



Review

Assessing Alexander's Later Contributions to a Science of Cities

Michael W. Mehaffy

KTH Royal Institute of Technology, 114 28 Stockholm, Sweden; mmehaffy@kth.se or michael.mehaffy@gmail.com

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Abstract: Christopher Alexander published his longest and arguably most philosophical work, *The Nature of Order*, beginning in 2003. Early criticism assessed that text to be a speculative failure; at best, unrelated to Alexander's earlier, mathematically grounded work. On the contrary, this review presents evidence that the newer work was a logically consistent culmination of a lifelong and remarkably useful inquiry into part-whole relations—an ancient but still-relevant and even urgent topic of design, architecture, urbanism, and science. Further evidence demonstrates that Alexander's practical contributions are remarkably prodigious beyond architecture, in fields as diverse as computer science, biology and organization theory, and that these contributions continue today. This review assesses the potential for more particular contributions to the urban professions from the later work, and specifically, to an emerging “science of cities.” It examines the practical, as well as philosophical contributions of Alexander's proposed tools and methodologies for the design process, considering both their quantitative and qualitative aspects, and their potential compatibility with other tools and strategies now emerging from the science of cities. Finally, it highlights Alexander's challenge to an architecture profession that seems increasingly isolated, mired in abstraction, and incapable of effectively responding to larger technological and philosophical challenges.

Keywords: Christopher Alexander; The Nature of Order; pattern language; structure-preserving transformations; science of cities

1. Introduction

It has been widely acknowledged, even among his most hostile critics, that Christopher Alexander was one of the most influential architectural theorists of the second half of the 20th Century [1–3]. The author of *Notes on the Synthesis of Form* [4], “A City Is Not a Tree” [5], *A Pattern Language* [6], and other seminal works, is undeniably well-cited by other scholars; at this writing, his book *A Pattern Language* holds 11,608 citations on Google Scholar, far exceeding most other works of architecture [7]. There is also evidence that his ideas have also deeply affected many other architects. For example, according to the Pulitzer prizewinning architecture critic Robert Campbell, Alexander “has had an enormous critical influence on my life and work, and I think that's true of a whole generation of people” [3]. Alexander has also had a remarkable influence among notable figures across disparate fields, including sociologist Richard Sennett [8], Agile co-developer and Wiki inventor Ward Cunningham [9], *The Whole Earth Catalog* publisher Stewart Brand [10], developer of software hits *The Sims* and *SimCity* Will Wright [11], and musicians Brian Eno [12] and Peter Gabriel [13], to name only a few.

Among scholars of an emerging “science of cities” in particular, Alexander's work is also readily acknowledged. About “A City Is Not a Tree,” UCL's Michael Batty has asserted, “Fifty years on from his path-breaking article, there is now recognition that the kind of complexity and diversity he was alluding to is an essential feature of urban living” [14]. Luis Bettencourt, formerly of the Santa Fe Institute and now the University of Chicago, has similarly argued that “By setting a new course for

architecture, Alexander almost single-handedly placed its questions among the great mysteries of the universe and offered its perspectives as new starting points for scientific enquiry. Thus, “A City Is Not a Tree” is the beginning of a unified science of cities and of a dialogue between the city as a natural phenomenon and other complex systems” [15].

Yet Alexander’s early 21st Century works, particularly the four-volume magnum opus, *The Nature of Order: An Essay on the Art of Building and the Nature of the Universe* [16], have received far less attention. Indeed, *The Nature of Order* scores less than 1000 total citations on Google Scholar (the sum of all citations for its four separate volumes). One problem, according to Michael Batty’s UCL colleague Stephen Marshall, is obvious: “The length—and expense—of the books must surely disadvantage their popularity. The work would pack more punch if the essential messages could be summarised in a much shorter volume” [17]. Indeed, several other authors have sought to summarise the key material in a shorter volume, including Alexander’s co-editor Nikos Salingaros [18] and former collaborator Jenny Quillien [19].

The Nature of Order also provoked an early and hostile reaction in mainstream architectural publications, no doubt attenuating its readership. For example, a widely-circulated book review in *Architectural Record* by William Saunders, then editor of *Harvard Design Magazine*, savaged the work as “a self-deceptive, sloppy, ill-informed, and numbingly repetitious book full of contradictions, foggy generalities, and extreme and unsupported assertions” [20]. Perhaps worse for Saunders, as he later wrote in his own magazine, Alexander’s overall approach today “has little ‘cultural capital,’ particularly in architecture schools in which newness, art, and complexity are valued, and belief in timeless and universal human needs is considered naïve” ([20], pp. 1–2). According to this view, it appears, the man is simply irrelevant.

It is of course difficult to reconcile this view with Alexander’s earlier prominence. One possible explanation is that Alexander started his career on a solid academic and scientific footing, but then veered into a fringe realm of solipsism and pseudo-science, offering only sloppy new-agey ideas without scientific rigour. Indeed, Saunders and others did seem to support that view.

In this review, I aim to show that on the contrary, whatever the defects of *The Nature of Order* in length, editing, or other respects, it represents the clear culmination of a remarkably consistent corpus over a long career. The evidence will show that Alexander’s work is in fact a straight line from his days as a Cambridge (UK) physics student, in which he has dealt with precisely the same topic throughout: the ancient philosophical subject of *mereology*, the relation of parts to wholes. His work sought to develop useful new design tools to affect the genesis and transformation of these parts and wholes toward more successful results, from a human point of view. Evidence for his success—including that of his later work—comes in large part from the useful application of his ideas by many other designers and investigators in fields as disparate as computer science, engineering, organisation management, service design, educational curriculum, biology, and a dizzying number of other subjects. Further evidence comes from the parallels to the work of other philosophers on contemporary problems of knowledge, technology and design, and tantalising hints of useful progress on offer for these problems.

After an essential summary of Alexander’s early work leading up to *A Pattern Language*, we will turn to the distinct contributions of *The Nature of Order*, exploring some of the philosophical parallels, and the ancient and contemporary human problems (like those of mereology) for which he proposes solutions. Although Alexander has himself been surprised (as he admits) by the philosophically challenging results of the work described in *The Nature of Order*, I will show that they are in fact closely related to the findings of a number of other philosophers and scientists—a comparison that Alexander himself was never particularly interested in making. The paper will then conclude with a preliminary assessment of the relevance of Alexander’s later work to an emerging science of cities, developed in part by Batty, Bettencourt and others.

We can also note that Alexander’s long career, spanning from Gropius’ 1950s Harvard to the digital world of Wikipedia that he helped to shape, reveals as much about the modern history of planning and architecture, and the philosophical issues hardly confronted, let alone resolved, as it does

about Alexander's own diverse, often difficult, but (as evidence presented here will show) still-useful and relevant corpus.

2. Early Work: 1950s to 1977

After studies in physics and mathematics at Cambridge (UK), Alexander turned his attention to architecture, getting the first (and to date only) PhD in architecture at Harvard. He published his thesis soon after as his first book, *Notes on the Synthesis of Form* [4]. The book enjoyed a wide readership beyond architecture, and was said to be required reading for researchers in computer science throughout the 1960s. It was also said to be influential for a generation of architectural theorists including Lionel March and Horst Rittel [21].

Similar to Herbert Simon's classic paper from around the same time, "The Architecture of Complexity" [22], *Notes* addressed the problem of design as a question of part-whole relations. Both sought to map the structure of that relationship, so that it could be better exploited by designers in a cybernetic age. Both found roughly hierarchical structures, which Simon referred to as, "nearly decomposable hierarchies." For Alexander, that "nearly decomposable" aspect was key: the connections that did not obey the neat hierarchy turned out to be especially important.

As Alexander put the challenge; how does a designer develop a successful configuration out of the set of elements identified in a design program? At one time in human history, this could be done through a direct, intuitive, "unself-conscious process", as he termed it. However, in the current age, with its myriad variables and technological formalism, this would have to be done through a "self-conscious process." His concern was to outline the essential features of such a methodology, so as to aid designers in their task. The challenge was really to recapitulate the exquisite good fit that was readily observable in so many traditional designs—in contrast to too many modern designs, whose failures and inadequacies, he noted, were becoming painfully evident.

Similar to Simon, Alexander saw that the parts of a design problem tended to relate to the wholes through a hierarchical relationship: parts have sub-parts, and the sub-parts have sub-sub parts, and so on. Simon used the phrase "nearly decomposable hierarchies," noting that these structures were not perfectly hierarchical, but only "nearly" so.

For Alexander, even more than for Simon, this was a key insight. These non-hierarchical relationships, these "overlaps", and web-network aspects provided crucial characteristics of the structure. That insight was the central point of his widely discussed paper of the following year, "A City Is Not a Tree". The "tree" to which he referred to was a mathematical hierarchy of parts and wholes, with wholes composed of parts, themselves, wholes composed of sub-parts and so on (Figure 1). As Alexander pointed out, it can be a profoundly limiting structural relationship:

Whenever we have a tree structure, it means that within this structure no piece of any unit is ever connected to other units, except through the medium of that unit as a whole. The enormity of this restriction is difficult to grasp. It is a little as though the members of a family were not free to make friends outside the family, except when the family as a whole made a friendship. ([5], p. 15)

By contrast, what he termed a "semilattice"—what we would today call a complex network [23]—had overlap, redundancy, ambiguity, and interactive relationships (Figure 2). For a city, this was an essential feature of its dynamism, its complexity and richness:

It must be emphasized, lest the orderly mind shrink in horror from anything that is not clearly articulated and categorized in tree form, that the idea of overlap, ambiguity, multiplicity of aspect and the semilattice are not less orderly than the rigid tree, but more so.

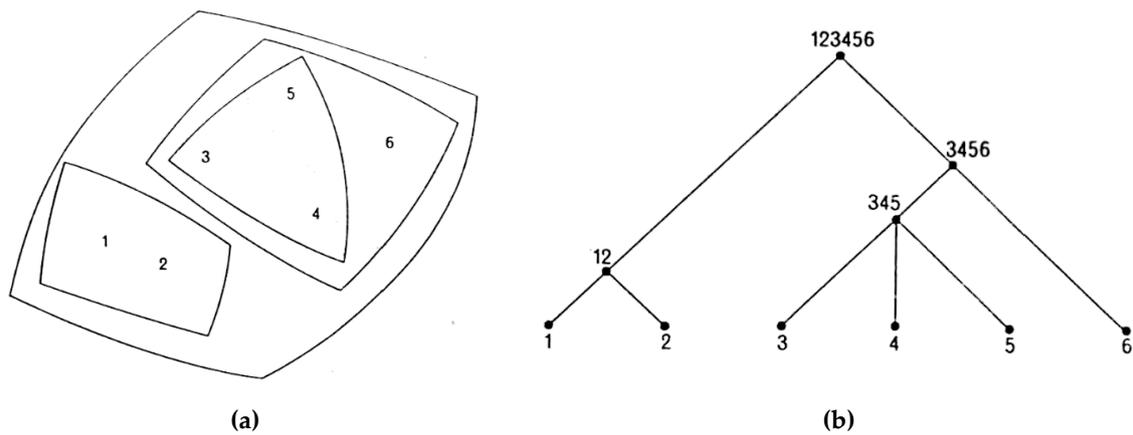


Figure 1. Alexander’s figures from “A City Is Not a Tree” [5] illustrate what he means by a “tree”, or a hierarchical structure segregating elements into well-defined sets without overlaps. Each category has its own distinct branching sub-categories, shown as a set diagram in (a) and a network diagram in (b).

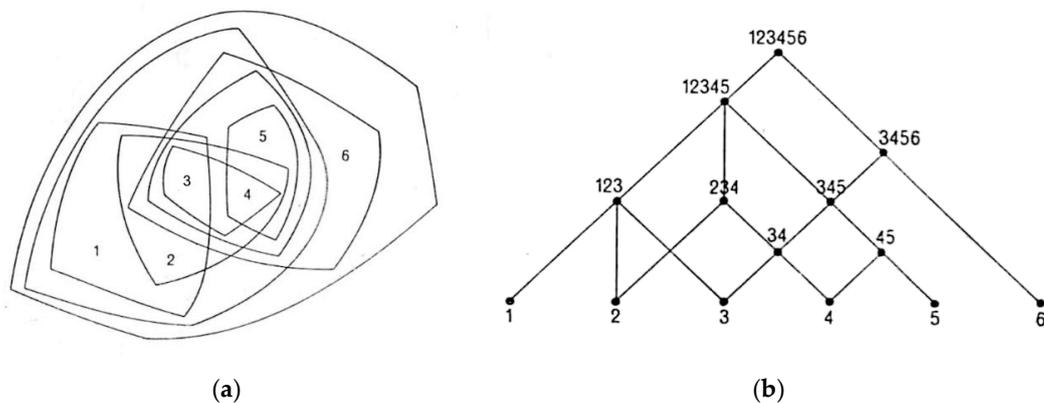


Figure 2. Subsequently in “A City Is Not a Tree” Alexander illustrated how a “semilattice”, or what we would now refer to as a complex network [23], has interconnecting or overlapping sets. Again, this is shown as a set diagram in (a) and a network diagram in (b). While this may seem messier, he said, it is actually a “thicker, tougher, more subtle and more complex” kind of structure, with greater internal connectivity. This structure is actually more closely related to many natural structures, including natural cities.

In that sense, Alexander was going beyond Simon in pointing out the crucial structural overlaps of the “nearly decomposable” web-network, and in drawing key lessons for the optimal functioning of designs, including the design of cities. However, as Alexander noted, contemporary city planners were not yet heeding that crucial message. The problem was, in large part, in the way they conceived of the design problem; an insight for which he drew more from cognitive psychology than from mathematics. The mind, he noted, tends to default to these more easily managed mental categories—and for planners, that meant dealing too much with tree-like plans:

It is for this reason - because the mind's first function is to reduce the ambiguity and overlap in a confusing situation and because, to this end, it is endowed with a basic intolerance for ambiguity - that structures like the city, which do require overlapping sets within them, are nevertheless persistently conceived as trees. ([5], p. 28)

However, for cities this can be immensely destructive:

The city is not, cannot and must not be a tree. The city is a receptacle for life. If the receptacle severs the overlap of the strands of life within it, because it is a tree, it will be like a bowl full of razor blades

on edge, ready to cut up whatever is entrusted to it. In such a receptacle life will be cut to pieces. ([5], p. 32)

“A City is Not a Tree” became one of the seminal planning criticisms of that era, joining Jane Jacobs’ *The Death and Life of Great American Cities* [24] and other works to shape the thinking of a new generation of urban and architectural reformers. Among other impacts, it had the result of slowing the development of so-called “new towns” as well as tabula-rasa “urban renewal” projects.

We might well pause here to ask whether the deeper lessons of “A City Is Not a Tree” were truly learned by planners and architects, then or since. Certainly, we can see many developments around the world today that continue to be segregated into tree-like components, that are rather lifeless creations of their architect-artists, meant to be admired as gigantic sculptures, but hardly lived in, shaped by transformative acts of overlap, ambiguity, and vitality in self-organisation. Mostly we are supposed to passively admire the static works of a technical and artistic priesthood of makers.

Meanwhile, Alexander noticed an intriguing feature of the scheme he called “the diagrams.” Due to the overlaps, and because of the fact that some elements were connected by “strong forces” and some by “weak forces,” it was possible to identify clusters of elements that were in fact sub-units—if overlapping ones—of the environment. As he described in the preface to the ten-year anniversary edition of *Notes*, he came to refer to these sub-units not as diagrams, but as “patterns.”

Part of his insight came from his own work in computer programming. Using a computational process to model the synthesis he was describing, he noticed that amid the unwieldy torrent of data, he saw recurrent patterns containing the same repeated clusters of elements, forming the same partial sub-solutions to a design problem. Perhaps these patterns could simply be abstracted, he reasoned, and re-combined in useful ways, while still preserving the essential contextual, web-network structures of the patterns. This was a breakthrough.

Another breakthrough was that Alexander came to recognise an important relationship to language in his finding. The beauty of the scheme was that the sub-units could be combined, much as the words of a sentence could be combined in a language-like way. Just as language allows ambiguity and overlap, and the capacity of, say, poetry, so this “pattern language” might also allow a more poetic combination of design elements than the previous generation of list-like specifications.

This was in fact a uniquely innovative mereological scheme, a way of exploiting the power of language structures to combine and to build up greater wholes, applying the same compositional benefits to the world of design and to the built environment, where they were heretofore woefully absent. We were getting the mathematical deadness of “tree-like” laundry lists before, gussied up in the improvised costumes of architect-artists. Now we might get the actual poetry of a literate environmental language once again.

This application of what he called “pattern languages” was not meant to serve as an automated system of design—Alexander soon disavowed “design methods”, the field he helped to inspire—but a technological tool to guide designers in a more fluid, human process, helping to ensure that the sum of individual bits of design formed a more coherent whole. Once again, the question was how parts could be organised through design to form more coherent wholes, not how wholes could be made mechanically out of regimented parts, however alluringly packaged by architects.

The recognition of the language-like web-network of patterns (Figure 3) was a major advancement in Alexander’s thinking, and it prompted another insight. Perhaps human beings had already been employing something like a “pattern language” in traditional cultures, developing a web-network of extremely well-adapted elements. Indeed, he observed, apparently humble vernacular buildings were in fact remarkably complex and well-adapted to their challenges from a human point of view. Perhaps something like this adaptive process, supported by language, was deeply rooted in the actions of builders, as they went about shaping their own environments in the past. Perhaps this language-like structure—this wholeness in relation to parts—was not something he invented, but something he recapitulated; something actually rooted in the nature of things. (As Alexander once told me, “I thought I had invented something, but I realised actually I had discovered something.”)

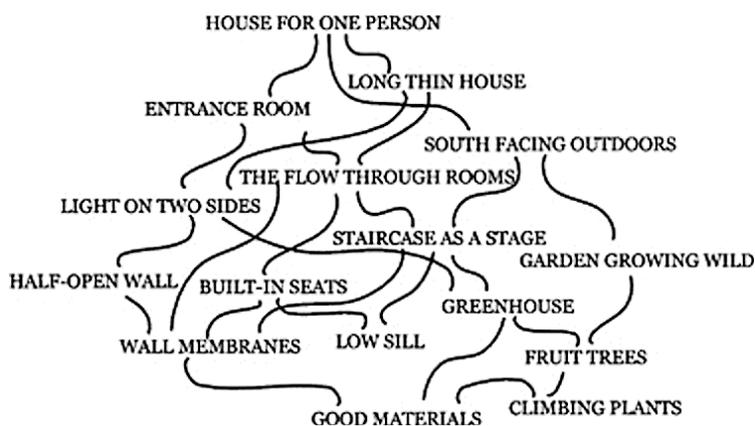


Figure 3. An illustration from Alexander’s *The Timeless Way of Building* [24], showing how the patterns within a language are connected through an overlapping web-network structure, similar to the one described in “A City Is Not a Tree” [5].

Alexander and his colleagues published *A Pattern Language: Towns, Buildings, Construction* [6], an initial volume of 253 patterns in 1977, together with a companion volume describing *The Timeless Way of Building* [25], describing the organic, piecemeal process by which we once engaged (and could engage again) the generative power of language.

3. The Nature of Order, 1977–2003 and Since

The popularity of *A Pattern Language* among a wide audience (well beyond architects) was certainly remarkable, and gratifying to Alexander and his colleagues. The aforementioned William Saunders noted that it “may be the most-read architectural treatise of all time” [1]. Many do-it-yourselfers did purchase the book, using it to build their own homes and other structures. However, Alexander was dissatisfied to see that many of the resulting structures did not have the wholeness he had hoped. As he later told me, he came to feel that he had not dealt with the problem of geometry sufficiently—that the wholeness he sought in relation to parts must occur within the geometric configurations of space [26]. That set Alexander on a 25-year project to explore wholeness in the geometries of space, culminating in the publication of *The Nature of Order: An Essay on the Art of Building and the Nature of the Universe* [16].

The next section will summarise the most distinctive ideas of *The Nature of Order*, assessing their philosophical antecedents and progress made in resolving current challenges. From there, we can briefly assess progress made in other fields with these and related ideas, before returning to the question of specific contributions for a science of cities.

3.1. Adaptive Morphogenesis

Alexander devoted a great deal of the discussion in *The Nature of Order* to the process of creating particular geometric structures in the built environment, applying an evolutionary adaptive process of the sort outlined previously in *The Timeless Way of Building*. This account should be familiar to anyone who is acquainted with the literature on complex adaptive systems. What Alexander did uniquely was to tease out specific insights and methodologies for architecture, urbanism, and design in general.

Moreover, Alexander saw, and drew lessons from, an intimate relationship between the structures of the human environment and the structures of the natural world. By studying natural structures, and the form-generating processes that created them, we could apply specific lessons to our own structure-generating processes—where they had gone wrong, where they may have gone right, and the specific tools and strategies we could distill from that process. In particular, Alexander saw capabilities in natural form-generating processes that were superior to current human technologies, and that therefore could offer helpful lessons for the improvement of human design and construction. (In this respect, he foreshadowed more recent work in the fields of biomimicry and biodesign).

Specific tools and strategies were discussed in the book, along with prototypical tests and results, although as Alexander acknowledged, they were all, to varying degrees, in need of further development. Among them were “generative codes” (for shaping a group output); “mirror of the self” (for making stepwise design evaluations and decisions); “sequences” (which might be thought of as patterns of process); and “procedures” (combinations of diagnostic and prescriptive sequences applied through a step-wise process, much as a doctor would conduct a medical procedure).

In addition, Alexander saw the structuring of the human environment, as an instance of nature itself at work, and as such, a suitable research subject for a deeper experimental understanding of the universe, its structures and processes. Just as architecture is informed by the sciences, and by the philosophy of science; so too, Alexander believed, architecture can be a proper research subject to inform the sciences on topics of structure, complexity, and mereology. This was in part why the book was subtitled “An Essay on the Art of Building and the Nature of the Universe.”

Once again, we see Alexander the mereologist, drawing conclusions about the nature of part-whole relations and their operations by human beings. Once again, we see that Alexander was hardly the first in the line to develop this topic. Perhaps the most obvious parallel (and one of the oldest) is to Aristotle and his “hylomorphism,” that is, his theory of matter and form. For Aristotle, matter at one scale becomes form at a higher scale, in turn becoming matter at the next scale. Aristotle even used an analogy from the built environment: clay is matter that becomes the form of bricks, whereas bricks are matter that become the form of a house, and so on. In turn, houses are matter that create form in a city, and so on and so on [27].

This brings us back of course to Simon’s “nearly decomposable hierarchies”—or Alexander’s “trees” and “semilattices.” Clearly Alexander has added something to this very old equation, as we can now see: the language-like structures of ambiguity, overlap, and endless generativity, through a particular kind of web-structure with its own web-processes. We can now begin to employ these insights to create particular forms and geometries, and compare them to those of natural and ancient human structures, with their remarkable capacities and effects, to learn new lessons and perhaps exploit similar benefits.

3.2. Space as a Field of “Centers”

The first step in this spatial mereology is to get a handle on the units of space—what Alexander referred to in a previous paper as “the atoms of environmental structure” [28]. For him, these units were “centers” (sic), identifiable nodes of relationship in space that have a salient clustering relationship with other nodes. This was an essentially contextual picture of structure, or more properly what has been termed a “scientific structuralist” perspective. There is also a close parallel to what has been termed a “structural realist” view, perhaps best described by Russell [29]. We might say that, while structure is “all there is,” and reality has no mysterious “nature” underlying its observed structure, nonetheless this structure is itself mysterious, synergistic, and in some primordial sense, alive.

Perhaps the closest modern philosopher to this point of view is Alfred North Whitehead [30,31], whom Alexander cites at several key points in the book. For Whitehead, the universe consists of “actual entities” or “actual occasions” that are bound up in a relational system that is always in process, always emerging from its precursors. Life itself is emergent from these structures, and to some degree immanent in them.

Again, what Alexander has added to this picture is a focus on the specific processes of the built environment, and how they might transform regions of space. Turning to a phenomenological perspective, he catalogued “15 properties” that seemed to characterise consistent groupings of “centers” (sic) in nature, at least from the point of view of human experience. We might think of them as 15 “patterns” along the lines of *A Pattern Language*, but this time not of specific design configurations, but of the most salient classes of geometrical relationships in our environment. Among them are structures that would be familiar to any modern mathematician or geometer: fractals (“levels of scale”), local symmetries, boundaries, alternating repetition, and so on.

These properties were not meant as specific methodological elements of design (“now use this property, now that”) but rather, as conceptual frameworks for honing the designer’s decision-making and sensitivity to the mereological results. The “15 properties” also have their counterparts in transformations that tend to produce the respective properties (and sometimes others)—for example, dividing, grouping, folding, symmetry-breaking and so on. By understanding how these processes lead to new structures, designers can be more attentive to contextual (and therefore often unpredictable) steps that bring them about.

3.3. Structure-Preserving Transformations

Alexander pointed out that a good-quality design is almost always in part a transformation of what existed before, rather than a “tabula rasa” creation of wholly new parts, however creatively imagined. In this respect, such a transformation preserves at least a part of the existing structure. This process is iterative, adaptive and continuous, as we can see in natural morphogenesis (Alexander provided many illustrative examples, e.g., Figure 4), as well as in traditional human design processes, helping to account for their often remarkably exquisite fit.

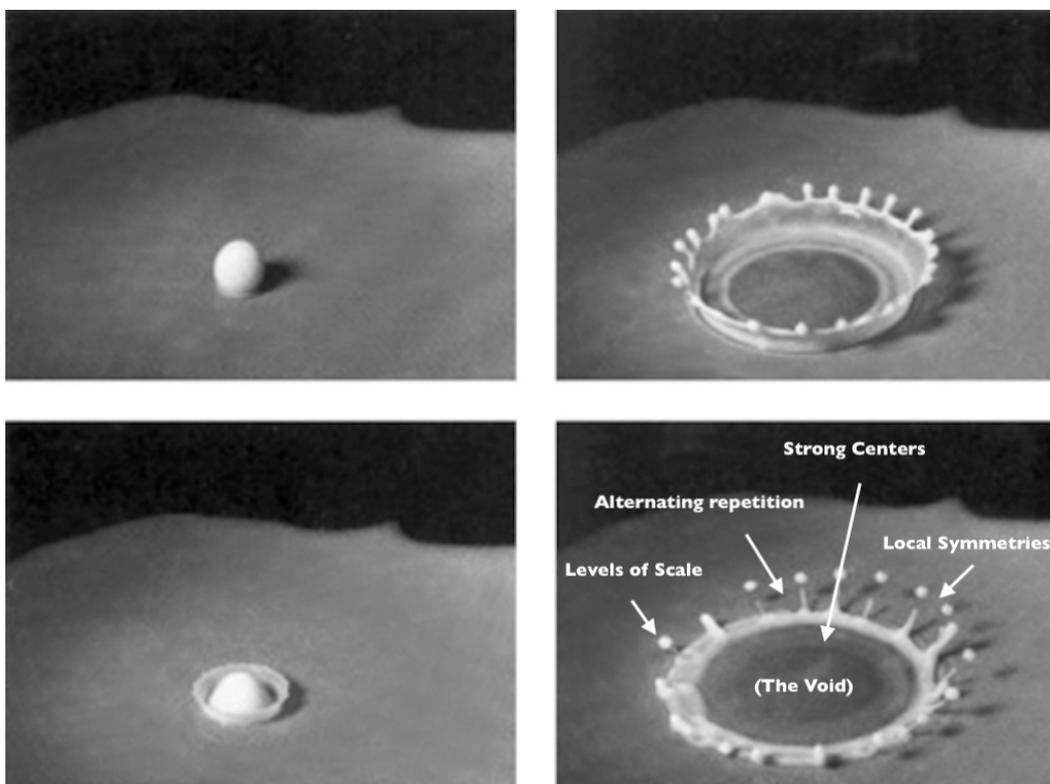


Figure 4. Alexander used this famous Harold Edgerton photo series of a milk drop to illustrate a “structure-preserving transformation,” in this case articulating new structures as the drop strikes a thin sheet of milk. This author has added labels identifying some of the characteristic geometric properties described by Alexander—strong centers, alternating repetition, boundaries, local symmetries and others. Alexander identified 15 categories to describe broad classes of these emergent properties, in nature and in human design. Original image © 2010 MIT. Courtesy of MIT Museum.

At this point, Alexander came even closer to Whitehead’s “process philosophy”, but again, this time with the designer’s interest in the hands-on details of the stepwise process, especially from a human and social point of view. A “maker” (designer, builder, artist, etc.) is immersed in a world of process in which the made result is never static, but only more or less permanent. The goal is to create a “preferred” outcome. This was very close to Herbert Simon’s famous definition of design as devising

“courses of action aimed at changing existing situations into preferred ones” ([32], p. 111). The focus was on the courses of action—the processes—and their relationship to the preferred results, as those are understood and achieved.

Similar to Simon, Alexander packed many new and important questions into that elegant definition. Who is doing the preferring, and on what basis? If a group, how do they agree—or can they? How do they know what steps will bring about that preferred result? What happens when it doesn’t? What happens when the preference changes, when the process opens up new possibilities? And so on. Unlike Simon, Alexander formulated at least partial answers to these questions, in the form of his mereological scheme—one that described structures arising as the result of human transformations in search of preferred human benefits—that is, of human value.

Alexander came to believe that the role of value and the qualitative could not be removed from the equation, for the simple reason that this is the aim of a “preferred” outcome, by definition. That is, it is preferred because a living human being prefers it and values it. This is the unavoidable a priori reality for any account of design as an empirical process, and any attempt to deny value, or to define it in positivist or mechanical terms, is a kind of abstract sleight of hand that only appears to make the problem go away. That value may emerge from structure is not to say that it can be reduced to a “psychological” phenomenon, or otherwise disposed of or ignored. For Alexander, as much as for Whitehead and others, value must be the foundation of all good empiricism.

3.4. “A Science of Qualities”

In this, we see Alexander the qualitative scientist, and we also see where many architects and positivists begin to misunderstand and discount him, levelling the charge of “pathetic fallacy” and even arrogant forms of absolutism and essentialism (as Saunders for one claimed). They should become more acquainted with the philosophy of science, and the current problems of subjectivity and “inter-subjectivity” that are of necessity being confronted in many fields including neuroscience, artificial intelligence, philosophy of mind, and many others. While Alexander was not careful to map his own ideas within these often-mature fields; indeed, he did seem unaware of and even uninterested at times in the similar work of others, he can hardly be called out for transgressing some well-established boundary into pseudo-science. On the contrary, he can be seen at the forefront of a lively topic in the sciences and the philosophy of science, along with many other investigators. Again, his unique contribution is to make the rare, and in some respects unique, trans-disciplinary connection to the structure of the human environment, with abundant structural examples and enticing insights.

One example of such a parallel philosophical account is provided by the biologist Brian Goodwin, a founder of theoretical biology and a founding member of the Santa Fe Institute, an interdisciplinary think tank dedicated to research in complex systems. Goodwin, who worked briefly with Alexander on a small design project, wrote and spoke extensively about the need for a “science of qualities” to inform the next stage of scientific progress [33]. He pointed out that this endeavour is well established within the history of science and philosophy, notably in the scientific contributions of Goethe and others. Goodwin also discussed the parallels between his ideas and those of Alexander in an interview with architectural historian Brian Hanson [34].

3.5. Holism

A key feature of Alexander’s account was the recognition of interdependent, system-wide characteristics that occur within every stage, and that we can only understand and account for as an entirety—a phenomenon more commonly described as holism. This is certainly not a new idea in science: in quantum physics, for example, it has been a preoccupation almost from the beginning, notably in the writings of Niels Bohr [35]. For Bohr, wholeness was closely related to the notion of phenomena as inseparable subject-object systems, which must be so regarded as an unavoidable next step in the advancement of science. Bohr’s observation has an intriguing parallel with Alexander’s more phenomenological approach to the design problem. Later proponents of this view of wholeness

include the quantum physicist David Bohm [36], ecologists like E.P. Odom and G.W. Barrett [37], anthropologists like Vincent Descombes [38], and philosophers like Hubert L. Dreyfus [39].

It is important to note that Alexander's concept of wholeness can be quantified and measured as a mathematical concept—a point made by the mathematician Nikos Salingaros [40] and by the geographic information scientist Bin Jiang [41]. Jiang has noted that wholeness occurs in a simple diagram provided by Alexander, in which a dot is added to a rectangular sheet of paper. In one sense, the dot breaks the symmetry of the sheet, with its regular borders. However, in another sense, the dots create new forms of order, new regions that are related to one another in a complex pattern that is inseparably whole (Figure 5).

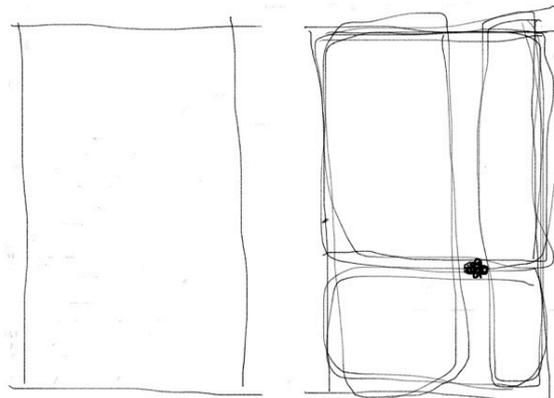


Figure 5. Alexander provides the simple example of a blank sheet of paper (left) with a dot added (right). This “symmetry-breaking” creates new regions within the rectangular piece of paper, which are overlapping and interrelated to one another within an inseparable geometric whole. (Redrawn by the author).

Once again, we see the uniqueness of Alexander's mereological contribution, as it is applied specifically to the act of design. Always at the core was the idea that good design is not a “tree” of elements working in a neatly reducible system, but rather, a contextual “semilattice,” a field of complex wholes within space, amplifying one another to form larger wholes. One cannot take this world apart and put it back together again mechanically, any more than one can take a cat apart and put it back together, and expect it to meow. The structure exists—perhaps lives, in a primordial but real sense—as an irreducible whole, full of web-like interrelationships and dependencies. One may be very precise about “diagnosing” (much as a doctor would do) the particular structure and condition of any part. From there one may develop tools to act on parts and wholes so as to achieve the preferred outcome, usually to “heal” them or make them more whole, but one must look carefully at the totality of the whole at every step.

3.6. *Panvitalism*

Since Alexander started with the empirical perspective of the investigator, he also found himself forced to accept the post-positivist premise that the life and lived experience of the investigator is a given, as is the life and lived experience of their fellow human beings, and others in the ecosystems that surround them and on which they depend. From there it is not too big a leap to regard the built environment itself as an extension of living systems, no less so than beehives or turtle shells.

Alexander took this idea one radical step further: like Whitehead, he accepted the premise that life is an immanent force in nature, which is shaped, amplified or suppressed by various forces—including the actions of human beings. The resulting “living structure” is a real thing in the world, no less than a human body. This is perhaps the hardest idea for more positivist-oriented investigators to accept in Alexander—what we might call “panvitalism”. For some it is too close to what they would consider a “pathetic fallacy”—projecting one's own subjective experience of life onto inanimate objects.

Yet Alexander was hardly the first to imagine what Whitehead memorably referred to as “Nature Alive” ([31], p. 148). Similar to Alexander, Whitehead saw, in the reigning positivist and mechanist conceptions of nature, confusion over the relation of facts and value, and a failure to recognise that facts are actually secondary abstractions, derived from (and necessarily presuming) the experience of valuation in the first place. “Matter matters,” we might say, because the force of a wall pushing against our fingers, or the effect of an electron stimulating a sensor visible to our eyes, informs our brains about the abstraction (created in our brains) of “matter”. In the first instance, and forever more, it “matters” to us.

For Alexander, this also meant that we cannot avoid the engagement of our own qualitative experiences and feelings about the world around us, as a primary foundation of design judgment. To do so is not a pathetic fallacy, but rather, an engagement of a highly evolved system of detection of those structural characteristics that most enhance our own lives, and the life around us. Nor can we ultimately make a fundamental distinction between the point of living systems and that of non-living ones, but rather, we must treat them as part of a series of larger wholes, proceeding inseparably up to the largest scales. (Indeed, this continuum is described in one of the “15 properties,” which he terms “not-separateness.”) The actual fallacy is to deny the *inseparable a priori* role of value.

While this view suggests a complex and ambiguous state of affairs, and one that Alexander referred to as “degrees of life,” it is not (as post-modernists and post-structuralists would suggest) arbitrary or self-invented. It connects us in an essential structural way to our own deeper relation to the rest of the world. It opens a helpful gateway to the shareable inter-subjective valuations of others, and indeed of larger groups and even entire societies. More particularly, it puts aright our connection to the made world of the maker, in relation to the secondary abstractions we make to do so—the ones in which we may become lost and confused, if we are not very clear on our basis of valuation. So we are, in too many cases today.

3.7. Synthesis

Alexander’s scheme, described over four volumes, went very far in uniting a number of these ideas. For example, we can increase the degrees of life within a structure by increasing the density of its centres. We can achieve this result by transforming such a structure, preserving and extending its wholeness. (In fact, he later referred to “structure-preserving transformations” as “wholeness-extending transformations.”) We must do this by engaging ourselves as inseparable observers and qualitative judgment-makers, relying on our own deeper connectedness to these larger systems, and our own subjective (and shareable, inter-subjective) experience of value, by us as humans and as living beings in the world. We can share these inter-subjective evaluations with others, since we and they share common connections to human experience and quality. We, and they, can participate in an enriching process of adaptive morphogenesis at many scales of time and space. We can do all of this with the various methods, tools and strategies that Alexander profiled along the way.

Far from a gauzy new-age theory of design, then, *The Nature of Order* offered another rigorous set of contributions on design as a *human* act—meticulously observed, carefully documented, and solidly anchored in well-recognised contemporary problems of science and philosophy. It was, as Industrial Design Magazine said about *Notes on the Synthesis of Form*, yet another book “about the art of design, what it is, and how to go about it”, this time much more deeply informed about the nature of geometrical form and process.

4. Potential Contributions to a Science of Cities

As we saw previously, Alexander’s ideas have already been successfully appropriated by many other practical researchers in fields as diverse as computer science, organisation management, engineering, service design, and other areas with a design focus. Much of this development began with the application of pattern language methodology to computer science, and so-called “pattern languages of programming”—or as they are also known, “design patterns.”

Less well known is that Alexander's deeper philosophical ideas about process, qualitative methods, inter-subjectivity, and holism, have also been embraced and applied by many in the computer science community—a group that is not known for its embrace of unworkable speculative methodologies. Ward Cunningham, one of the pioneers of pattern languages of programming, has said he was first and most deeply influenced by *The Timeless Way of Building*, and only later by *A Pattern Language* [42]. Cunningham went on to develop wiki (the basis of Wikipedia and other innovations) and was also a co-developer of Agile methodology, which in turn has had a widespread influence in management and other fields [9]. Alexander's later ideas in *The Nature of Order* are also frequently taken up in the annual computer science conference "Pattern Languages of Programming" or "PLoP", developed by Cunningham and others from "The Hillside Group" [43].

Other fascinating applications of Alexander's later ideas can be found in biology, probably none more so than a 2009 paper by Newman and Bhat [44] proposing a "pattern language" model for the evolution of multi-cellular life. Several years later, co-author Ramray Bhat wrote a paper comparing Alexander's ideas more directly to complexity in biological processes, in a paper titled "Understanding Complexity Through Pattern Languages in Biological and Man-Made Architectures" [45]. In his paper, Bhat did look specifically at the ideas of *The Nature of Order*, including the formulation of "15 properties" for which Bhat found many analogues in biology.

How then might we also apply these apparently fruitful ideas to the emerging sciences of cities? As Bettencourt suggested, Alexander has given us "the beginning of a unified science of cities and of a dialogue between the city as a natural phenomenon and other complex systems" ([5], p. 46). Here are several potentially fruitful topics from his later work.

4.1. City Evolution as a Comprehensible (and Modifiable) Emergent Outcome of Complex Adaptive Systems

Alexander described the detailed workings of rule-based algorithmic processes as they generate the form of cities, a process that he termed "adaptive morphogenesis". The individual actors (not only architects, but also many other participants) are "agents" in a kind of massive "cellular automaton," following relatively simple rules (created and modified by themselves) to produce a complex and largely self-organising result. If we can tease out these rules, we can make interventions to improve the outcome, following Simon's definition of design as "devising courses of action aimed at changing existing situations into preferred ones." (I am certainly not the first to point this out; for example, our colleague Besim Hakim has described this aspect of Alexander's work as well [46].)

Alexander's unique contribution to this subject was to propose a number of "courses of action" in considerable detail; project pattern languages, community mockups, generative codes, etc. We may question whether these actions are practical or even feasible at this stage; but we may also take the example of the earlier computer science developments as suggesting that others may well develop more practical methods along these lines into the future. Already a number of "early adopters" have begun using Alexander's methods in their own architecture firms and other enterprises, with tantalising if so far limited results. One interesting example is in the work of Kubala Washatko Architects of Milwaukee, WI, who feature resources from *The Nature of Order* on their webpage [47]. This author also uses a number of methodologies developed in *The Nature of Order* in international urban design and development consulting work.

4.2. Building Process as the Interaction of Multiple Distributed Agents

Alexander helpfully pointed out some of the actions among a variety of agents within city-building that generate form, or conversely, that constrain form, or cause its degradation into undesirable states from a human point of view—what he termed "massive process difficulties". One of these undesirable states is, for Alexander, the output of many contemporary architects, which he has often savaged. Some architects may take umbrage at the apparent certainty of his judgments as to the "undesirability" of much of modern architecture; but it is undeniable that many human beings who are not architects

do share his judgments, as he summed up memorably in an introductory passage of “A City Is Not a Tree:”

The non-art-loving public at large, instead of being grateful to architects for what they do, regards the onset of modern buildings and modern cities everywhere as an inevitable, rather sad piece of the larger fact that the world is going to the dogs. ([5], p. 1)

Of course, Alexander was hardly the first to note this disparity between the judgments of architects and laypersons. Indeed, the evidence for this state of affairs is abundant in the literature [48]. More importantly, Alexander did more than wring his hands. In that paper alone, he gave a quite precise mathematical account of the structural relationships that he believed had gone awry, namely, the overly segregated hierarchical “tree” structures of modern city planning. In *The Nature of Order*, and in the later book *The Battle for the Life and Beauty of the Earth* [49], he took this analysis much farther, examining the *processes* by which these structures are imposed, and the institutional systems by which this happens. These he summarised under the generic term “System B”—the institutional counterpart to the “self-conscious processes” of *Notes on the Synthesis of Form*, whereas “System A” was the institutional counterpart of the unself-conscious processes described therein. What we need, he concluded, is a transformation in the capabilities of this System B, so that it is able to produce the more satisfactory well-adapted form that he began to describe in his very first work. Again, he proposed many specifics, which again may or may not be fully feasible at this stage—but they do suggest promising potential for further development.

4.3. A Dysfunctional Relationship between Art and Science in Modern Cities

William Saunders’ earlier-referenced remark about Alexander’s alleged irrelevance unintentionally revealed a much greater problem within the siloed profession of architecture. His comment—that “in architecture schools... newness, art, and complexity are valued, and belief in timeless and universal human needs is considered naïve” ([20], pp. 1–2) stands in marked contrast with a science of cities that is concerned with the actual structure of form-generation and its measurable outcomes, including its impacts on human beings. Such a science has interests far beyond the parochial scale of specialist artist-architects and their efforts to create “newness” for its own sake, or what former Michigan Architecture Dean Doug Kelbaugh has criticised as “architectural neophilia” [50]. (Kelbaugh is far from alone in this self-criticism, as one can see from the writings of critics like Peter Buchanan [51], and even leading architects like Rem Koolhaas [52].) Then too, next to the kind of multi-agent adaptive morphogenesis that Alexander describes, the individually imagined expressions of apparent “complexity” can be seen as quite weak and trivial—examples of what the urbanist Matheu Heile has referred to as “fake complexity” [53].

One is reminded of Jane Jacobs’ famous critique of the role of art within modern city-making, which she described as having entered an unhealthy relationship with human life: “the result of such profound confusions between art and life are neither life nor art: they are taxidermy ... this is a life-killing (and art-killing) misuse of art” ([23], p. 373).

To be sure, Alexander described a place of honour for art within his scheme of adaptive morphogenesis: it was a kind of enrichment of the structure, an expressive illumination of the existing shared meanings of the city and its buildings. It was not an abstract expression that *supplants* the life of the city, with a monstrous out-scale neoplastic sculpture. Rather, it was a rich structural expression that supported and enriched city life and quality. In that sense, Alexander offered a radical counter-critique of the kind of “commodified art” that seems to pass as mere packaging of older-generation industrial “products,” marketed by Saunders and others. Seen in this light, their efforts to prop up the old art-packaged industrial regime (of GM, Armour, Rockefeller et al.) seems the more reactionary by far.

Against this critical backdrop, the criticisms of William Saunders and other defenders of the status quo seem less like incisive critiques, and more like reactionary attempts to prop up a corrupted paradigm that (as many have pointed out) is all too ready for collapse.

4.4. Aesthetics as a Non-Trivial Indicator of Life-Supporting Order in Cities

Alexander made a deep connection between aesthetics and well-being—and in that sense he joined many contemporary investigators who have shown a link, including Ulrich [54], Kellert and Wilson [55], and many others. A broad survey of the research literature on this topic by Cold, titled *Aesthetics, Well-Being and Health: Essays Within Architecture and Environmental Aesthetics*, demonstrates the growing body of evidence for Alexander's observations [56]. Alexander goes a step further, and proposes that aesthetic qualities are in fact indicators that allow us to detect structures that will promote our own health and well-being—that is, our own life and its quality. He is not the first to see a relation to our own evolutionary psychology—see for example Dutton [57], but he seems to be the first to propose such a detailed structuralist theory of environmental aesthetics. For him, aesthetic experiences are the ways we recognise the deep life supporting order, or conversely, life-degrading disorder—of our human environments. Again, art plays a role as an agent of enrichment and illumination, but it must be a supportive and nurturing role, in service to the life of the city and its inhabitants. Alexander concludes that we must move very far, in theory and in practice, from where we are today.

At present, aesthetics is a controversial topic in architecture and urbanism—denigrated on the one hand as merely “in the eye of the beholder,” a matter of relativistic social construction and varying taste, yet elevated on the other hand by those who give prizes for the most aesthetically pleasing architecture (but again, to whom?). Alexander pointed the way to a plausible schema in which aesthetics does have a structuralist anchor, with common shared patterns through history. Yet his conception left ample scope for individual variations, differentiated local expressions and, yes, novelties. It would be interesting indeed if these insights could be developed to apply more broadly to the city as a complex adaptive system, integrating its cognitive and aesthetic aspects. There are echoes of Lynch and his “imageability” [58] as well as Jacobs' discussion of “the uses of visual order” ([6], p. 372–391). In *The Nature of Order* Alexander took these insights very far indeed with tantalising insights, perhaps suggesting a remark by E.O. Wilson that “the science of aesthetics awaits its Mendeleev” [59].

4.5. A More Human-Centred Application of Data and Metrics

Alexander's methodology sits very comfortably alongside more quantitative, reductionist methodologies like Space Syntax and Multiple Centrality Assessment. In fact, Alexander cited Space Syntax developer Bill Hillier several times in *The Nature of Order*. But whereas Space Syntax is an analytical tool for measuring systems with global connective properties that manifest at local places, as Hillier described it ([60], p. 189), Alexander's tools sought to *generate* global connectivity (and other forms of larger-scale order) by employing local iterative, agent-based processes. The goal was to mimic the same self-organising capacity seen in other complex adaptive systems—including the “unself-conscious processes” of past human city making. Alexander saw no reason that this process could not be recapitulated, this time with data, computing, and other technological advancements.

Alexander himself did not generate urban metrics using his later ideas, as that was not the focus of his own work. However, a number of other investigators have done so applying his frameworks, including this author. A scenario-modelling tool called WikiPLACE has used Alexander's methodology, among others, to guide design decisions with a reasonably good prediction of changes in greenhouse gas emissions in relation to variations in urban form; the same methodology was intended to be used to model other urban metrics [61].

It is important to note again the human focus of this use of data; anchored in human processes, applied to human ends, and always applying qualitative as well as quantitative assessments, frequently and iteratively. Moreover, it sought to engage data in a more coherent generation of whole systems, for greater human benefit.

4.6. The Current Incomplete Stage in the Evolution of Technology, Design, and City-Making

Finally, one hears the voice of a technological (and architectural) critic, but also a hopeful reformer who sought to chart to a path forward, and as growing evidence suggests, may well have done so. For Alexander, the recent history of our “modern” technological civilisation could best be described as a series of mistakes on the way to a wiser application of the powers of technological abstraction. Just as “A City Is Not a Tree” pointed out the mistakes and consequences of an overly tree-like conception of the city, so *The Nature of Order* pointed out the mistakes and consequences of an overly mechanical conception of the generation of form. We could now imagine, and develop, another kind of technology, more life-supporting, more adaptive to broader human needs and shared feelings, and capable of producing more satisfying results. (That includes the urgent need for a more genuine form of “sustainability,” more rooted in deep biological processes.) Such as transformed technology could succeed in that task because it could take seriously the human being, and human life—life in an even broader sense—as the central aim of its processes. It could do so now, because it could learn the deeper lessons of the new sciences of complexity—a point that Alexander made memorably in *The Nature of Order*:

People used to say that just as the 20th century had been the century of physics, the 21st century would be the century of biology... We would gradually move into a world whose prevailing paradigm was one of complexity, and whose techniques sought the co-adapted harmony of hundreds or thousands of variables. This would, inevitably, involve new technique, new vision, new models of thought, and new models of action. I believe that such a transformation is starting to occur... To be well, we must set our sights on such a future. ([16], pp. 568–569)

5. Conclusions

We see, then, that in spite of Alexander’s heretical reputation within the architecture profession, his idiosyncratic formats and mistakes, and his own disinterest in drawing parallels, the actual work was always situated deeply within recognizable and often ancient topics of science and philosophy, from his early work on the synthesis of form to his late-career work on “the art of building and the nature of the universe.” Topics of mereology (part-whole relations), hylomorphism (the transformations of matter), ethics (what is good architecture, and what is good practice), ontology (the nature of reality), and other perennial human concerns, can be seen throughout his work. In that sense, Alexander’s contribution was less about making specific technical and quantitative contributions to an urban science, than in providing a broader theoretical and philosophical foundation for its future (and much-needed) advancements.

At the same time, Alexander’s contributions of practical tools, methods and insights is prodigious, as we have seen, and the demonstrated usefulness of these contributions already spans from computer science to organization management to biology, and other fields not ordinarily influenced by developments in architecture or urbanism. If these successes are any indication, Alexander’s later work, with its many intriguing and undeveloped threads, may well expand an already rich trove of insights for further useful development.

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