island). The Common lands were vacant land first granted by Dutch provincial authority to the government of New Amsterdam in 1658. To facilitate their sale, Goerck prepared a subdivision plan with 3 long parallel streets, which would eventually become 4th, 5th and 6th avenues, with an east-west length of blocks identical to the one in Goerck's plan. This plan started the rise of New York real estate market and ascent of land values.

In 1811, the Commissioners' map overlaid a seemingly uniform grid of rectangles over the rugged island. The grid was above all an easy format for the subdivision and development of land. The grid system stripped the land of topographical markers and specificity, and repackaged it as standardized building lots. The grid re-conceptualized the island in a real estate market. And it worked beyond all expectations. In 1807, the assessed value of New York City real estate was \$ 25 million. In 1887 it was \$2 billion, a 80-fold increase.

From a seemingly homogeneous grid of blocks overlaid on a rocky, hilly, inhospitable island partly covered with marshlands, how did highly differentiated neighborhoods emerge, with urban and social fabrics as different as Soho, Tribeca or the Upper East Side? In reality the grid contains 2 patterns that create variety. One pattern is formed by the street widths (30 meters for the avenues, 20 meters for standard cross streets, with 15 major cross streets 30 meters wide at irregular intervals). The second pattern derives from block dimensions. All blocks are 60 meters wide north to south, but their length east to west varies diminishing from the center to the shorelines. From Third to Sixth Avenue blocks are 280 meters long. Moving eastward they shrink 189, 198, 195 meters long. Moving westward, they shrink uniformly to 244 meters long. Manhattan avenues are at a higher level in the hierarchy than Manhattan streets: first by their metric properties; second by their topological properties. Avenues are about 12,5 km long and 30 meters wide while streets are around 2.7 km long and 20 meters wide, except 15 major cross streets that are 30 meters wide. This break of symmetry in the pattern creates a metric scaling.

But even more important is the break of symmetry in the topological properties of avenues and streets. Graph theory defines street continuity by the number of links between nodes (segments of streets between intersections). It defines a street connectivity by the number of other streets it connects (that is it intersects). As Manhattan avenues connect 155 streets and are made of about 144 blocks, while Manhattan streets connect about 11 avenues and are made of 10 blocks, there is a steep topological scaling between avenues and streets.

The scaling hierarchy in Manhattan street pattern comprised originally only 2 main scales (or 3 if we create an intermediary category for the main cross streets). This has been enough for the network to evolve in 200 years. The initial hierarchy with 2 levels has been transformed into a hierarchy with 4 levels, with towards the lower level small streets cutting through some blocks, and towards the upper level urban highways circling the island. This increase in hierarchy is reflected in the topological modifications of the grid. On a surface of 35.4 km², the number of nodes of degree 4 characteristic of the pure grid has remained stable (1592 now compared to 1460 in the Commissioner's plan) while the number of odd nodes (degrees 1, 3, 5 characteristic of singularities and of more complexity) has doubled from 369 to 670. The density of nodes has increased (+ 17% to reach 60 intersections/km²) and the density of links has also increased (+21% to reach 11/km²) but they remain much lower than in a complex network like Paris. Sustainable networks must achieve a right balance between complexity (which reduces connectivity) and connectivity (which reduces complexity) (Marshall 2005; Salat 2011). The highly connective Manhattan grid has above all grown in connectivity compared to the Commissioners' plan by addition of new avenues (Lexington and Madison, which have divided in 2 the longest 280 meters blocks) and of Broadway diagonal.

Blocks were subdivided for land sale into identical plots of 205m² area, which, under the influence of market forces, started to consolidate and create a differentiated platting ordered by combinations of the same basic module very early in the process. An example is the strategy of Charles Moore for developing his estate, which eventually became the vibrant and differentiated Chelsea neighborhood. Free market is a formidable time accelerator for differentiation and emergence of scale free structures. Dating as early as 1835, the map above illustrates the strategies of sellers of vast estates. Charles Moore developed his estate into Chelsea village, centered on Chelsea Square he had donated to the Episcopal Church in 1819. The break of symmetry created by the Square, Church and public garden created a cascade of differentiation in the size and value of the plots in relation to their location near or far from Chelsea Church. In 1820 Moore had evaluated his estate at \$ 17,000. His wealth was estimated at \$ 350,000 in 1845 and \$ 600,000 in 1855, that is a multiplication by 35 in 35 years. Differentiation and asymmetry in land prices occurred very quickly in the seemingly uniform Manhattan grid. In 1860, real estate along Fourth Avenue ranged from \$ 3,500 to \$ 8,000, while lots along Madison Avenue were valued between \$ 18,000 and 55,000 at proximity of Madison Square.

The breaks of symmetry in plot size and land value have created an enormous potential of differentiation. The most impressive diversification, which has ensured the vitality and enduring success of Manhattan, has occurred at the plot scale. In a scale-free morphological field like the grid and platting system of Manhattan, the position and the form of each element are influenced by its interaction on different scales with all other elements. When the result of all these interactions creates a form, it is neither symmetrical nor fixed. It displays a degree of plasticity that allows it to evolve.

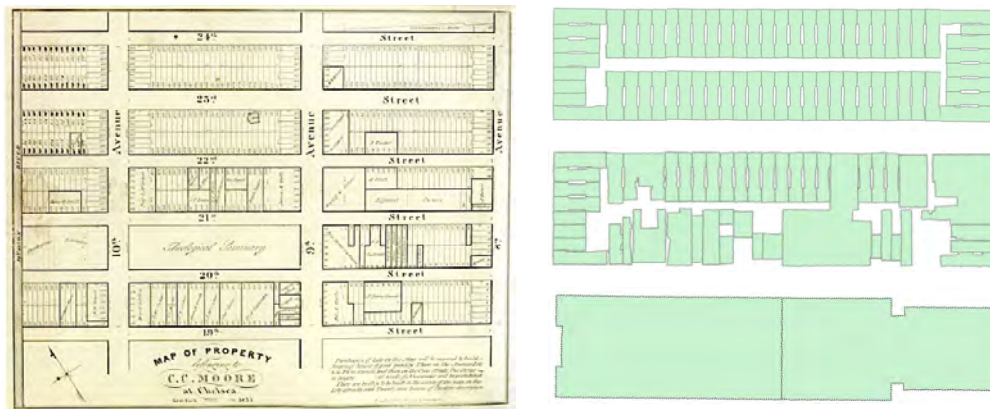


Figure 12: Map of Charles Moore real Estate in 1835, which eventually became Chelsea (top), and progressive consolidation of plots in Manhattan, from the original plot subdivision in 1811, with an average plot size of 205 m², to an intermediary plot consolidation, with an average plot size of 255 m², and an extreme plot consolidation, with an average plot size of 6,100 m² (Source: Authors).

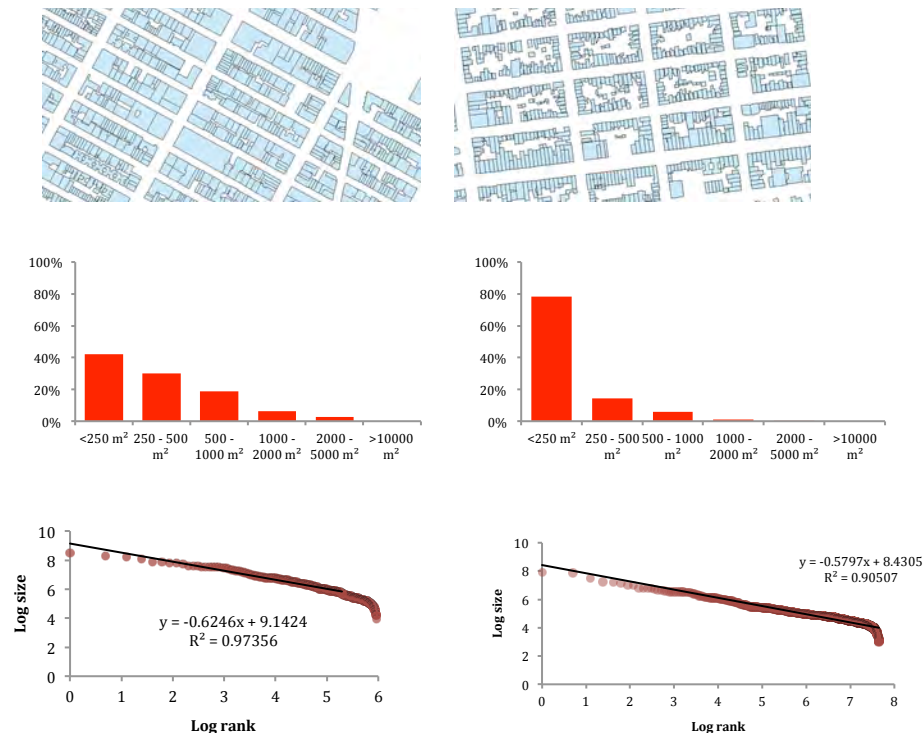


Figure 13: From an identical small-scale modular unit, the platting in Manhattan is highly adaptive: left around Madison Square, right in more residential Brooklyn, with corresponding rank size analyses (Source: Urban Morphology and Complex Systems Institute).

Highly adaptive Manhattan platting follows an inverse power law with a scaling parameter higher than in Paris (0.6 compared to 0.5), showing a steeper hierarchy of scale. It is interesting to note that the scaling parameter in Lower Manhattan, which has the much longer history of being formerly the Dutch town of New Amsterdam, of which it has kept almost unchanged its street pattern, has a scaling parameter for platting of 0.5, characteristic of European cities like Paris.

40% of the plots around Madison Square have kept the original platting of early 19th century, while the other 60% have consolidated at various sizes. In more residential Brooklyn, 80% of the plot sizes date

back to early 19th century. The plot sizes distribution inverse power laws allow for a large variety in the diversification of neighborhoods. In the very first decades after the Commissioners' plan of 1811, Manhattan vibrant emerging land market started to diversify the size and values of the plots, leading to a complex system.

This fast emergence of complexity of urban fabric, real estate market and economic activity in Manhattan lead to a multiplication by 8 of the population in 50 years making Manhattan as early as 1860 one of the largest city in the world with 800,000 inhabitants and to a multiplication by 80 of the real estate value of the city in 80 years (between 1807 and 1887). The emergence of complexity was fostered by breaks of symmetry in the apparently homogeneous grid and by a fine grain market of about 300,000 land plots of 205 m² (quite interestingly the size of plots of South West of France medieval 12th century new towns called "bastides"). As a comparison on the same area of 66km², Chinese recent urban developments display only about 250 giant superblocks; 1,200 times less plots than in Manhattan, which is even amplified by infrastructure oversizing compared to the Manhattan streets and avenues. This lack of fine grain restricts the market to 3 to 4 giant developers ("oligopsony") and prevents the emergence of a free market for land with a diversity of actors. This lack of market mechanisms is responsible for the economic failure of these new Chinese developments and their transformation into ghost towns with 64.6 million empty homes while 260 million urban migrants are waiting for decent housing. In New York on the contrary, 2 centuries of complex uneven growth and intensification have led to an extremely bumpy multi-fractal urban landscape for demography, development, energy, and most urban parameters.

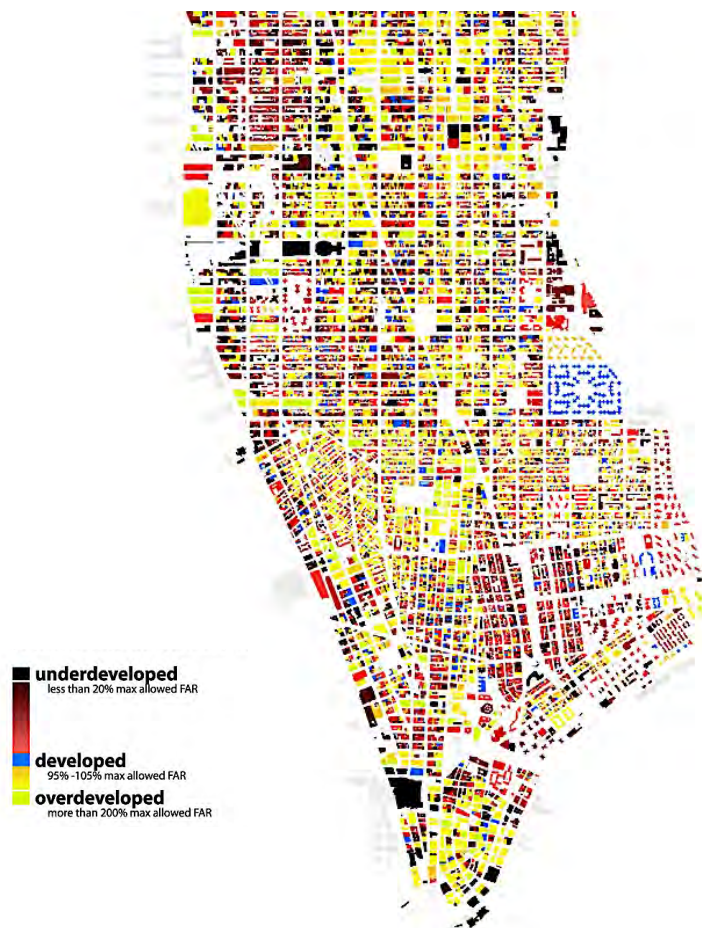


Figure 14: Manhattan uneven development (levels of FAR development of Manhattan blocks) (Source: Authors).

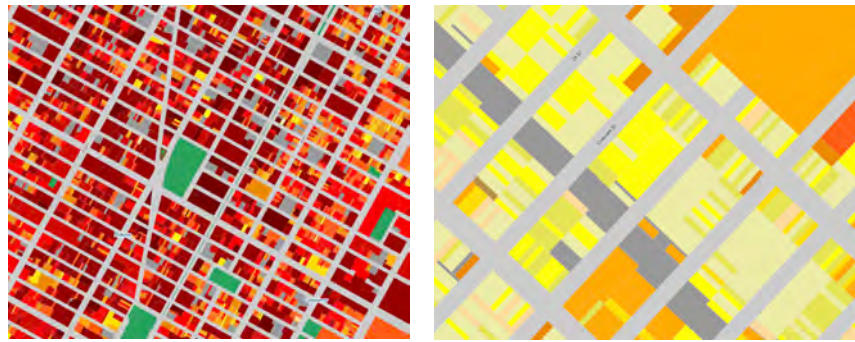


Figure 15: Manhattan detailed energy map reveals the fractal landscape of energy densities in in kWh/m² at plot level. The energy density at the tax lot level (in kWh/m²) varies more than 100-fold (Source: Howard et al. 2012)

150 YEARS OF COMPLEXITY GROWTH WITHIN THE EUCLIDEAN GRID OF CERDÀ'S DEVELOPMENT PLAN FOR BARCELONA

Unlike Manhattan, Cerdà's plan for the extension of Barcelona (Example) is a homogeneous and isotropic grid. No direction is privileged: all the blocks are square (113.3 meters side) and all the streets are 20 meters wide except the diagonals and a very few main long-range connecting roads. Cerdà plan led to dividing 13 km² into 550 identical blocks. This lack of intermediary scales in the hierarchy has incited in recent years some planners to propose a functional reorganization with "superquadras" (superblocks comprising nine square blocks). Instead of adding a larger scale of superblocks, the natural bottom-up evolution of the city has been to develop, and intensify the smaller scales of the street pattern with a denser network of small narrow streets. From a "flat hierarchy" when planned, the scale-free properties of the Example have increased. On the 13.4 km² of Cerdà's plan, the number of links per node has increased in 150 years by 45% (from 845 to 1,223). Nodes with 3 links have been multiplied by 2.4 (from 172 to 415). Nodes with 5 links have been multiplied by 2.3 (from 18 to 42).

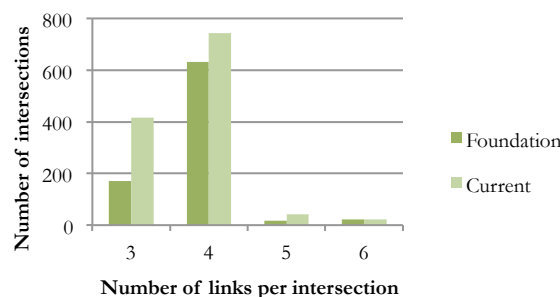


Figure 16: Number of links per node in Barcelona's Example from Cerdà's plan to now (Source: Urban Morphology and Complex Systems Institute).

This increase of the number of odd links per nodes reflects an increase of breaks of symmetry compared with the initial regular plan with a majority of even nodes (4 for the nodes on the grid, 6 for the nodes on the diagonals perfectly integrated in the grid), which represented 77.5 % of the nodes in Cerdà's plan and represent now only 62.6 %. The 20 meters wide "carrers" planned by Cerdà remain anyway dominant in the metric properties of the network: 180.6 km on a total of 222.1 km in Cerdà's plan to be compared to 161.2 km on a total of 228.1 km now. Smaller blocks have anyway resulted from the division of the large blocks, with the result to divide by 2 the standard deviation of the block size distribution compared to an inverse power law. We observe

in 150 years a growth in complexity and connectedness of the network: the density of nodes increases by 44 % (from 63 to 91 street intersections/km², still far from the more complex and connected network of Paris (circa 160), which results from 2000 years of evolution); the density of links increases by 40% (from 118 to 165). The cyclomatic number (that is the number of closed cycles in the network) increases also by 30% (from 55 to 76 cycles/km², still far from cities with a longer history like Torino (117) or Firenze (156)). This increase in the cyclomatic number improves the connectedness and the pedestrian quality of the urban fabric. The average distance between intersections decreases from 126 meters to 105 meters, which also improves the walkability. The linear density of the street network is high (17 km/km² to be compared to 22 in Paris and 3 in Beijing).

Measuring socio-economic breaks of symmetry with information theory

Information theory can provide a metrics of cities breaks of symmetry in diversity of uses and thus in complexity. Shannon and Weaver proposed an equation similar to the entropy equation to measure the quantity of information a message contains. They defined an information bit as the amount of uncertainty that exists when one has to choose between two possibilities: for each possible trajectory an information bit is added. If we consider that each legal entity of the urban system (economic activities, associations and institutions) is represented by an ideogram, a word in the urban dictionary, we can build urban messages and calculate the amount of information they contain. The value obtained (H) is the measure of diversity and of organized information. Diversity indexes have a greater meaning when applied to the temporal evolution of the urban territory. Studying the increases or decreases of H in a specific territory allows us to approach some of the potential dysfunctions of the urban system, as well as the elements that provide stability. When we evaluate the relationship between the consumption of resources (E) that are necessary to keep a specific organization (H) through time, we obtain an equation of efficiency (E/H) that may become a guiding function for urban policies.

A complex unequal socio-economic spatial structure overlaid on the physical isotropic field of cerdà's grid

Socio economic phenomena are not distributed according to Gaussian laws but to inverse power laws with high range of inequality. There is a contradiction between Cerdà's homogeneous plan and the structured scale-free diversity of economic activity destined to take place into it. For 150 years the spontaneous development of the city has increased the spatial scale-free properties of its physical form and of its network of connections, achieving an about 50 % increase of some key parameters from which the potential of interactions derives. This growth of complexity in the city structure and fabric has been provoked by the economic vitality of Barcelona and in return it has shaped the urban geography of socio-economic diversity. Despite the initial lack of spatial scaling, economic and social activity has made differentiation emerge along a major break of symmetry non predicted by Cerdà. Life has been stronger than top down planning and has chosen what Cerdà did not choose for the center of Barcelona. This break of symmetry has created a strong economic anisotropic morphogenetic field within the isotropic grid and it is also reflected in the scaling hierarchy of flows along transportation axes. Like in physics and like in semiotics, breaks of symmetry in cities create structure and meaning. Passeig de Gracia in Barcelona connects the original city that became the Barrio Gotico to the preexisting village of Gracia and is thus slightly shifted in the orthogonal grid of the city's extension without being a diagonal that would be integrated in the grid. It has been developed first in an astounding Art Nouveau Style. These two breaks of symmetry in space and in time have given Passeig de Gracia a central connective position and created a subtle large-scale order in the repetitive urban fabric of square blocks of Cerdà's Eixample. The crossing of the two diagonals that Cerdà intended to become the new center of the city did not break any symmetry and remained marginal compared to Passeig de Gracia.

Mapping urban Shannon information on a territory reveals the breaks of symmetry in the development of the urban fabric, and in some cases its elements of centrality. In Barcelona, we can see how the breaks of symmetry in information structure the apparently spatially uniform Cerdà plan. 34% of Barcelona's economic activity must be described by 6 bits of information, Eixample and the Barrio Gotico being the urban territory with a greater diversity. 87% of Example obtains values over 6 bits, becoming the fabric with the greatest diversity of legal entities (economic activities, associations and institutions) (Busquets & Corominas, 2010). Example has been built and is still being built slowly, as complex systems are built in nature. Example radiates activity around it; it is a true heart that beats diversity, extending urban complexity by the pedestrian axes that pass through it. The part of Example around Passeig de Gracia and the part of Barrio Gotico connected to it by Passeig de Gracia show the highest level of diversity and organizational structure in terms of information theory. They are the true heart of the city.

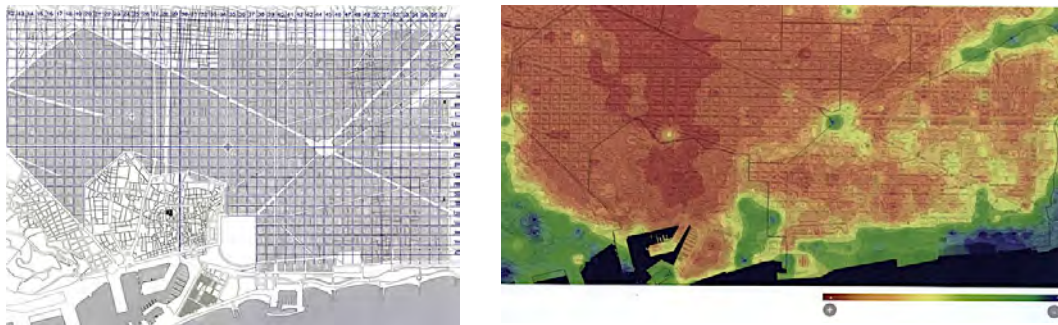


Figure 17: Left: Barcelona grid of square blocks in the Eixample with the Barrio Gotico. Right: Concentration of bits of information per individual (Source: Agencia d'Ecologia Urbana de Barcelona).

Connectivity increases structural information. On the contrary, when an axis presents a discontinuity in the linking of activities, the fabric is simplified, showing a hole in the diversity map. This is what happens at the crossroads of the diagonals that failed to become the centre of the city. The proposed designs for the Plaça de les Glories and its surroundings were put forward in terms of continuity and resolution of the traffic, but they became a barrier in the urban diversity continuous flow.

WHAT SHOULD PLANNERS DO AND MUST NOT DO?

Emergence is the opposite of the utopian simplified orders that architects such as Le Corbusier have tried to impose on cities. Huge quantities of energy are needed in such artificial repetitive orders to maintain urban systems in a stable state. Modernist cities, with abstract giant forms imposed from the outside, obstruct the emergence of small-scale connections, whereas the continuous creation of connections in historical cities favored their evolution. The continuous fabric of traditional buildings with courtyards, because of its connective forces developing inwards, has a stabilizing impact on the urban system. Giant modernist buildings standing in loneliness isolation do not connect into the urban fabric. They have a destabilizing impact and fail to create an evolving adaptive structure. Modernist architects turned their back to the universal laws of urban evolution by working with large-scale elements only and making the urban land a blank slate devoid of the incremental successive layers of historical traces. The Utopian machinist juxtaposition of vast homogeneous zones, made of a repetition of very big objects, hinders the appearance of emerging properties that were not integrated or even forecasted or predictable into the initial framework of the system.

Planners should create the framework for future evolution. They should not constrain this evolution. Successful plans are simple but subtle plans that leave ample room for unexpected and unpredictable change while enduring for millennia. Roman Empire plans lead to cities as

different as Torino, Firenze, Bologna, and Paris. When the Commissioner's designed Manhattan map in 1811, long before the Industrial Revolution, in the period of Napoleonic wars in Europe, none of the technologies that made the power and wealth of the city in the 20th century could have been imagined: electricity, automobiles, subways and elevators where not only unpredictable, they were unthinkable, they were undreamt nightmares of a distant future. Without them, the typical urban form of Manhattan, the skyscraper, could not have been built. And yet, the Commissioner's plan was able to accommodate the unpredictable and to endure for 2 centuries, making Manhattan the world economic capital. Urban form does not follow function. It must successively or simultaneously adapt to many different and even contradictory functions. Planners should understand that the future cannot be controlled and that attempts to control it leads to dead cities, to ghost towns. Living cities are like chessboards where an endless number of different games can be played. It is the role and responsibility of the planner to design the chessboard, not to play the game. Life should play the game.

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LIFE IN DESIGN: CHRISTOPHER ALEXANDER AND THE NATURE OF ORDER

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Abstract

How we build reflects how we understand the world around us. The architectural style of a period thus corresponds to the cosmological and epistemological beliefs then dominant, and objections to one are likely to line up with objections to the other. Christopher Alexander provides a strong example of that tendency. His opposition to architectural modernism and postmodernism reflects opposition to tendencies within modernity that present themselves as rational and liberating but are in his view very different in character, and his project involves restoring balance to modern understandings in a way that makes room for what he calls "the phenomenon of life." He thus reaches results similar in basic ways to those reached in traditional and vernacular architecture but in a very different manner. It is not clear however that his approach can be generally followed.

Keywords: Christopher Alexander; modernity; science; traditionalism.

We need to understand our surroundings, so we demand that our built environment make sense to us. That is why we build it in the image of what we believe about the world. If it is too much at odds with how we understand things generally, it seems stupid, fraudulent, confusing, or aside the point. For that reason disagreements regarding the nature of the world reappear as disagreements regarding architecture and urban design. If Richard Dawkins and Joseph de Maistre were on a city planning commission together, they would not see eye to eye on the appearance or location of the town hall, library, and cathedral.

The dominant tendency of public thought in recent decades has favored replacement of the traditional familial, civic, cultural, and religious aspects of social life by technically rational processes embodied in world markets and neutral transnational bureaucracies. Le Corbusier pointed out the design implications: "the core of our old cities, with their domes and cathedrals, must be broken up and skyscrapers put in their place" (Wilhelm Röpke, 1998). Such views made him a natural ally of the masters of the modern world, who want to turn social life into a rational machine that is easy to understand and control. When he died in 1965, *Pravda* said that "modern architecture has lost its greatest master," while President Johnson commented that "his influence was universal and his works are invested with a permanent quality possessed by those of very few artists in our history." Lyndon Johnson and the Kremlin may not have known much about art, but they knew what they had reason to like.

Times change, but not that much. In the world of architectural style modernist rationalism has supposedly been replaced by postmodern playfulness or irrationalism, which has its own cosmological implications. Architects like Peter Eisenman view the world as essentially disorderly, inhuman, threatening and anxiety-producing, and contend that is what architecture should be (Alexander and Eisenman, 2004). Otherwise, it is kitsch, comfort food, inauthentic, and perhaps incipiently Nazi, because it is likely to try to force some image of a fantasized past order on recalcitrant reality.

The political effect is the same as modernism. The Legalist thinkers of ancient China, brutal rationalists who invented the totalitarian state, found they could apply Taoist celebrations of the incomprehensible to their own ends. Lord Shang, who was one of them, went so far as to

punish people for praising the laws: they had no business forming any view at all on matters of state (Rubin, 1976). Contemporary postmodernism has similar implications. Business and government put billions of dollars into building projects that disorient people, disorder thought, debunk normal human responses and relationships, and convince people their understanding of reality cannot be relied on. The inevitable effect is to make us more easily manipulated. That result aligns with the social, moral, and metaphysical outlook behind technocracy: the world is composed of atoms and the void, together with human sensations and will. In such a world nothing has an essential nature, and desire and will are the only possible principles of valuation, so the will of the strongest becomes the final standard and treats the people as a formless mass of raw material.

That outlook has its apologists, but it denies that anything could be specially worth willing, so the world it evokes is as inhospitable to human life as the architecture to which it gives rise. Surely something has gone wrong. Man and beauty are part of the world, so it seems unlikely that the world in its essence could be so much at odds with them. And to the extent the world is a mixture, it seems right to support the beautiful and harmonious against the disruptive and inhuman elements that are also present. If someone wants to be a nihilist, he has no grounds for objecting to comfort food more than anything else.

But what to do? Traditionalists and others may complain, but few of them are in a position to put forward a clear response that deals with modern difficulties in a way that connects with current ways of thinking. Christopher Alexander is extremely helpful for that reason. He is not a traditionalist or a conventional thinker of any kind, but an architect, trained as a mathematician and scientist, who loves beauty, hates inhumanity, recognizes the superiority of traditional built form, and has spent his professional life looking for ways architects can do better.

As someone trained in the natural sciences, he tries very hard to make his views as definite and explicit as possible. His first major work, the underground classic *A Pattern Language* (written with several collaborators), (Alexander, Ishikawa, and Silverstein, 1977) therefore emphasized the specific. It set forth a system of some 250 patterns (e.g., balconies should be at least six feet deep, rooms should be lit from two directions) that crystallized practical wisdom today's architects and planners ignore or have forgotten. They were similar to principles followed by traditional builders throughout the world, and were intended to make buildings, neighborhoods, cities, and regions more beautiful and livable.

In spite of his scientific disposition, Alexander tends toward a sort of populism. He hoped that people could use the patterns to build beautiful humane buildings for themselves. It did not work: people followed the recipes but came up with bad designs. Patterns are needed, it seems, but vision and higher principles are necessary to guide their use. *The Nature of Order*, (Alexander, 2002a) a four-volume work almost thirty years in the making, tries to supply what is missing by calling for vision and exploring the most basic principles that govern whether a built environment becomes a place in which one would want to live.

The book is an extraordinarily ambitious attempt to bridge the gap between modern thought and goods destroyed by modernity that have normally been attainable only through tradition. It goes to the root of the issue: better building requires an understanding of good design that is integrated with what is good in human life generally. It follows that to deal with architectural problems Alexander had to deal with the impossibility of rationally discussing value in today's public discourse.

His discussion therefore has to go to very basic issues, and become metaphysical and even religious. He attributes our current inability to discuss good design intelligently to Cartesian epistemology and its resulting ontology, which radically distinguish fact from value and reduce reality to elementary particles acting locally. On such an understanding, "value" is simply personal opinion, and architecture can only be a matter of technology, ideology, or arbitrary will. The inevitable result, as the traditionalist thinker Russell Kirk observed, (Kirk, 1982) is an architecture of servitude and boredom: servitude, because order is based purely on the will of the stronger, and boredom, because arbitrary order presents nothing of human interest.

So what to do? Alexander wants to extricate architects and planners, as well as their clients and victims, from an intellectual and practical dead end. He values the solidity and usefulness of scientific reasoning, along with modern life generally, so his strategy is to extend scientific reasoning so it can deal with questions of good design while remaining objective and verifiable.

To do so he needed to identify a feature of good design that is basic to any setting we would want to inhabit, that designers from healthy traditions have in fact favored, that observers from very different backgrounds recognize consistently, and that scientists treat as real. The feature he identified is life. Life is good as well as scientifically respectable. Traditional designs and good art generally seem alive, contemporary buildings and cityscapes generally do not. Further, it turns out that if you show people images and ask which seem more alive they give similar answers, and their tendency to do so increases with practice. So it seems that life is a basic, objective, and determinable good that has been lost in present-day design, and Alexander has spent years analyzing the structural features that increase it.

The first volume of *The Nature of Order* is therefore called—and deals with—*The Phenomenon of Life* (Alexander, 2002b). It proposes that life is a matter of wholeness defined by “centers” that contribute to each other in complex ways as part of an interlocking hierarchy. A tree, for example, is a whole made up of roots, trunk, branches, and leaves and so on, each made in turn of smaller components. All the components contribute to each other, and they are separately identifiable, but it can be a bit artificial to say exactly where one ends and the next begins. Further, a tree is itself a center within larger wholes such as a grove or forest.

He identifies fifteen features that promote the wholeness and living quality of a system. Modern constructions routinely lack those features, and that lack is what makes them deadening. The fifteen features include:

- *Levels of scale.* A structure engages us more if it includes smaller structures a third or quarter its size, which in turn include structures that are similarly scaled-down, and so on down to the level of fine detail and up to the level of the whole world.
- *Strong centers.* An object is more compelling if its components point toward some central region or structure that integrates it as a whole.
- *Boundaries.* Something is more noticeable if it is framed, and the whole of which it is part is more integrated if something connects one component to another. Well-articulated boundary regions serve both purposes and help make built objects comprehensible.
- *Positive space.* We will not like the shape of something, at least in the long run, unless we like the shape of the surrounding space it creates through its presence.

And so on.

Alexander’s specific examples, which range from Turkish carpets to wild meadows and Italian hill towns, show how his fifteen features order both the natural world and a good built environment, and even contribute to the functionality of hand tools and other objects of daily use. His analysis thus connects the aesthetically valuable to the natural, functional, and demonstrable, and so makes it harder to shrug it off as a matter of personal preference, social convention, or ideology.

His approach also connects good design to inner experience. “Which design is more alive” generally calls forth the same answer as “which better reflects what you are,” and the answers of ordinary people to the latter question most often correspond to the judgment of experts as to aesthetic value. Further, because center contributes to center in an overall living system, a built environment that is full of life makes those who inhabit it feel more alive. The theory thus explains how life is deeply enhanced, if not quite redeemed, by beauty.

His final point, which he believes he needs to establish the full validity of his theory, is that reality forms a single integrated system. If certain arrangements of space are objectively more alive than others then life must somehow be implicit in space itself. His views on architecture, he says, are based on:

a conception of the world in which the air we breathe, the stones and concrete our city streets are made of—all have life in them ... This is not merely a poetic way of talking. It is a new physical conception of how the world is made (Alexander, 2002b).

His aesthetics thus imply ontology.

The book is brilliantly illuminating, and persuasively connects objective goods to properties that are natural, functional, and concretely identifiable. As such, it is a major contribution to aesthetic and architectural theory. It gives those who generally accept modern ways of looking at things but are willing to expand them to accommodate realities they tend to slight a solid way to view aesthetic goods as more than personal preference, social convention, and ideology.

The theory does not, of course, solve all problems. His approach as he presents is not at all practical. His own buildings look like places one would like to be, but the process of trial and error through which he develops them, however well it demonstrates his theory, is too time-consuming and crisis-ridden, and perhaps too dependent on his special talents, for general use.

Further, his fifteen properties are powerful but not sufficient any more than his 250 patterns were. He says as much:

These things, the patterns, the properties, may play a role in my being able to create life in things. They actually do play a role. But they are far from certain ... the life is really the primary thing, and the properties are really secondary (Alexander, 2002b).

The continuing need for something transcending every system of rules and concepts leads Alexander ultimately to religious categories. He nonetheless tries to limit recourse to them, referring occasionally to God but in general favoring more impersonal East Asian concepts, which require less extension of the scientific concepts he favors.

Alexander's work occupies a halfway position that may be unstable, a situation that is likely inevitable in the case of a work that breaks so much new ground. He wants the benefits of tradition: the emergence of functional and satisfying forms from intuition, experiment, and winnowing guided by a conception of ultimate reality as somehow spiritual. He wants to get them, though, by extending the modes of thought characteristic of a radically anti-traditional and anti-spiritual age. He proposes to do so by presenting an analysis of the qualities of natural and traditional form that makes it living and therefore good, suggesting recursive trial and error procedures for developing living forms, and proposing a generic spiritual understanding of ultimate reality to guide the process.

It seems doubtful, however, that the benefits of traditional ways can be restored by understanding what they are and determining the minimal changes to existing understandings that will be sufficient to bring them back. Explaining how the benefits of one way of being come about does not tell us how to get them again when that way of being has disappeared. Hegel describes the problem in his preface to *The Philosophy of Right*:

Philosophy ... always comes on the scene too late ... When philosophy paints its gray in gray, then has a shape of life grown old ... it cannot be rejuvenated but only understood. The owl of Minerva spreads its wings only with the falling of the dusk.

It is therefore not surprising that (apart from his own buildings) Alexander's examples of good design are almost all from the vernacular, often from times and places like the European middle ages when artists were anonymous because high art itself was vernacular. It seems that retrieval of what tradition gives us requires a rebirth of tradition itself, which requires acceptance of the goodness and authority of the implicit patterns of reality, and willingness to attend to those

patterns and wait for them to manifest themselves without forcing our own views on the matter. That means, in effect, the end of modernity. What is called postmodernity is at once the summation and self-demolition of modernity. We need what lies beyond it.

As Alexander realizes, the understandings on which design rests go all the way down. We get the good by giving it our all, and if so a basic transformation of life and thought will be needed to get us out of the hole into which we have fallen. Alexander pushes his analysis far enough to recognize the need for an ultimate standard that transcends rules and concepts while remaining concretely real. His approach makes that standard—in effect, God—an add-on to modern scientific thought. It seems doubtful that will be enough.

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A FULL HOUSE

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Abstract

A fictional child knows which buildings suit him. He talks with an anthropologist, an historian, an architect, and a depth psychologist: he wants to know why some buildings suit him while other buildings don't. The child's own experience corresponds with the experience that led Christopher Alexander to undertake his research. We can recognize this child in ourselves.

Keywords: buildings that suit us.

Birds build nests. Bees make hives. Foxes hollow out the ground. Ants pile it up. They make the homes that suit them. They construct the homes they are capable of building. Each individual home is unique, but the structure of the homes varies little.

People set up tents, hollow out rock cliffs, weave twigs into yurts. People build houses of wood or brick, stone or concrete, discarded cardboard or steel and glass. People build flats and office blocks, stations and airports, stadiums and shops, museums and temples and funeral parlours. Each individual building may be anything but unique, and the structure and the style of the building vary to a vast degree.

'Why,' asks the child, 'do our buildings come in such an array of sizes and shapes, styles and materials? Why don't we build like the animals do, with a form and a pattern that always suits us?'

'Because,' the anthropologist is quick to answer, 'we have so many possibilities.' 'And more or less money,' adds the economist. 'And complex forms of building organisation, of who builds what and who may profit from it,' reminds the sociologist. 'Neither can we forget historical factors,' says the historian, perhaps a bit pedantically.

It is clear that we do not begin with a clean slate. We inherit boundaries and then break them down. We can learn from tradition or else turn our backs on it, ever striving for a new form, a new spatial composition, a new combination of materials. We can set up new boundaries because they serve us, or we can banish boundaries and turn the built world into sprawl. But the child refuses to be silenced. The child gets to the heart of the matter. The child wants to know why some buildings and towns suit us, while others do not.

The child's question is psychological and spiritual, scientific and historical. His question is so significant that we wonder why we forget to ask it ourselves. Is there, in fact, an objectively present need for certain kinds of delineated space for human beings to inhabit? Or can we get used to anything, assuming our very psychological inheritance will evolve along with the spaces and towns we build?

A building is not a language, but like a language a building has its own grammar. It has a front and a back, an above and a below. It has walls with holes in them. It has rooms of different sizes, suited for different activities: some are better suited for dwelling in, while others are meant for moving through. A building's spatial configuration is analogous to syntax in language: some combinations make sense, while others do not; some serve us well, but others serve us poorly.

At this point the apt historian draws our attention to spatial patterns which have recurred in buildings throughout human history, regardless of cultural or technical differences. Eighteenth-century architectural theorists, fond as they were of cataloguing, tried to codify building plans into a limited number of suitable configurations.

The contemporary professional architect rebels passionately. The architect points to buildings which only new technologies and techniques have made possible. The architect, whose craft concerns boundaries and limits, will in no wise be limited or bounded in designing new buildings. What is important is that they be new.

'You're missing the point,' interrupts the child. 'Some of my favourite toys are new. Many of my favourite toys are old. Some of them I got as gifts. A few I made myself, thanks to some help from my dad. I don't care whether they're old or new. What I care about is that they suit me.'

'What I care about is that they suit me.' The child has hit the nail on the head. The value a building has, the suitability a town has: these are the qualities that count. After all, not only the architect but the entire human race must inhabit them. What do buildings and towns do to us? What do they do for us? When do they suit us, and when do they provide us with an improper fit?

Is there an objective answer?

If there is an answer, then the answer must come not from a theory, not from an ideology, not from belief. The answer can only come from human experience. And human experience is like a house: what you see is not all you get. Beneath the inhabitable rooms lie the basement and the subbasement, which in turn rest on the foundation. Sometimes we know consciously what suits us: we know already which rooms are our favourites. But at other times we need to look deeper if we are intent on discovering the truth. We can consult our dreams and myths. We can study the limits to our perception. We can attempt to discover, in fact, how we perceive spaces and boundaries. And perhaps most important of all, we can acknowledge what the spaces and boundaries mean to us, what they mean for us, whether they suit us.

By attending to the record of built buildings through the ages, we can acknowledge how we feel in them and what they connote for us. We can rediscover what we perhaps already knew: this room is too low; this hall is just wide enough; this stair invites us to climb it; this window feels like a letter box; this porch is right in every season; this continuous glass wall needs stickers of birds on it: otherwise both we and the birds will fly into it.

By attending to what goes on inside our heads, we shall probably keep ourselves honest. If our chief goal is to belong to a club of established architects, our wish to be part of the group, part of the age, may make us forget our authentic experience. And the child demands honesty, unadulterated and uncorrupted.

Not only does the child demand honesty: the child is gifted as well. He is bright. He already knows that asking people which buildings they prefer may not provide all the answers. People, the child has observed, respond at different levels of awareness. They may even try to give the answer they assume the questioner wants. Or they may try their best to prove they are trendsetters, choosing the buildings which have just been hailed in the newspapers. How, the child wonders, can we get to the heart of the matter?

Normally, sceptical of theories, the child suspects that certain theories may indeed disclose the truth, provided they grow out of documented human experience. The child wants to know what goes on in our heads and in our bodies when we inhabit a room or a building, a square or a town.

Who could better satisfy the child than a depth psychologist who devoted his life to studying children—how they develop, how their consciousness grows, how they create? D. W. Winnicott (1971) is just such a psychologist. The theories he developed while observing children led to his conclusion that playing is necessary for survival, and that it is impossible to be creative without building on tradition.

At the beginning of our lives, we know virtually no boundaries. In our experience, we simply are our mother and her breast, our brother and the beast on our bedroom curtains; we are light during the day and darkness during the night. In essence, however, we are all budding architects: we begin to build boundaries; we begin to differentiate between mine and thine. The day dawns when we look at our mother and see our own face reflected in hers. And if our mother is good at her profession, she engages us in a game of hide and seek. She leaves us for a

moment, only to return soon afterwards, showing us her face again. It's quite a significant step in our development when we discover we're not our mother. We discover we're still alive, even though she's left the room. You could say we've built a wall around ourselves, a wall that protects us from identifying with everyone and everything else. This wall contains us: it allows us to forge an identity.

We continue to grow as we continue to play. Not only do we discover that mother or father have not disappeared forever, even though they may have stepped out of the room; we find that our favourite toy animal can play the role of mother, father, or friend for us. The house we're building is growing along with our own emerging identity.

As our house grows, as our identity takes shape, we're not only architects: we're historians as well. We have memories. We can enjoy and trust the memory of our absent mother in the face of our stuffed bear. We may even hide the bear in order to delight in finding it again. We have not been abandoned after all. We all tread the path of psychological development, and we tread it as we play. We follow a path that depends on memory.

The inquisitive child is pleased to learn of Winnicott's observations. If playing and building depend on memory, the child reasons, then one would expect that real buildings grow out of memories as well. Do they? The child turns again to the architectural historian.

The historian who comes to his aid has tried to be as honest as the child himself. The historian has searched the record of built buildings for a common denominator: he has not been content to regard buildings as mere examples of various styles. And the historian has hit upon a building theme as universal as the developmental history of every child. The theme is containment.

The child must reflect for a moment: he must consult his memory and his experience in order to savour what containment entails. 'Containment: oh yes—the castles I build with my blocks contain a safe dwelling space, protected from potential attackers. And I remember that my favourite bear contained my absent mother's face. My toy chest contains my treasures.'

The more the child reflects, the more he remembers how vitally important the experience of containment is. He recalls being sent to his room after a temper tantrum. The room's walls contained his unbridled emotions until he was able to distinguish between his feelings and his identity. Perhaps the historian is on the right track, the child thinks.

'Judge for yourself,' retorts the historian. 'Journey with me to distant lands and different climes. Look at the first buildings we built. Look at the buildings we built afterwards. What do they share with each other? Containment. The need to contain. Not just people and animals, but gods, our most precious treasures.'

The historian leads the child through books and pictures, through models of buildings and actual buildings. The child discovers that throughout virtually all of human history, the first buildings and then the most important buildings were built not just to protect people from the elements: they were built in order to contain a god, a divine treasure, a memory essential to human development and wellbeing.

As though he were the first person on earth, the child delights in encountering the same spatial pattern, again and again. He sees temple gods, Athena herself, full of the literal Greek treasures, the Torah, the Shiva, the Buddha, the consecrated Host, the mihrab that reflects the presence of the holy centre in the experience of the beholder. He sees courtyards with fountains. He sees thresholds after thresholds in the Forbidden City, culminating in the room fit only for the emperor. They are all set apart. They are all contained. 'Why?' the child wonders. But hardly are his words out before his memory presents him with an image of his favourite stuffed bear.

'Of course,' exclaims the child. 'My bear contained my memory of my mother. That's why I gave him a special name and built a house for him in my room. I treated my bear with the same respect that grown people give to their gods, to God. I needed my bear to remind me not only of my mother: I needed him to remind me I was not alone in this world.'

'Right you are!' The voice comes from someone else. It's not the historian. It's a wise woman, another depth psychologist. The child wonders how she got into the room. She explains

that the historian invited her. He wanted corroboration. He wanted to be as sure as possible that containment is the theme and the purpose of architecture. That's why he sought an expert with experience in observing that most elusive part of our being: the human soul.

'And that's precisely why people refer to me as a depth psychologist,' the woman clarifies. 'Depth psychologists are not terribly interested in behaviour alone or in manipulating people's behaviour. We're searching for what really makes us tick. We look at dreams, at themes in literature, at patterns in music, and even the spatial compositions of buildings and towns. We find similarities, over and over again. And we make maps in an attempt to order our observations and our insights. This is very difficult territory—at once empirical and hypothetical. We can't see the soul; we can only derive its existence from the experience we observe.'

'Please go on,' pleads the child. 'I like playing with maps. I like extending my boundaries into uncharted territories. Who knows what we may find there?'

'Drawing a map of the soul—of the psyche, depending on which language you prefer—is tricky. It's tricky because we can't view it in the same way we can see the gall bladder in "a patient etherised upon a table" (Eliot, 1971). We're not dealing with visible organs; we're dealing with patterns and attitudes and experience.'

'I don't mind,' interrupts the child. 'I want to know what you've discovered, or at least what you think you've discovered.'

'Well,' the woman continues, 'the evidence is quite unassailable for anyone who wishes to look at it honestly. And the evidence supports the historian's findings: it's all about containment and relating to what we've contained.'

The child recoils. 'Stop using abstractions, please. Show me the maps. Let me see them; let me feel them; let me touch them and play with them. Let me discover for myself whether they've charted the territory I know.'

'I can be brief,' the depth psychologist replies. 'Remember how at first you couldn't distinguish yourself from your mother or your brother? Remember how you were everything else in the world?'

Because the child is still honest, he has to admit he's forgotten this stage in his development. 'But I do remember how important my bear was for me,' he offers. 'And I know how my room helped me contain my anger. I see now—no, I remember—how a building can contain my most precious treasure.'

'Exactly. Take a look then at the map we've made of the psyche. It's in the form of a circle. In the middle is the soul, the source of life and direction, the unconscious, the beginning.'

'Yes,' squeals the child. 'And that's where I was too when I feared I didn't exist any more after my mother left the room.'

'Right again,' confirms the woman, pleased at the child's awareness. 'But gradually you developed a sense of yourself as distinct from your mother, as different from the shadows on the wall, as owner of feelings rather than as the feelings themselves. This sense of yourself, this discovery that you're an "I" in relation to others, this experience we've called the ego. Whatever our school of thought or interpretation, we depth psychologists agree that the ego starts out in the undifferentiated paradise at the centre of the map of the soul and then moves, as it grows stronger, to the circle's edge.'

'I see a parallel with our most cherished buildings,' notes the child. 'The centre is where we start from and what we hold dear. The edge of the circle is a boundary which contains the centre. And the ego, that part of me which is more or less conscious, can look either to my inner centre or to the outside world beyond the circle.'

'You're precocious indeed,' the woman responds. 'You've got it. You understand the map. You're aware of your own experience. You haven't swept it under the carpet.'

At this point the child feels terribly proud of himself. The depth psychologist is aware of his pride. In fact, she uses his pride to illustrate the next phase of the soul's map.

'What happens when you feel so proud of yourself for grasping such a difficult experience? Do you feel you could conquer the world?'

'Well, now that you mention it, yes.' I feel as though I had just sailed the seven seas and had claimed new territories for my king. He'll reward me and give me a noble title!

'And therein lies the danger,' says the woman, as calmly as possible. 'Without intending to do so, you've just described what depth psychologists call the inflated ego: the "I" that feels unbounded, the "I" that thinks it can conquer everything in sight, the "I" that is blinded by its own apparent power. When your ego is inflated, you forget its source. You forget your own developmental history. You forget your bear. You forget your treasures. You forget to contain them. The all-powerful ego is Prometheus, who stole fire from the gods without foreseeing the consequences.'

'But I know what happened to Prometheus: I just read a book about the Greek myths. His pride led to suffering on a daily basis. An eagle pecked away at his liver, day in and day out.' The child is clearly not unaware of his cultural history.

'I'm very glad you recalled Prometheus,' the depth psychologist says. 'We don't concoct myths to explain what we don't understand scientifically. We receive myths from dreams, from visions, van moments of insight. And the myths tell us as much about the nature of our experience as any scientific experiment can tell us. But why stop at Prometheus? Why not continue on to a mythical encounter which is even closer to our own culture?'

'Yes, I'd like that,' the child admits, now more curious than ever. 'What have you got in mind?'

'Malachi, the minor prophet whom Handel and, in our day, Mark Helprin (1977), acclaimed as a major prophet. You know what he said? "Return to me, and I will return unto you." And you know whose voice said it? The voice of the living God.'

'Wait just a minute,' the child cries. 'I thought we were learning about architecture—the architecture of built and bounded space, and the derived architecture of the soul. Why are you bringing faith into the picture?'

'Because,' the depth psychologist explains, 'faith is larger than a particular tradition of faith. Faith is an experience which we all share, even if we've been coached and educated to dismiss it. The voice that challenges us to return is none other than the treasure which dwells at the centre of our psychic map. The voice was present before our ego developed. And the voice always has the last word.'

'How in the world can you be so sure?' asks the child. He's not entirely puzzled: his intuition gives the woman the benefit of the doubt. His memory begins to blossom. He almost understands the point the cartographer of the soul is trying to make. But not quite.

The woman continues. 'Perhaps I can clarify the map of the soul better if I quote one of the pioneer mapmakers. Jung recorded that not one of his clients during the second half of his life regained his equilibrium before he rediscovered what Jung called a religious attitude. The prophet's words sum up that attitude better than a whole book of words could do. In psychological terms, the ego rediscovers its role in life, gets back on its given path, comes home to its rightful house when it acknowledges and remembers it's not a god. The healthy ego recalls its humble beginnings in the undifferentiated paradise of unconscious life. It recalls its centre and its source. It remembers its origin. And its origin is at the centre of the depth psychological map. Call it God, call it the source, call it the living centre, call it the Other before the ego learned to distinguish itself from an Other. Call it the treasure which architecture throughout history has sought to contain, to set off, to consecrate.'

The child is still. After a rather long silence he associates the map with a story he's heard, a story he only partly understands. Not entirely sure of himself, he dares a question nonetheless. 'Are you talking about an offer?'

The depth psychologist is stunned by the child's inherent wisdom: she can't reply immediately. But the architectural historian, who has been listening attentively all along, is less reticent. 'I can't think of a better way to describe the attitude that led to our most enduring buildings and towns. The architect—if indeed there were an architect—and the builders were not

primarily interested in power or personal gain. Neither were they building only for themselves. They were building for the whole community. The cathedral, the palace, the covered market, the town walls were for everyone to enjoy.'

'I understand,' adds the child. 'But that's not entirely what I meant by an offer. I was thinking more of what went on in the soul of the builder while he was building. I was thinking of the map of the psyche. If you build as an offer, then you're honouring the centre of the map. Your wages and your own pride are not your chief goals. I know this attitude, this stance: I know it when I'm playing. When I play, I'm not concerned with accomplishing something, with proving myself, with being evaluated. I let my ego go, just as I let my bear go, only to find him again. When I play, I come home: I come home to a full house.'

Now it's the historian who needs a moment of silence. This child is wise indeed. Or perhaps he hasn't succeeded in learning to be dishonest. He's seeking the truth, and the truth has set him free.

'You know only too well,' begins the historian, 'that our world is more than a stage we can play on. It's also a battlefield, a marketplace, and a laboratory. It's a factory too, and not just a factory where we make things and perhaps turn the workers into machines: our world is a factory of ideas and concepts as well.'

'I follow you,' assures the child. 'Do you mean that sometimes this factory of ideas gives us other attitudes than the experience of an offer?'

'That's exactly what I mean,' says the historian behind a broad smile of appreciation. 'And the best way I know to explain it is to hold the map of the soul next to the map of history, next to the record of countries invading other countries and new technologies which conquer and replace old ones. When we invade another country, we acquire land which really isn't ours. It's just like the experience of the ego when it steals territory that previously belonged to the centre. The ego then fancies itself as centre. It knows no bounds. It has no need of other people or other dreams. It has no need of gods or treasures. It races on, beating everyone and everything in sight.'

'I need to take stock,' declares the child. 'I think I grasp the difference between building as an offer and building chiefly for personal gain. I know the distinction too between a building that belongs to the whole community, that nourishes every member of the community, and a private castle hiding behind guarded gates. And I've seen more than enough shops and malls along endless roads where people fear to tread outside their cars. It's as though everyone forgot about the community. And not only that: it's as though everyone forgot how to play, forgot his own history, forgot his own path of psychological development. It's very sad. But it's more than sad: if the map of the soul's development is accurate, then the buildings and towns we've built recently don't suit us at all. They are like clothes of the wrong size. They're too hot in summer and too cold in winter. They have very little to do with who we really are. Besides that, they make me forget how to play.'

'Yes,' say the historian and the psychologist in one breath. 'We're racing along toward a goal that cannot possibly be our true home. "The falcon cannot hear the falconer." (Yeats, 1977)'

'What is to be done?' the child demands.

The historian pauses for a moment before trying to answer the child's question. The more he reflects, the more he sees the two maps, side by side: the map of our built world and the map of the soul. He clears his throat and looks straight into the child's eyes to make sure he's listening.

'It seems to me we can take two routes that lead to reconstructing a full house, a house we all recognise as home. One route is clearly marked on the map of the literal townscape. Taking this route we can work to change building codes, we can try to organise the building trades and the money lenders in a more healthy way. We can build buildings which both we and our clients feel truly at home in. And once we've peopled even a small part of the world with full houses, more and more people will want to live in them. It may be a long battle, but the presence of a real building or a real town may convince us far more effectively than words.'

'And the other route?' interrupts the child, just as curious now as when the conversation began.

'The other route is printed on the map of the soul. That makes it difficult for everyone to see clearly, but since we've already experienced it in our own development, it can't be terribly unfamiliar. Following the other route,' the historian continues, 'requires at first no action in the outer world at all. It simply means giving ourselves the chance to be still, to reflect, to remember. Are we builders? We'll ask ourselves why we're building, what we're building, and whom we're building for. Are we architects? We'll ask ourselves not just what we think we want, but what we need, what our souls need. Are we town planners? We'll ask ourselves if the laws we uphold truly help people to live in a house that suits them, in a house they can play seriously in.'

The child grows slightly impatient. He wants to make sure he understands the paradox of following two routes on two different maps simultaneously. He wonders which route comes first. He has no difficulty seeing buildings and towns which give him a feeling of joy, but he's not so clear about the change in attitude which the psychic map offers. 'Can you draw the inner route for me so that I can see it distinctly?' he asks.

The historian obliges him. 'I can try. Remember your experience with your bear? Remember building towns with your blocks? Remember your dreams? The way you played with them was the way of analogy, the way of synthesis, the way of regarding your toys, your family, your whole world as enchanted. Everyone in the world knows this way, because everyone has been a child. And a child does and builds what suits him.'

The child can't resist interrupting again. 'I'm not sure I know all those adult words—analogy and synthesis.'

'That's all right,' the historian reassures him. 'You know from experience what I mean. From playing you know that a thing is never only a thing, that it's always alive. You can engage it in conversation, and it answers you. You know too that time falls away when you're playing: you don't have to meet deadlines, you don't consult the digital clock every ten minutes, you don't reflect on yesterday or plan for tomorrow.'

'That's true.'

'But something began to happen in the Western World several hundred years ago. People challenged their leaders, who had often treated them as slaves. Perhaps the Enlightenment wasn't the first step; perhaps the change was growing gradually; perhaps its seeds were planted long before. The exact time is not what's important; what matters is that we discovered new ways of building and fighting, new ways of thinking and believing, new ways of making things and selling them. More and more we forgot the past we all share, our own past as players. More and more we learnt not to synthesise but to analyse, not to build but to dissect, not to dream but to control. We're still in this developmental period now. We haven't yet discovered how to combine the new visions and the new techniques with our own human nature, our own development as players.'

The child doesn't need to know all the supposed facts of history in order to grasp the history of a quite radical change—in attitude, in a way of being, in a way of regarding other people and things in the world. An image of the psychic map has stayed clearly in his mind. He sees Ego dressed as a relentless Napoleon, conquering not only the territory outside the circle but confiscating its inner, holy centre as well. The child knows this attitude doesn't suit him, because it keeps him from playing.

The historian senses it's time to bring the conversation to a close—not forever, but for the time being. 'Our conversation began,' he reiterates, 'when you asked why we so often don't build the buildings and the towns which suit us. We've all tried to understand how the history we've inherited is at odds with our natural history, our history of development. To make things simpler than they actually may be, we've drawn two maps to help lead us to a house that suits us, to a full house we can play in adequately. We've discovered we need to follow both routes: one in the outer world of action and one in the inner world of reflection, of remembering who we are and

how we became who we are. Fighting ill-suited laws, changing the organisation of the building trades, actually building joyful towns and buildings: they require an offer because the route is anything but smooth. Honouring the central court on our psychic map demands an offer too: your ego may be frightened of relinquishing its power, but if it remembers the joy of playing, then it can offer itself quite easily.'

'Yes,' the child responds. 'Two routes on two maps. But aren't the two maps really one single map? How can you separate work and play, action and reflection?'

'We can't. And we don't need to,' the historian reminds him. 'All we need is a song, or perhaps a poem that will sing itself within us. We need a song to remind us that our buildings contain not only furniture and machines and people: they contain our souls and their centres as well. And if the arrangement of spaces we build fails to contain our treasure, then we need to build different buildings and towns.'

'Yes, yes! Give me a song. Give me a song that reminds me how to play again. Give me a song that will help me build buildings that suit us when I grow up. Give me a song that will give me courage.'

The historian thinks neither long nor hard. The end of a poem starts to play resoundingly in his mind. 'Why shouldn't we sing it?' he asks himself. 'Why shouldn't it sing us?'

'The song,' he gently tells the child, 'is a poem which grew in the mind of Cesar Vallejo (1974) during the dark night of the Civil War in Spain. It's not only about that war. It's not only about the map in the outer world. Neither is it only about a change in attitude belonging to the map of the inner world. It unites them both. Here, I give you Vallejo's song:

si la madre
España cae—digo, es un decir—,
salid, niños del mundo; id a buscarla!

if mother
Spain falls—I tell you, it's just a thought—,
Out, children of the world; go and search for her!

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