Planning, complexity, and welcoming spaces: the case of campus design

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1. HOW TO BUILD A FRACTAL CITY THROUGH BUDGET ALLOCATION

The geometrical notion of fractals combines components of different sizes, as observed in a majority of natural and artificial complex systems. Most persons know of fractals as visual images; nevertheless, fractals also define a stable systemic structure that can be applied to improve most planning applications. Fractals contain many essential system properties: (i) a hierarchy of spatial and temporal scales; (ii) a high degree of interconnectivity among scales, both on the same level (laterally) as well as linking among distinct scales (vertically in a scaling hierarchy); (iii) where appropriate, linked components by means of scaling similarity; (iv) a "universal distribution of sizes" that requires very many small scales, several intermediate-size scales, and only a few components on the largest scale; (v) placing equal importance on the connections among elements as on the elements themselves (Batty, 2018; Batty & Longley, 1994; Salingaros, 2005, 2018a, 2018b).

Evidence-based arguments and observations point to healthy, living urban fabric having complexity that shows fractal structure in its component sets. Such a distribution of sizes is not seen in post-war cities of the USA, however, but only in historical centers and in self-built informal settlements. The reason for this is the imposition of mono-functional use zoning. This difference reveals a major weakness in how cities are poised to face sustainability in the future. Surprising as it may appear, fractal ideas underlying the planning framework help in sustainability (Mehaffy & Salingaros, 2015). We should learn from traditional energy-conserving design and planning solutions and not expect miracles from technological fixes. Almost everybody talks about it, but few know how to achieve adaptive complexity in urban structure. Yet it is possible to build the fractal city by controlling its funding.

Dutch architects grasped the advantages of biophilia (Salingaros, 2015a) and fractals well before those topics were more widely appreciated in design and planning. Rejecting monolithic housing blocks, planners introduced the complex and variegated "cauliflower districts" (*Bloemkoolwijken*) as a new typology for suburban housing. Low-rise horizontal clusters mimicking a fractal represent the opposite of the vertical concentration and monotonous simplicity of high-rise blocks. Built during the 1970s–1980s, these now account for 20 percent of housing stock in Holland. They have the advantages of plenty of natural green, pedestrian regions and footpaths mixed with car paths (*Woonerven*), and complexity in the large-scale planning footprint. Certain misunderstandings, however, prevented their total success. It is now possible to diagnose what went wrong, using complexity theory. This analysis will help us to better plan an academic or corporate campus.

First, "cauliflower districts" are mathematical "trees" because their path connectivity is top-down hierarchical. Roads end in a pedestrian *cul-de-sac*. But, as Christopher Alexander pointed out even before this urban typology became popular, a living city is not a “tree” but a network (Alexander, 1965). The number of connections required to spontaneously trigger urban life is therefore several times that available in a typical “cauliflower district” (Salingaros, 2005).

Second, planning thinking of that time mistakenly believed that a designer could simply introduce complexity on the plan by copying a fractal. This doesn’t work because the resulting complexity is not adaptive, and what is produced actually stops evolved complexity. Adaptive complexity can only arise from allowing the design to evolve, either in real time on the ground (as discussed later in this chapter), or in virtual simulation in response to forces such as flows and social vectors (see Appendix 1).

Third, post-war design relies on standardization and modularity, even when breaking out of the restriction of monolithic forms. Consequently, the components of the “cauliflower districts” tend to be strict repetitions of standard modules. For this reason visitors hate them, as it is very hard to find the right address. Adaptation never allows any module to repeat unchanged, since local forces will inevitably shape it and vary it. Nature rarely shows monotonous repetition, whereas observed monotony signals an industrial type of human intervention (Salingaros, 2018a, 2018b).

Fourth, the “cauliflower district” is supposed to be strictly mono-functional, following modernist planning principles. Adhering to the discredited *CIAM* model of segregated uses turns the region into a bedroom suburb. As a purely *residential* zone, the potential of liveliness arising from the complexity of mixed use is prevented because possible interactions are limited (Salingaros, 2006, 2015b). Geographical complexity in the plan is insufficient without a requisite social and network complexity.

A geometric design for the proposed layout of a campus or for the shape of a single building could follow fractal structure, which comes with advantages (Sussman & Hollander, 2015; Sussman & Ward, 2017); however, it is almost impossible to implement correctly within the present-day mindset. The reason is that both processes of conception and implementation have become rigidly fixated upon a single scale, whereas generating fractals requires paying close attention to many different but related scales simultaneously. Part of the solution to “sustainable” space could be a fractal distribution of funding (see Appendix 2). It would also help to mimic a fractal distribution of the project, process, program work, responsibilities, and phases as well. Distributing the entire process among distinct scales (or portions) can break out of a monolithic industrial approach.

A “fractal” funding formula enables us to generate all the required sizes in an urban ensemble. How do we optimally spend money on building welcoming urban fabric? It has to be done using a fractal cost distribution. Suppose we have a central source that allocates different sums to specific projects, where each project competes with the others for funding. This is the case with a university campus, since the majority of the budget comes from a single source, with the possible exception of specific donations for individual buildings (and even those often have to be matched by university funds). The administration has to argue for its projects’ approval in front of the funding agency, its own coordinating board, or the government.

The conventional procurement method is rigidly anti-fractal because it concentrates on the largest projects: those need the most money, and not getting them approved carries the greatest risk. But that top-heavy mindset too often ignores the intermediate and small-scale projects. Present-day thinking assumes that those can be accomplished by way of the university’s general operating budget, or from discretionary funds found here and there. Yet that is seldom the case, and a systemic imbalance towards the largest scale remains to shape the built environment in undesirable ways.

There is already a built-in prejudice against evolved complexity in the built environment. The only way that complexity can appear when focusing exclusively on large projects is if it is designed as an artistic whim that has nothing to do with human adaptation. Such arbitrarily-designed complexity works against human sensibilities and uses. Furthermore, it represents an unscientific injection of complexity, ignoring the crucial role that living environments play in generating and requiring complexity (Mehaffy & Salingaros, 2015; Portugali et al., 2012).

A big project is easily presentable, hence an important marketing tool. The architect draws a pretty picture of the large standalone new building, which is used to convince decision-makers. The idea of a single structure and its striking image can be linked to expectations of how this addition will make the university look like it is growing and thus modern, progressive, and successful. The current system creates dead spaces in-between indifferent standalone new structures. But it is much harder to use smaller, interlinked projects to market the university's value. Human psychology works against presenting an intricate, complex, adaptive environment: *it has to be experienced in person because its life-affirming qualities do not show in a picture!* (see Appendix 3). On the other hand, psychology shows as well that, after a while, newly-created architectural megalomania loses its newness and gets outdated (Rennix & Robinson, 2017). Such highly-visible projects can go into decline quickly, becoming largely unattractive as a whole.

Christopher Alexander suggests a better funding formula for spending money on campus construction and upkeep. Just as a fractal has components whose sizes obey an inverse-power distribution, we propose the same law to govern funding for projects according to cost/size (see Appendix 2). An inverse-power distribution is one where the number of objects in a system is inversely proportional to their size: there exist only a few large objects, several more of intermediate size, and very many smaller ones, increasing in number as they get smaller. Fractal funding would support only a few large projects, several of intermediate cost, and very many low-cost projects, in a balanced relationship that favors the lower-budget ones.

A simple means to apply a fractal distribution to the funding formula is to divide the total budget into equal portions; say five. Then assign each 1/5 portion of the budget equally among a group of construction proposals having roughly the same cost/size. That will automatically guarantee that the smaller the projects are in terms of funding, the more of them will be approved. (And the largest projects together will only receive 1/5 of the total budget.) While we may never be able to systematically change the presently skewed budgetary process, just getting fractal thinking into the heads of university planners as they work to prioritize projects might begin the process of creating a greater equity in overall place-making within the campus.

This revolutionary approach to budgeting is also the best way to keep healthy urban fabric in repair. Most interventions and additions that can make a great deal of difference for the better are of small or intermediate size. Those need to be done often. The largest projects, which the current system is skewed to privilege, are possible only every few years. The university sees large new buildings as visible proof that it is growing, and, while it may not display such a building in a student brochure, it feels satisfied with the news coverage. But those big projects are disastrous when they fail. Of course they make money for the architect and builder, but that's not helpful to the institution.

Alexander first proposed this fractal funding formula in his long-term urban plan for the University of Oregon (Alexander et al., 1975). Alexander's result was based on his own original analysis, and came before the introduction of fractals into architectural and urban theory (Batty & Longley, 1994; Salingaros, 2006). This inverse-power distribution is essential for the stability of all systems, as for example ecological systems (Salingaros, 2005). There are deep justifications for this approach that have to do with complex systems. If by past precedent the formula for funding projects has become skewed towards the largest scale, we have to work to remedy this imbalance. How projects are funded can be key to creating more human-scale spaces and places through adaptive complexity.

2. THE UNIVERSITY CAMPUS AS A MICROCOSM OF TRADITION

The specific form language of buildings, together with the urban space typology, determines whether the campus provides a healing environment or not. Those are responsible for either failure or success. Traditional form languages linked to climate, cultural heritage, and geography work best, but both industrial-modernist and avant-garde buildings could turn the campus into an alienating experience.

There are several reasons why this is true, and quite a few of them can be answered by complexity sciences. For example, a town plan dating back to the middle ages is attractive because its road system allows discovery; the traditional town has a balanced and fractal-like mix of old and new, which somehow is comforting to human perception that subconsciously looks for distinct scales as in a fractal; and so on. This conclusion generates violent controversy between architects and New Urbanists, despite being proven by recent experiments on perception (Mehaffy & Salingaros, 2015; Sussman & Hollander, 2015; Sussman & Ward, 2017).

Figure 18.1 Conventional landscapes of a US University campus (author's drawings)

Well-defined urban space is not merely an aesthetic option; it is a vital component to the human experience of a campus (Alexander et al., 1977; Salingaros & Pagliardini, 2016). The most valued universities have prominent open spaces, not necessarily large, but always distinctive and well defined by their boundary. University open spaces work best of all, and are the most memorable, when flanked by historic buildings with well-developed coherent form languages in their designs. This is not an arbitrary choice among styles but a necessary component to establishing a visceral connection with the user (Salingaros, 2006). Those spaces frequently define the university's identity for the rest of the world. What the student or visitor remembers is formed as body memory from the visceral experience of its urban spaces, not primarily the architecture of its signature buildings that might be visually memorable (see Appendix 3). The latter leave mostly an intellectual impression (even though the buildings' façades help to define the informational qualities of the urban space).

This is not a call to build on the basis of a fake identity, with nothing but mock-historic buildings. Again, traditional form languages are to be preferred simply because their organized complexity works best to define the information field focusing on the open spaces. More traditional buildings share fractal qualities and natural scaling, which modernist and contemporary buildings purposely avoid. For example, by sponsoring fashionable high-tech architecture, recent high-profile corporate campuses have achieved mediocre or even hostile outdoor spaces. But while those brand new campuses are highly appreciated by contemporary architectural culture, I doubt that their employees get the most benefit they could have out of the site.

The industrial-modernist design paradigm has created segregated mono-functional zones within a campus, while isolating the campus itself as another distinct functional zone detached from the living city. This formalist thinking has led to new campuses being built deliberately far from any existing urban fabric. Contradicting the plurality of architectural styles found in a traditional city, a new campus could turn into a showcase of fashionable but non-adaptive buildings. While those may be awarded architectural prizes according to 1920s' aesthetics, neuroscience proves that the information they present works against cognitive appreciation (Salingaros, 2017; Sussman & Hollander 2015; Sussman & Ward, 2017).

Creating welcoming urban space depends upon several factors, including the setting, building types, etc. Many universities pride themselves on having buildings designed in contemporary styles placed prominently around campus, and newer additions seem to follow an institutional model of standalone buildings. Contemporary campus buildings are being funded with donations from wealthy donors (who expect their name to grace that building), but research shows that more traditional architecture lends itself better to a learning environment (for anecdotal evidence, see the discussion on publicity brochures, below). The reason is that older form languages connect much better with human cognition, attributable to the "biophilic effect" (Kellert et al., 2008; Salingaros, 2015a; Sussman & Hollander, 2015).

New design is welcome, unless it eschews fractal structure altogether, in which case it is hopeless at connecting viscerally with the user. Minimalist façades are simply "not seen" (Sussman & Hollander, 2015; Sussman & Ward, 2017). And then, even if a building has some sort of fractal scaling, the form's generative process must be adaptive to human dimensions and uses, and not follow an abstract scheme, for then it becomes irrelevant decoration. In other words: non-fractal structures do not adapt to human sensibilities, yet fractal structures that do adapt arise from the users' psychological and social forces, not the architect's whim.

Many readers (though not architects) would agree on criticizing concrete buildings and the brutalism of the 1950s through the 1970s of the past century. In other words, post-war modernism presents an uninviting face to human beings, and is appreciated only by a few individuals who judge it on the basis of abstract criteria. There is an option to build according to the latest designs that depart from concrete brutalism; some of which are appreciated by students as good learning environments. I can explain this by their inclusion of biophilic qualities such as lots of sunlight and views onto nature. These latest developments throughout the world can be visually stunning, and we encounter wonderful new buildings that seem to be a delight to work in. Nevertheless, I contend that their success is only partial, since most of those buildings still lack the other components of organized complexity such as fractal scaling and nested symmetries privileging the gravitational axis (Salingaros, 2018a, 2018b).

People perceive campuses with block buildings and hard open spaces as bleak, desolate, threatening, inhuman, even totalitarian (Kim, 2015; Liu, 2013). The human scale is missing. And yet this industrial style has shaped a majority of institutional construction for decades. Those out-of-scale buildings responded to a steep growth in the number of students, and reflected the prevailing design aesthetic when they were built. It would appear that school administrators decided to industrialize education, and concluded that industrial-modernist architecture was most appropriate for the task. The campus became a non-pedestrian urban region with buildings placed too far apart to connect. School managers and their enforced way of administrating chose a particular style that goes along with that philosophy.

Pre-modernist buildings frequently provide, through their materials and designs, organized information that helps trigger a greater sense of wellbeing, which in turn promotes greater participation and engagement on the part of students, faculty, and staff. Industrial-modernist buildings emulate sensory deprived environments, which can create a degree of hidden anxiety that permeates the learning experience (Salingaros, 2006). Experiments in neuroscience show that it is harder to learn and retain information in stressful situations or environments (Chen et al., 2008). Studies on this key effect are sorely needed. One new example comes from Christopher Alexander's new campus outside Tokyo (Alexander et al., 2012). When the old school was housed in concrete block buildings, the students, teachers, and staff hurried to depart as soon as classes were over. In the new campus, commuting buses had to be scheduled for much later because very few people wished to leave.

Based on common logic, parents expect their children to learn from traditional stores of knowledge that has been tried and tested. While innovation in the learning environment is expected and welcomed, it is not supposed to displace inherited knowledge. I don't think that parents wish to pay for experimental and unproven methods of education, but would prefer for someone else's children to be used as guinea pigs. By analogy, a traditional center of learning represents cultural inheritance, and that should also reflect in its buildings. Evidence shows that this conjecture is true.

An informal survey of brochures put online to entice prospective students in the USA (and even more, to convince those students' paying parents) reveals them to feature strictly traditional buildings. Those older buildings have an instinctive appeal because they link to stable and timeless values. While universities may indeed have industrial-modernist or alarmingly "contemporary" buildings on campus, those are not usually displayed in brochures. Expensive private institutions with long-standing prestige, especially, employ psychological marketing techniques to justify the high expense of a university degree. Those schools invariably present their traditional campus buildings instead of their more contemporary (abstract) structures, since people typically respond to the thrill of architectural transgression with alarm, and may subconsciously sense that inherited knowledge is also being threatened.

Various other explanations could be given for this, but I believe those to apply only to a restricted number of schools, and not in general. I name but three of the world's top universities— Harvard, Cambridge, and Oxford—that identify themselves as traditional learning environments in part because of their traditional architecture. These universities are showcases, but this doesn't say much about quality of life. But maybe you don't want to live or work in a traditional Oxford campus.

Two separate design problems are relevant to institutions of learning: (i) choosing an appropriate architecture for new buildings, and (ii) laying out the plan of the campus. The first question leads to a sort of schizophrenia, because parents tend to want traditional "reassuring" buildings (and "reassuring" is psychologically associated with traditional and perhaps Art Deco design, but with neither brutalist modernist nor twisted contemporary forms), whereas the university is pushed by fashion trends to choose the opposite in new buildings. It would appear that the administration recognizes this conflict, preferring that the parents discover the alarming contemporary buildings on campus—representing transient ideas—only after their children start to attend classes at that institution.

From a complexity argument, design "diversity" would be welcome, but from physiological arguments, every building or structure has to share common reassuring qualities. First, every building has to invite the user visually to approach and enter it, which presupposes certain old-fashioned design geometries such as bilateral symmetries about a vertical axis, subdivisions that show scaling and self-similarity, a well-defined welcoming entrance, etc. (Sussman & Hollander, 2015; Sussman & Ward, 2017). Second, an ensemble of buildings will be perceived as coherent only if all of them share common design elements and symmetries at a distance while maintaining their individual identity (Alexander, 2001–2005). Diversity in building styles could lead to a healthy "robustness", and obviously this diversity can be of outstanding quality, but this doesn't necessarily imply a neo-classical style of some kind. In other words, while complexity adds to a pleasurable experience, it must be coupled with organization; otherwise the experience becomes a negative one (Mehaffy & Salingaros, 2015; Salingaros, 2018a, 2018b).

Laying out the campus plan creates a conflict between the need for additional buildings, and the necessity for all students to reach their classes within a 10-minute walk (the normal break between classes). These two demands are irreconcilable if the campus keeps expanding with singular new buildings, as most do. The solution is to implement an intelligent compactness and intricately folded complexity. Traditional spatial solutions work best for creating complexity that adapts to human needs instead of being a meaningless abstraction (Mehaffy & Salingaros, 2015; Portugali et al., 2012). The opposite trend, which is to erect standalone industrial-modernist or "signature" buildings, negates compactness and useful urban spaces.

The degree of complexity plays a determining role here. In the minimally-complex case, concrete buildings from the 1960s are often positioned in a well-organized grid. We would say that those are too organized, as there is nothing more to discover. Moreover, having regularly-spaced block buildings leaves amorphous urban voids lacking a sense of enclosure, which can never define an effective public space. Interventions in such a minimal ground plan have to step in line or they could break up the entire idea, thus making it almost impossible to introduce needed complexity on smaller scales (Salingaros, 2015b). This case is easily countered by examples that do not work so cleanly, as in some traditional setups that have grown piecemeal and organically over decades that make it easy to get lost. The latter case has far higher complexity. We should look for a balance between these two situations, because a campus with life cannot be the result of a black and white distinction.

Institutions that have gambled with their endowments to erect gleaming new buildings by trendy architects are participating in a very expensive experiment. They invested in flashiness instead of reinforcing the spatial urban qualities of their campus according to time-tested design rules. They took a massive bet that those cutting-edge university buildings will draw in a new generation of paying students. Campuses with buildings predominantly from the 1960s and 1970s, in particular, are taking this direction to distance themselves from the inhumanity of an outdated industrial landscape. And these new buildings are definitely shown on flyers. Nevertheless, this move could easily backfire if the new buildings are inhuman but in a different way.

A separate misconception is that cutting-edge research requires alien structures to house it, and thus universities erect flashy new buildings to draw in research dollars. Whether that occurs or not is a matter to be determined by future applicant statistics and number of grants. Innovation in knowledge and research is mistaken for an "image" of innovation ostensibly shown by a building's façade. Partial results already hint that the experiment of innovation through fashionable but disruptive design is a dismal failure because it creates negative publicity. Lists of "The ugliest campuses in the USA" invariably include precisely those institutions whose buildings' design purposely panders to fashions that naturally oppose our biology. Who wants to go to a university that is included in such a list?

Christopher Alexander's high school/college campus outside Tokyo was built in 1985 (Alexander et al., 2012). Alexander and his design team researched deeply into Japanese architectural culture to extract a form language appropriate for a contemporary institution of learning. The result is a modern campus that has comfortable, timeless qualities. Several factors are responsible for this success: (i) fractal-like structures; (ii) geometries and circulation flows that evolved on the ground, and were not formally imposed; (iii) shaping the experienced spaces to maximize positive psychological and social impact; (iv) embodied memories of historical culture with which all the users feel comfortable; (v) an unusual insistence on the presence of water (an artificial lake) and green spaces, which provide strong biophilic qualities. Students, teachers, and parents love it. The only problem that arose was with the local construction companies, which had been expecting to build the usual concrete boxes. (The remaining sections will describe Alexander's design and planning methods in sufficient detail to enable their direct application to actual projects.)

3. WELCOMING OPEN SPACES AND AVOIDING PLANNED ISOLATION

It is possible today to build learning institutions that offer a marvelous, life-enhancing environment for students, faculty, and staff. The experience of any particular campus depends upon its spaces and perceivable organized detail, more than imageability. Those qualities are what the visitor remembers, and what the students, faculty, and staff experience every day (see Appendix 3). This result is not accidental or haphazard, but can be achieved by deliberately applying mathematical design guidelines. Those combine visually-oriented design with functionality. (Although some would argue that this is exactly what modernism is supposed to be about, starting with the Bauhaus, I mean something entirely different.) Sidestepping formal design entirely, I use only tools linked to psychology and the sociology of space. I list some of the most common mistakes made in campus design below, so that knowing to avoid them will lead to a much improved result.

Many campuses built in the past several decades contain dysfunctional urban spaces. Those spaces do not invite, and in many cases actually prevent pedestrian use expected of an open plaza. The problems can be divided into two categories: (1) impediments to crossing the space, and (2) problems inherent in the surrounding structures.

Physical obstacles to traversing open space include continuous low walls for sitting that disrupt possible diagonal paths (whereas those low walls could be very effective when situated radially/transversely); badly-placed commemorative structures, sculptures, statues, or pools of water that also block direct paths; misusing green in a lawn that is out-of-bounds for people and which prevents direct paths across a plaza; changes of ground level that cannot be easily negotiated; steps that prompt a pause and mental concentration in the user, which could have been eliminated; unnecessarily steep sloping ground, etc. All of these built features betray a lack of understanding of what mechanisms make an urban space function as a pedestrian environment (Salingaros & Pagliardini, 2016). Built structures that are positioned inside an urban space by judging how they fit aesthetically into the plan as seen on a computer screen, but which ignore the emergent path structure, will degrade rather than enhance that urban space.

Paths become robust when reinforced by an adjoining edge (Salingaros, 2005). Paths work less well psychologically when crossing open ground. Linear elements such as benches, low walls, lawn boundaries, and stairs need to run *next to and parallel to* potential paths, not across them. A sufficiently wide staircase encourages flow along its bottom step much more than transverse movement up-and-down the stairs themselves. People feel comfortable walking alongside a guiding structure. Yet so many cases of planning with the above errors are consequences of design as abstraction that ignores human biology (Mehaffy & Salingaros, 2015; Salingaros, 2017). In terms of complexity theory, coupling paths with boundaries organizes spatial complexity. Complexity is essential for life, and the utility of a plan depends upon its coherence and organization. This is not to be confused with simplification, which instead destroys complexity (Salingaros, 2018b).

A second set of problems concerns the buildings surrounding the open space. The ideal qualities here include compositionally rich and visually welcoming façades containing highly-ordered geometrical information, fractal scaling, and the multiple symmetries of traditional buildings. One feels the desire to cross a plaza or open space when attracted by a visible, emotionally-welcoming goal on the other side, whereas minimalist concrete, bonded brick without patterns or features, and glass curtain-walls—none of which attract us emotionally—trigger the opposite effect (Sussman & Hollander, 2015; Sussman & Ward, 2017). Another welcoming quality of the boundary is to be found in porticoes on one or more sides of the plaza (Salingaros & Pagliardini, 2016). Such a protected space encourages pedestrian activity all around the boundary of the open space. Discontinuous arcades may look nice but are, as a consequence, hardly used.

Traditional principles of human-scale urban design and planning shape a campus to make it fully alive, especially when the urban fabric is intimately connected to non-university functions somewhere on its perimeter. In terms of complexity, joining two distinct complex systems—the campus and the city outside—can be beneficial to both, if it is done correctly. The two systems must maintain their separate identity while interacting with each other to form a loosely-defined larger system. Success depends on the border between the two complex systems, which has to be physically and psychologically robust while being semi-permeable at the same time (Salingaros, 2005).

The planning habit of mono-functional zoning was imposed to unnecessarily separate a campus from a region of city. This way of thinking is responsible for the "corporate campus" of major companies isolated in the woods, or at least far out in suburbia. But, while that setting has positive biophilic qualities through contact with nature, it is deliberately not part of the city. (There is as yet little direct evidence that students studying in nature are better off or have better results, but the general health benefits are incontrovertible (Keniger et al., 2013; Shanahan et al., 2015).) An even worse precedent is the misleadingly-named "office park", which is just a cluster of unrelated office buildings with no trace of a green park. Both of those urban typologies define a working life separated from the rest of humankind.

Historical evidence points to the intentional isolation of workers from city life so that they could be totally controlled by the employer during the workday (Mozingo, 2011). The corporation tried to force employee allegiance by isolating them, in a prime case of social engineering. Many people believe that the same idea was applied to high school and college campuses, implementing a fortress typology in order to better control rioting students. This claim is unsupported, however: it just happens that an inhuman architectural style coincided with typologies whose principal concern was security.

While the corporate campus was, at least in name, supposedly copied from the traditional university campus, its urban model is the suburban shopping mall surrounded by vast areas of open parking. Everyone commutes by car. By now this typology has come full circle, with institutions of higher learning copying the isolated corporate campus and suburban office park. Could there be any other reason why campuses are sometimes isolated entities? Perhaps a reason is to offer students a completely different rhythm of life. Yet that again points to deliberate isolation from the rest of the community.

4. ALEXANDER'S DESIGN PATTERNS FOR THE UNIVERSITY OF OREGON

Having summarized the campus design problem, and the obstacles human-centered design faces, I now present some useful techniques. Solutions exist in a published body of work that is marginal to contemporary architectural culture. Living environments in general, and a campus in particular, can be designed using a toolkit that includes the following: (i) design patterns (Alexander et al., 1977; Mehaffy et al., 2020); (ii) geometrical techniques for organizing complexity developed by Alexander in *The Nature of Order* (Alexander, 2001–2005; Mehaffy & Salingaros, 2015; Salingaros, 2018a); (iii) fractals and complex system theory (Batty & Longley, 1994; Salingaros, 2005, 2006, 2015b, 2018b); (iv) biophilia (Kellert et al., 2008; Salingaros, 2015a); (v) neuroscience (Salingaros, 2017; 2020; Sussman & Hollander, 2015), plus supporting work by other researchers.

Design patterns are discovered as design invariants in the most successful architectural and urban solutions. Stripped of irrelevant factors such as style, materials (possibly), or extremely specific local adaptations, a framework for the most adapted design solutions is found to repeat from culture to culture and from region to region. Those prototypes can be documented for re-use in a similar situation. Design patterns are templates that vary with each application and will adapt to local conditions. Purely geometrical considerations merge with human biological and cultural needs into a socio-geometric design pattern.

Christopher Alexander and his colleagues documented a set of design patterns in the classic book *A Pattern Language* (Alexander et al., 1977). This book contains well-ordered fields of attention, and expresses Alexander's early search for order. Design patterns had to be supplemented by new geometrical insights that came to Alexander later in his career (Alexander, 2001–2005), and which strongly influenced the subsequent set of patterns published more recently (Mehaffy et al., 2020). Alexander did not formulate the notion of time evolution of designs and the city, which is so relevant within the complexity sciences. His proposal is to offer a set of rules that should govern any future development, so that following those guidelines will guide any inevitable change in an adaptive direction. Doing this avoids the easy solution of the Master Plan that determines every construction detail for 50 years or so, but which is non-adaptive.

We can use design patterns to design a campus today that will embody all the positive qualities of our best-loved historical institutions. A college or university campus represents an urban microcosm, with its limited yet often extensive area and restricted mixture of uses. One needs different buildings for classrooms, research laboratories, libraries, student housing, cafeterias and student activities, sports, maintenance, administration, etc. The pedestrian realm is paramount, since students have to walk from building to building. Essential vehicular connections ideally should go around or under the main network of pedestrian paths.

Alexander created a long-term planning strategy for the University of Oregon campus in 1975, based on design patterns. This is crucial in that it allows adaptation, self-organization, emergence and co-evolution. Alexander's design rules for the University of Oregon are universal. Some of those patterns appear in *A Pattern Language*, whereas others are to be found only in the lesser-known book *The Oregon Experiment* (Alexander et al., 1975). The Oregon patterns were employed in the design of the Tokyo campus mentioned earlier, but were supplemented with further geometrical insight that forms the subject of *The Nature of Order* (Alexander 2001–2005; Alexander et al., 2012). I recall some of those findings here, and explain how they apply to a broader vision of campus design. The pattern descriptions given below are my own summaries.

Oregon Pattern 2: OPEN UNIVERSITY. "Do not isolate the university by surrounding it with a boundary; instead, interweave at least one side of the campus into an adjoining city, if that is possible."

Oregon Pattern 3: STUDENT HOUSING DISTRIBUTION. "Locate some student housing within the center of the campus, with different percentages in regions as one moves away from the center. The first 500 m radius containing ¼ of the resident students; ¼ in a ring between 500 m and 800 m radius; and the rest outside 800 m."

Oregon Pattern 4: UNIVERSITY SHAPE AND DIAMETER. "If possible, situate classrooms within a central core of ½ km radius, and non-class activities such as administration, sports centers, and research offices outside."

Oregon Pattern 5: LOCAL TRANSPORT AREA. "Give priority to pedestrian flow in the central core of the campus, within a radius of ½–1 km. Vehicular traffic here must be made to go on slow and circuitous roads."

Oregon Pattern 12: FABRIC OF DEPARTMENTS. "While each academic department ought to have a home base, it should be able to spread over into other buildings and interlock with other departments."

An obsession with mono-functional zoning often forces all student dormitories on a campus to be clustered together, while all administrative functions are housed in a single, imposing building, etc. Yet that is a mistake. Functional segregation does not produce an ideal learning environment, as it works against mixing and variety. Segregation reduces complexity that is necessary for life. A campus has to have a high degree of intricate overlap, without threatening easy pedestrian navigation. This sort of diversity leads to robustness.

The departmental pattern (*Oregon Pattern 12 given above*) seems to relate well with the multi-layered reasoning from complexity sciences. It also points to a pragmatic approach that has a major influence on planning morphology. Whereas it is standard practice to segregate academic departments into separate buildings, this never works in practice. Suppose the "Chemistry Building" is funded and built. Yet by the time the Chemistry Department gets to move into its new offices and laboratories, it has either grown or shrunk in size, so it no longer perfectly fits the building. It is more practical to adopt the approach that no single building should be expected to contain a university department entirely. Thus, it makes better sense to physically connect a building to adjoining buildings rather than have it standing apart.

The exceptions to this mixing are exactly analogous to those that circumvent mixed-use zoning. Heavy industry and other sources of air or noise pollution have no place inside the city fabric. In the same way, if there are nuclear research facilities or animal testing laboratories on the campus they should be located at a distance for obvious reasons.

Understanding how a city works as a complex system also helps to understand cultural and social fragmentation. Unfortunately, other forces contribute to that; therefore, planning alone cannot prevent this undesirable phenomenon. A complex as opposed to a minimalist vision of the city helps to distribute built forms on many different scales. Pedestrian paths form a network of connected urban spaces, and design has to protect those paths from encroachment by vehicular traffic (Salingaros, 2005). This approach offers integral connectivity between the campus and the city outside. The special requirements of a campus give it even more urgent pedestrian needs. Every building needs vehicular access, but that must take second place to pedestrian connectivity. This hierarchy is enforced by the planning and design (not by posted signs), but other than that is the result of the spontaneous use of space.

5. "WALKABOUT" DESIGN WITH HUMAN SENSORS

Alexander's implementation of participative design—essential for endowing human qualities to the result—does not limit itself to discussion, but makes shared design decisions directly on the ground. Those crucial findings guide the project in a very different way from the usual New Urbanist "charrette". In the "charrette", a design drawn up by professionals is then debated openly with future users and interested parties; changes are made *on paper* following feedback and suggestions (Bond & Thompson-Fawcett, 2007). Design methods using emotional feedback from people have a lot in common with how spontaneous self-built cities (informal settlements) arise. Slum dwellers do not follow building regulations, but are instead guided by their intuition and the physical limits of available materials, space, and topography. Incorporating aspects of that design freedom into conventional practice yields a method that adapts better to human feelings and sensibilities.

My colleagues and I have proposed implementing this method to upgrade informal settlements and erect new self-built housing around the world (Salingaros et al., 2006). That relates in an essential manner to campus design. We need both the ability to change an existing site lacking human qualities, and the tools to do so. Mimicking the bottom-up creation of informal settlements gives us some idea (worked out below). In campus design, legal constraints will assure that particular standards are being maintained for accessibility, prevention, safety, etc.

Given modern industrial materials and systems of construction, there is an economy to rectangular spaces in terms of standard materials, labor, and utility. Regular building codes have a very limiting effect on design freedom, and act against individual negotiations with existing conditions. And yet, an intuitive design and planning method obviously worked for millennia. Ever since people have had to rely on architects and the building industry (for one century), they have forgotten or have suppressed their instinctive dwelling-making skills. If today's industrial-modernist paradigm is to be overcome, or at least modified to obtain a more human design, we need to re-awaken those timeless methods of design (Alexander, 1979, 2001–2005).

I'm going to delve into the design methodology known as collaborative, consensus, or participatory design. That approach involves eventual users in an essential manner in producing the design. I will focus only on one specific component of the collaborative method, which makes design decisions on the basis of direct emotional feedback in an exploratory method for creating nourishing urban fabric. An intuitive judgment based on the users' feelings and imagination is mapped before construction, giving birth to the design by using what already exists on the site directly.

A reader may like the method I describe below, but should keep in mind that its application presupposes a revolution in planning. The spatial planners, architects, and urbanists are about the only people who care about the design of the space they're using to do their work. Students, faculty, and staff usually assume that design and planning are taken care of by others, not themselves. What I emphasize is that *all* stakeholders of the university who use the spaces of a campus every day have to become aware of how to optimize its geometry.

The method is the following: choose a group of about five people, and include a child if children are going to use that place for any extended time. The group walks the grounds trying to imagine the proposed building fronts already standing; not in some predetermined form, but asking rather where a built wall and openings would feel best to reinforce those open spaces. This "walkabout" guarantees that the future urban spaces are going to be well defined on a human scale and are connected by a network of pedestrian paths. For this process not to be ill-defined, the group needs some rules and guidelines of what is possible; hence, the group should include someone trained and knowledgeable in Alexandrian Patterns to guide the process. Decisions are reached by discussion and consensus.

Alexander suggests for the group to carry wooden stakes and poles with small flags on them (Alexander et al., 2012). These are used to mark the paths, the boundaries of open spaces, and the footprint of the imagined buildings. String can be stretched between stakes on the ground to mark a line. Someone could hold a large Styrofoam panel and stand in particular spots so that the group can decide if that's the optimal position for a wall. If all goes well, multiple factors such as solar orientation, adaptive use to wind flows, levelness of the land, and regard for natural elements on the site (trees, boulders, sharp drop-offs, steep hills, etc.) will be accommodated just by the sensory feedback.

The exploratory design group should include persons who have a strong interest in using the built urban fabric after it's completed. It is recommended to have someone with sufficient technical knowledge to help provide structure to the decision-making process. Individuals participating in the "walkabout" should be encouraged to draw upon their human intuition and visceral sense of place to guide them in their conclusions. This can be difficult at first, given the decades of industrial-modernist construction led by architects and professional builders, which distanced users from their instinctive sense of dwelling and place-making. The detachment was achieved by institutionalizing both design and construction.

After this design walkabout has been carried out on the actual grounds, and checked once again after the positions of other key elements have been decided, the discovered plan is transferred to a measured drawing. "Cleaning up" the design so as to align directions and tidy up the geometry should be resisted, since that may invalidate the empirical discoveries of the group. This is the opposite of the standard procedure, in which everything down to the details is drawn in the office, and then built. In the conventional design approach, the users get to experience the final configuration after it is permanent; i.e. only after it is too late to make any adjustments, or even to correct major errors and omissions.

Alexander's method puts our human sense of place ahead of industrial design practices, by promoting human intuition of how we react to forms and spaces ahead of formal planning. Exploring the site on foot, independently of existing paths and road structures (except for features that absolutely cannot be changed) helps to establish an optimal connected network of pedestrian paths linking urban spaces. By not being controlled from above, unexpected design features can emerge spontaneously, generating a degree of organized complexity unheard of in conventional planning. At the same time, the exploratory process discovers how the pedestrian network should connect to internal and external vehicular networks.

Alexander himself used this method to build a new high school/college campus outside Tokyo, as previously mentioned (Alexander et al., 2012). Once the urban design and the architecture of each individual building had been determined, the construction of the campus was carried out via conventional methods. The resulting cluster of buildings and grounds show a degree of life that is never seen in conventional projects. Yet this adaptation is essential for human engagement and wellbeing.

The same method also applies to diagnosing already built urban fabric. An exploratory design group discovers and then maps those healthy places where it observes intense urban life, and which are deemed by their users to be vital. That quality is judged both by positive emotional feedback and by measuring the density of pedestrian use. Such spots are marked as being protected from damage or encroachment by new projects. Yet those key healthy places could be architecturally modest objects, such as a tree, a wall, a corner, a small structure, etc. that conventional planning would not hesitate one second before eliminating.

Equally important is for the exploratory walkabout to identify existing pathological paths and places. If a place or pathway triggers psychological distress, there is something wrong with its geometry. The sensations could be a feeling of being oppressed; made anxious or threatened by the geometry or by something else; of being too exposed; ill-at-ease, etc. These feelings are to be taken seriously. First identify those spots, and then think of possible restructuring and transformations to fix the problem—which is an emotional and/or intuitive reaction, not something that can be discovered from looking at a plan.

The group's mission is to let the collective imagination generate the most wonderful environment to replace what presently causes emotional discomfort. One has the conceptual freedom to envision knocking out walls and buildings' corners, change building façades entirely, tear down menacing overhangs and cantilevers, re-orient and displace paths, and build new sheltering structures simply in order to enhance emotional wellbeing. We are not beholden to any design ideology, nor do we adhere slavishly to build forms because they are there. All of this is, of course, hypothetical: what is actually feasible depends upon practicalities. Yet merely to contemplate such changes can be a profoundly liberating experience.

If a new planning scheme requires that something be demolished to erect a new building, then care should be taken to leave the documented healthy places alone while sacrificing the unhealthy ones instead (Alexander et al., 1977). This way of thinking can help repair the urban fabric by not allowing new construction in arbitrary locations, such as where someone thinks it's a good idea simply based on the plan. Herein lies the key to re-humanizing campuses from the 1960s defined predominantly by concrete block structures. The method outlined above permits selective interference, and can achieve much good. Trying to mitigate the negative effects of those campuses suffering from wind effects, and from psychologically cold and uninviting spaces and surfaces is possible through transformation. Once we are liberated from the confining idea of maintaining some formal "master plan", a step-by-step evolution could lead to the emergence of life.

Evolving systemic complexity is made possible by the "walkabout" experience. The group's collective mind evaluates an infinity of interventions that can be imagined, all generated virtually. Having a group instead of an individual mitigates against "image-based design" where something comes to mind from memory that is irrelevant to the present setting. The subconscious recollection of images is dangerous because it may lead to imposing one's ego on the built environment. Alexander has emphasized the absolute need for the designer to be "egoless" in generating and selecting from among adaptive alternatives (Alexander, 1979). When he expressed this notion, it was misinterpreted as "new age" philosophy, whereas it is, in fact, a facilitator for a sort of genetic programming in virtual design space.

6. CONCLUSION

How a campus evolves in time is determined by a complex system that combines the physical structures (static subsystem) with human actors (governing subsystem, or the system's intelligence). The importance of the decision-making process in how buildings, paths, and open spaces change by intervention is often ignored in planning discussions (De Roo, 2018). It is usually taken for granted that a "master plan" is sufficient to determine how the ensemble of campus structures grows in time, yet this approach is inadequate because it has no feedback. Intelligent input occurs only at the beginning. However, an intelligent systems-based approach will pay attention to the governing subsystem just as much as to the static subsystem. As known from systems theory, the governing subsystem has to be dynamic, and of comparable complexity to the system it governs (Salingaros, 2015b).

Moving towards sustainability and resilience, we cannot continue to apply a top-down inflexible plan that ignores feedback (De Roo, 2018). And neither can we allow random forces to degrade the system. Those could arise either from natural events such as building decay, or forces of progress: both require a decision on whether to upgrade or replace an existing structure, and as to the nature of its replacement. These are intelligent decisions that determine the evolution of the system on the ground. I used the work of Christopher Alexander to suggest some components of this required "intelligence", which could be adopted in the decision-making process. A university or corporate campus, by virtue of its central governance and funding, provides an ideal situation in which to apply these ideas.

Whether a campus provides a negative or positive psychological experience is due to effects occurring on a range of architectural and urban scales. Welcoming spaces are the consequences of an intelligent application of complexity in design. Mostly historical campuses feel welcoming and create a special positive feeling that encourages intellectual pursuits. We should be striving for this result in campus construction, whether in one new building, or across a completely new campus. But even older successful campus settings can exhibit radical changes in perception from one location to another nearby. So many students nowadays feel the urban geometry of their school to be hostile, without knowing exactly why. Architectural culture as taught in the majority of our schools of design does not understand the reasons for this, and can offer no remedies. Design tools collected here give us a robust framework for re-conceiving a campus according to its psychological impact on users. These insights will help in designing a new, welcoming campus, and repairing problematic spots on an existing campus.

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APPENDICES: COMPLEXITY, FRACTALS, AND EMOTION—EXTRACTS FROM *PRINCIPLES OF URBAN STRUCTURE* (SALINGAROS, 2005)

A.18.1 Appendix 1: Adaptivity and Self-organization (p. 232)

Self-organization is a property of a system that uses internal forces to influence its own structure or growth. That is, it is generated by some algorithm that causes it to develop internal coherence. We may not understand entirely how self-organization works, but it is seen in many natural systems. For example, snowflakes, spider webs, cauliflowers, eddies and whorls in fluids, etc. exhibit self-organization. Fractal form is an example of self-organization. Any natural pattern that shows organization on every level of magnification is the product of some mechanism of self-organization.

There is a crucial difference between self-organization and adaptivity, however. Whereas self-organization is driven primarily by internal constraints, adaptivity is driven by external constraints, so the system has to be open. A system may self-organize but not be adaptive; it is independent of its surroundings—that is, closed. A complex fractal need not adapt to anything outside its own symmetry. In that case, it develops the same intricate pattern regardless of where it grows. An adaptive system, on the other hand, whether it self-organizes or not, develops according to input from its surroundings. A snowflake-shaped city plan may be interesting because of the fractal interfaces it offers; yet it does not adapt to human activities. The same goes for a fractal pattern on a building—it's really only an abstract decoration.

A.18.2 Appendix 2: Fractal Distribution of Project Funding and Urban Elements (p. 77)

A large lump development includes large projects, but very few medium and small projects. The total amount of money allocated invariably nowadays goes to these large projects; and the larger the project, the more chance it has of being funded. This situation destroys the urban fabric, for the following reason. Ongoing repair of the fabric also requires the allocation of funds for a large variety of projects on all the intermediate levels of scale, and most importantly, for an enormous number of very small projects. What happens in practice is that the giant projects eat up all the available money, and therefore leave nothing to be spent on smaller and intermediate-size construction. Without repair, the entire city decays.

A funding distribution skewed heavily towards the large scale gives rise to a particular philosophy of urban growth. By ignoring the small and intermediate scales, urban actions become interventions, and then turn exclusively to the large scale. Any urban solution is erroneously believed to succeed only on the largest scale. Repair of existing buildings is deemed unimaginative or uneconomic, and piecemeal growth by adding successively to existing structures is not even seriously considered. The organic growth of cities, such as occurred for millennia to generate the best-loved urban regions all over the world, is ruled out. This philosophy has transformed our cities by replacing their natural, fractal structure with enormous, unlivable apartment blocks and unused urban plazas.

Traditional cities and towns contain urban elements of many different sizes; from the largest buildings down to street furniture, bollards, and potted plants. I claim that a necessary though not sufficient condition for a living city is that urban units be distributed according to an inverse-power law scaling (where the number of components is inversely proportional to their size). The larger buildings and open spaces should be few, and increase in number as their size decreases. Most important, there must be smaller urban elements, in increasing numbers, down to the human scale. These include clearly-defined subdivisions of larger units, as well as separate autonomous structures. The hierarchy does not stop there, however, but should continue through architectural scales in buildings, into the structural scales found in natural materials.

A.18.3 Appendix 3: We Connect Emotionally to Specific Pieces of the Environment (p. 159)

We love a city when we can connect to it intimately. We retain a warm memory of that interaction. This memory consists of visual, olfactory, acoustical, and tactile connections. All of these memories can be formed only on the pedestrian level, far below in scale than the shortest walkable path. Our largely subconscious memory of a city is formed on a visceral level, on the physical scale of our own bodies. The "soul" of a city exists precisely on its smallest architectural scales. This turns out to include the "detritus" which modernism tried so hard to eliminate—unaligned and crooked walls, a bit of color, peeling paint, architectural ornaments, a step, a sidewalk tree, a portion of pavement, something to lean against, someplace to sit down outside, etc.

The anti-fractal movement of the twentieth century began with a call to destroy ornament. Architectural ornament is an intrinsic part of the entire city, however, and destroying it destroys one segment of the city's scales. Such an action erases the levels in the urban hierarchy spanning the scales 1 mm to 1 m. Soon afterwards, structures that anchored urban space—built structures ranging from 1 m to 3 m, such as kiosks, benches, porticoes, gazebos, low walls for sitting, etc.—were erased. Last came the elimination of sidewalks and the pedestrian connectivity of nearby buildings. What was left was only appropriate to the automobile city, not for pedestrian movement.

The pedestrian city has something important to offer, namely—an emotionally nourishing physical environment. There is visual excitement, the joy of physical movement, the thrilling experience of vibrant city life, the sensory stimulation from urban space filled with other people of different types and different ages. Le Corbusier despised all of this, and he went about eliminating it systematically via the CIAM planning rules. His books on urbanism espouse only the delights of driving around in a sports car. The elimination of urban space, connected green space, and the human scale from the urban fabric removed the unique set of forces that generate and support the pedestrian city.

Urban life requires a connected network of pedestrian urban spaces, whose sizes obey an inverse-power distribution. A multiplicity of pedestrian paths is harbored and protected by open and semi-enclosed urban spaces. One cannot exist without the other. The network of urban space coincides with and supports the network of pedestrian paths. Architects no longer design urban spaces that people wish to spend time in, however, and any built urban spaces are totally disconnected from the pedestrian network, hence from each other.