# GENERATIVE URBAN DESIGN

Review and theoretical analysis.

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***Abstract-*** **Generative Urban Design is a relatively new Artificial Intelligence tool that aims to streamline the design process that would normally require several days or weeks to deliver results by providing countless design options that fully meet the requirements established by the project; Generative design has been used mainly in the field of industrial design; In recent years he has migrated to the fields of architecture and urban planning. The objective of this article is a review of the theoretical basis on which Generative Urban Design is based. This review aims to increase the understanding of the theories on which the operating rules of Generative Urban Design Artificial Intelligence (AI) programs are established.**

***Key Words*: Generative Design, Organized Complexity, Parametric Urbanism, Artificial Intelligence.**

## INTRODUCTION

The use of computational support for urban planning and design is mainly limited to modelling. Its use for performance analysis, either to inform the design process or to evaluate design solutions, while available, is still rare. Part of the problem can be the difficulty of conferring to a computer system the resolution of complex projects such as urban ones due to the large number of actors and variables involved. However, in the use of artificial intelligence, the system, like any other computer program, responds to the data provided to solve the problem and consequently the program uses logarithms that allow it to learn from the type of information, subsequently generating adequate solutions for the type of projects that are worked on regularly.

It is possible to mention that the development of artificial intelligence computer programs related to urban design obeys not only a process of technological evolution and practicality, but also theoretical processes that began to take shape around the 1960s, understanding the city as a complex entity. The following paragraphs seek to analyze the theoretical basis that comprises generative urban design.

## GENERATIVE METHODS AND COMPLEXITY.

Jane Jacobs expounded on the implications of the phenomenon of "organized complexity" for urban planners and urban designers in the last chapter of her landmark book The Death and Life of Great American Cities (1961). His influence on the discipline of urban planning, and on subsequent thinking about process and generativity, is undeniable. In the chapter called "The kind of problem that is a city" of his aforementioned work, Jacobs lucidly analyzes the implications of the scientific advances that were taking place at the time, in particular, the understanding of complex systems in which a series of factors were interrelated. in an organic whole. This was important to planners because they needed to be sure they were thinking about the right kind of problem and using the right tools to solve it.

Science, Jacobs wrote, had grown in the last 400 years from Newtonian, "two-variable" science to the other extreme of statistical phenomena, in which innumerable variables interacted. This trend reached its zenith at the beginning of the 20th century and fueled the phenomenal growth of industrial technology in its early phases. Gradually, however, 20th-century science began to understand the realm in between, where more than two variables interacted in important ways. This new domain opened up "immense and brilliant progress" for the life sciences, which has fueled much of the revolutionary work in genetics and other fields. In fact, since 1961, progress in this field has only accelerated, bringing amazing new insights into embryology, morphogenesis, cognition, and many other fields outside of the life sciences as well. Jacobs was one of the first to see the implications for urban design and planning.

But planning and architecture, he pointed out, were lagging behind, still trying to treat city problems as simple two-variable simplicity problems (so many jobs here, so many houses there) or statistics problems of future populations. managed, almost like files in a drawer. They misunderstood the type of problem and the challenges that are a city, with adverse results.

This amounted to a devastating critique of the top-down approach to master planning, from the highly influential Garden Cities movement, which sought to carefully isolate and segregate planning variables such as housing and employment down to statistically informed ones." towers in the park" by Le Corbusier and other modernists, relying on the statistical management of family sizes and income groups in schemes that conceptually do not look so much like giant filing cabinets.

With these techniques, it was possible not only to conceive of people, their income, their spending money, and their housing as fundamentally problems in disorganized complexity, amenable to problems of simplicity once ranges and averages were worked out, but also to conceive of dry traffic. , industry, parks and even cultural facilities as components of a disorganized complexity, convertible into problems of simplicity. Fuller & Moore [5] argue this as a disastrous strategy, likely to overlook critical organic relationships and likely to result in dysfunctional, sterile and oppressive environments, as long as we cling to unexamined assumptions that we are dealing with a problem in the physical sciences, planning of the city cannot progress, of course it stagnates. It lacks the first requisite for a progressive and practical body of thought: recognition of the type of problem at hand. Failing this, you have found the shortest distance to a dead end [5].

Processes, says Jacobs, are essential in cities and in the ways in which we must interact with them. The neat segregation of previous planning methods should be discarded, in favor of a more diverse and mixed model, managed not by simplistic top-down schemes, but by a kind of diagnostic approach, which seeks to understand and treat the existing system, transforming it. to a healthier state, almost like a medical professional would.

In the years since Jacobs' landmark work, many authors and practitioners have paid tribute to his insights. However, Jacobs reportedly found this irritating. The planners, in particular, came under his continuing harsh criticism for failing to respond to his criticism, worse still, for pretending to honor his ideas while in fact continuing with disastrous conventional policies. To her, apparently, the lessons of process and generativity embodied in organized complexity were not being taken seriously enough.

In the intervening years, several other prominent planners have taken up the challenge of dealing more effectively with "organized complexity." Bill Hillier, professor of architectural and urban morphology at the University 's Bartlett School of Planning College London, developed his theory of so-called "spatial syntax", a methodology that maps connective relationships within a spatial system and expresses the global connective properties of each element. In doing so, Hillier has devised an elegant tool for displaying, in discrete units, the results of a complex set of connections of a number of globally interacting spatial variables. A street segment that is well connected within its overall context shows high connectivity and therefore could be particularly appropriate for a retail function or civic element. In this way, local functions emerge from the generative properties of global ones, in exactly the same way, Hillier argues, as they did in many traditional organic cities [7]. Mike Batty , Hillier's colleague at UCL, has also developed a number of methodologies for analyzing and manipulating environmental complexity. Its "Advanced Spatial Analysis Center" has used generative algorithms to analyze various organic patterns and their generative rules. Batty and his team have paid particular attention to the properties of "self-organization," the tendency of systems to develop patterns of organized complexity spontaneously as a result of algorithmic sequences of activity. Just as flocks of birds form large-scale coherent patterns from simple distance rules followed by each bird, residents of an informal city can build remarkably coherent roads and other structures by following relatively simple rules [3].

These insights are parallel to and clearly based on the rapid developments in complexity science in general, and in particular the phenomenon known as 'emergence'. Researchers have been able to identify with mathematical precision the processes that give rise to complex structures from a seemingly simple set of rules, with useful implications for game theory, economics, biology, physics, meteorology, and many other fields. . In the fields of urban planning and design, insights can be used to understand the relationship between complex urban form and relatively simple generative rules, such as those followed by a group of actors in a construction process.

Batty 's tools is that they have applied these insights to the urban toolkit available to mainstream practitioners, indeed, to regrow urban complexity that previously existed or could potentially exist, with desirable results. Hillier's analytical technique, in particular, has been tried several times with remarkable success. His analysis of the proposed alteration of London's Trafalgar Square predicted a 16-fold increase in pedestrian activity. The actual results of the work, Hillier reports, came very close to that prediction.

**GENERATIVE DESIGN**

At present, the big cities around the world have presented an unprecedented development in part due to the incorporation of new technologies in the field of communications, architecture and construction; Within this incorporation of technology, artificial intelligence (AI) systems have gained more and more territory due to their great efficiency. Generative design has been applied in various industries ranging from automotive manufacturing, aerospace, and even architecture. In the year 1968 Christopher Alexander defines what could be called the bases of generative design that he then mentions as "generative systems" in which a system whose parts and rules will incrementally create the necessary holistic properties of the system on their own, and already at the beginning of the 21st century, Janssen, Frazer and Ming-Xi [8] integrate a series of genetic algorithms into the search processes for architectural forms, thus developing the first morphogenetic applications of design.

In the context of urbanism, the concept of generative design originates again from the first studies of Christopher Alexander and associates in the mid-1980s, in his book A New Theory of Urban Design", in this text they study a type of urban growth process, which is fragmentary, incremental and gradual, in which coherent ensembles are created within the urban fabric. Based on this, Alexander [1] they claim that large-scale order would emerge organically from the cooperation of individual actions. It is also worth mentioning that previous years Kevin Lynch defined "site planning" with certain implicit arguments in favor of generative urbanism. Lynch [12], mentions that only main roads, public facilities and the main landscape structure should be planned. The subdivision of internal areas (i.e., residential lots and streets) should be done when the actual building demand occurs within small sectors, from that perspective it can be said that it anticipates "future" techniques in which the computer or rather a software will allow designing, displaying and evaluating a set of events instead of a restricted group of stages.

It is also important to consider the focus on spatial planning. In this context, Salingaros [15] defined "organized complexity" as the source of planned morphological coherence. By arguing coupling as the process of building local connections between urban elements, it would basically be a planning perspective of urban design within complexity. Gerrits [6] addressed a new (evolutionary) understanding of planning and design in urbanism, in which, rather than completely composing the ultimate collective form in the name of city design, what he suggests is urban ordering through control of the individual acts of design within a flexible framework coordinated genetically by local codes.

Already in a current context with greater technological development, design generativity is basically described as the use of step-by-step design processes driven by the sequential collaboration of the participants involved, Kallioras & Lagaros [9] mention that (generative design can be defined as an assisted procedure. by computer in which case automatically a series of designs are proposed with the use of algorithms instructed to respect the needs and restrictions of the user, in a simple way a program that uses algorithms that give countless responses framed in the needs established by the designer.

The general trend described above actually goes hand in hand if it can be mentioned with the emerging idea of planning without a plan. However, despite the fact that there are theoretical perspectives on generative design, the already operational vision of generative urbanism continues to be developed, with few examples in which it has already been used. In this framework, design techniques through the full use of generative software suggest a serious methodological basis for practicing an approach to urbanism that is essentially adaptive and flexible as an alternative to planning with traditional methods.

### PARAMETRIC URBANISM

Considering both the emerging use of parametric design in urban projects and its intrinsic capacity for pattern formation, one might wonder if parametric design has the potential to define a new approach to urban planning and design in the name of "urbanism". parametric". To call a design paradigm in urbanism new, it is convenient to clarify both the characteristics of its spatial (morphological) and sociopolitical assumptions. In this sense, the clearest idea about the affirmation of "parametric urbanism" can be found again in the writings of the architect Patrik Schumacher, in a reading on Parametricism and the Societal Function of Architecture [16] adapts the parametric approach to urbanism, suggesting parametric design as a response to the need to establish and maintain a complex order within the evolving urban field. The term "field", in this context, connotes the theoretical continuity between the so-called parametric urbanism and the urban landscape. The "field condition", is relational, since the general form is characterized by a "series of intricate local rules" of aggregation rather than geometric compositional systems [2]. By simplifying, in this way a form of spatial coherence is ensured through small and incremental transitions and local variations that avoid fragmentation of the area. Already in the urban context, this conceptualization indicates a spatial form generated through an extensive network of zones demarcated by superimposed surfaces of the built terrain.

The practical application of the conceptual model argued by Allen [2], can be found in the parametric urban models that suggest a substantial change in the perception of urban form. For Schumacher [17] the associative geometry generated by parametric design alters the traditional understanding of 'space' through the discrete distinction of form and background. Thus, the concept inevitably challenges the familiar notion of "district" as one of the fundamental elements of the urban image. While the conventional feel of an urban district is characterized by recognizable borders that condition the feeling of 'inside' and 'outside' within the fabric [11], the smooth transition and continuous change in the morphology of the fields by urban parametric design diffuse such distinction. The established typologies of urban form defined by the zones and discrete objects are replaced by a new computer generated morphology defined by the relational fields of the associated urban elements, ie. pathways and building envelopes.

For Schumacher [17], this it means a remarkable shift from the traditional idea of delimiting urban space, through the composition of a few objects, to acts of organization and articulation of complex patterns generated with countless parametrically-generated building blocks. This approach is basically justified by the contemporary socio-economic and cultural context. For him, the cities of the post-Fordist network society require flexibility and variation in growth and transformation through continuous communication. Control of the self-regulating urban system can only be managed by rule-based computational processes rather than composition schemes. It is possible to affirm that behind this statement, an ideal model of a "parametric city" is inferred, supported by an analogy of complex spatiality and the varied order of ecosystems.

### PARAMETRIC DESIGN AS A GENERATIVE SYSTEM

In computational terms, generative systems involve blended procedures whereby simple geometric shapes (lines, planes, and volumes) are searched through different orderings to achieve a host of novel compound shapes and patterns. Although generative thinking has always been intrinsic to design thinking throughout history [13], advanced computing procedures have enabled designers to enhance the generative capacity of the design process by simulating endless potential solutions through advanced information processing, unlocking of the early cognitive limitations of the first programs in the simulation of complex shapes and patterns [20]. In this context, as a kind of generative design method, parametric design proposes highly complex variations through fully controlled algorithms. As a tool that works with generative algorithms creating hierarchical relationships, and involving a large number of inputs controlled by few processing rules, parametric design models can be considered within the notion of organized complexity. Due to their own orientation to the way geometric components are linked in some interdependence, in addition to the key concern of shape generation, parametric models are also considered to be in the class of so-called associative design [19],. It means that any change in one of the parameters of a component within the generative system ends with a relational transformation within the other components in the parametric models. Parametric models do not directly specify a design object as a target, but instead encode the design procedure that generates geometric variations within established parameters [4].

According to Sakamoto and Meredith [18], parametrics is a technique that allows the designer to create and transform design objects in an integral way by controlling the interdependent relationships between the parts in the entire geometric system. It can then be said that parametric design is the study of compositional systems by defining the relationships between the dimensions of the components in the way that they depend on various parameters [14]. Besides the ease of variation due to the innumerable design iterations within the models, the suggested geometric precision to control the shape of the design is the main power of the parametric design models. From a computational perspective, the most crucial feature of parametric design is the associative geometry established by the generative algorithm, that is, that all parts and complete subsystems of the form (i.e., network, envelopes, and subdivisions) are correlated with each other and They depend on common parameters. A single change to a component is received as processing input and triggers a chain of reactions in the other associative parts of the model [21]. For example, any controlled modification to the grid density value within a parametric urban model can automatically execute observed variations in the fabric grid design synchronously. This kind of algorithmic control over the myriad elements in a pattern-like composition system while manipulating their properties while preserving harmonious morphological variations cannot be accomplished with such ease by traditional design-by-drawing methods [18].

Design techniques based on algorithmic lines of code radically alter drawing-based design models (similar to CAD). By being able to work with interactive design components, design work has the opportunity to explore larger solution spaces, involving larger numbers of alternative shapes generated by different sets of parameters. The basic application of the parametric models derives in the establishment of an algorithm that relates the basic components of the composition of the design (lines, points and curves), which are not represented graphically at the beginning . In addition to the geometric components, the parametric platform consists of a series of functions that are linked by multiple connections. The complete set of relationships between the components of the system basically involves input data and processing operations that generate the visual results [10]. Through the operation of the algorithm, the simple set of numerical data is processed as the information that generates the consecutive geometry. That is, instead of drawing the line directly, the designer specifies the modifiable attributes of the line (i.e. start point, length, and direction) and the model generates its associative geometry itself.

**CONCLUSION**

Taking into account the complexity of cities and the fundamental tasks of the designer in the domain of computational design exposed here, it is possible to affirm that, in the case of a common use of parametric design in urban planning, it would be expected that the conventional role of urban designers will go from creation to control or supervision in the formation of new proposals for planned urban fabrics. This is not to say that designers are relegated to just an external controller, but they may have to transform their role in making design decisions. In terms of the generative methods, urban designers will be able to get involved in establishing the design rules to be followed by the algorithm and in the evaluation of the models emerged from the program in terms of the limitations established by the context and the preliminary design criteria.

In this context, it is not pertinent to think that urban designers should behave like programmers who write lines of computer code, but basically it is expected that they rationalize the design through explicit design rules and parameters to be integrated into the algorithms or, where appropriate, into the software. selected. However, there is no doubt that the new profile of the designer will require basic operating knowledge of computers for efficient participation in the programming phase. Another point that makes generative design significant for urbanism is that, unlike static models that ignore the dimension of time, generative design suggests various simultaneous types of modeling that allow one to simulate and observe the changing shape and behavior of the various design proposals over time. This feature represents an advantageous potential to challenge conventional urban design procedures based on static plans. Through real-time simulations of urban shape generation with actual codes, the emergent performance of existing rule systems can be efficiently evaluated.

However, the potential and benefits of generative urban design will always be subject to strong and well-established methodical connections between actual urban land development and planning processes and the design model. Unlike its first iteration in design history, this new compositional approach to urbanism would not be followed by a master architect composing large chunks of urban fabric with a pen, but by an architect shaping the fields of a parameterized cityscape with an algorithm.

**REFERENCES:**

1. Alexander, C., Neis, H., Anninou , A., & King, I. (1987). A New Theory of Urban Design. In Landscape Journal . Oxford University Press, Inc.
2. Allen, S. (1997). From object to field: field conditions in architecture and urbanism. Architectural Design , 127 (5–6), 24–31.
3. Batty, M., Couclelis , H., & Eichen, M. (1997). Urban Systems as Cellular Automata. Environment and Planning B: Planning and Design , 24 (1970), 159–164. http://journals.sagepub.com/doi/pdf/10.1068/b240159
4. Dino, IG (2012). Creative design exploration by parametric generative systems in architecture. Metu Journal of the Faculty of Architecture , 29 (1), 207–224. https://doi.org/10.4305/METU.JFA.2012.1.12
5. Fuller, M., & Moore, R. (2017). The death and life of Great American Cities. In J. Jacobs (Ed.), The Death and Life of Great American Cities (Vintage Bo). Random House. https://doi.org/10.4324/9781912282661

6. Gerrits, L. (2011). Cities, Design and Evolution. Planning Theory & Practice , 12 (3), 470–472. https://doi.org/10.1080/14649357.2011.617505
7. Hillier, B. (2007). Space is the machine. In Design Studies (Electronic, Vol. 18, Issue 3). Space Syntax. https://doi.org/10.1016/s0142-694x(97)89854-7
8. Janssen,J P., Frazer, J., & Ming-Xi, T. (2002). Evolutionary design systems and generative processes. Applied Intelligence , 16 (2), 119–128. https://doi.org/10.1023/A:1013618703385
9. Kallioras , A., & Lagaros , ND (2020). Deep learning based generative design. Procedia Manufacturing , 44 , 591–598. https://doi.org/10.1016/j.promfg.2020.02.251
10. Khabazi , Z. (2010). Generative Algorithms using Grasshopper. Morphogenesis , p 173.
11. Lynch, K. (1960). The Image of the City (Vol. 21, Issue 1). MIT Press. https://doi.org/10.2307/427643
12. Lynch, K. (1981). Site Planning (2nd ed.). MIT Press.
13. Mitchell, WJ (William J. (1990). The logic of architecture : design, computation, and cognition . MIT Press. https://archive.org/details/logicofarchitect00mitc/page/292/mode/2up?q=generative
14. Moretti, L., & Fondazione , L. (2009). Luigi Moretti and the Foundation della Rocca / Urbanistica e Ricerca Operativa (GEDV Vita, Ed.). GB Publishing .
15. Salingaros , N.A. (2000). Complexity and urban coherence. Journal of Urban Design , 5 (3), 291–316. https://doi.org/10.1080/713683969
16. Schumacher, P. (2011a). Parametricism and the Societal Function of Architecture . https://www.patrikschumacher.com/Texts/The Societal Function of Architecture.html
17. Schumacher, P. (2011b). The Autopoiesis of Architecture, Volume I: A New Framework for Architecture. In John Wiley & Sons Ltd: Vol. I (Issue 9).
18. Tomoko Sakamoto, Michael Meredith, AF (2008). From Control to Design: Parametric/algorithmic Architecture . Act -D.
19. Trummer, P. (2011). Associative design: from type to population. In Computational Design Thinking (pp. 179–197). John Wiley & Sons Ltd.
20. Verebes, T. (2013). Masterplanning the Adaptive City. In T. Verebes (Ed.), Masterplanning the Adaptive City (First Edit). Routledge. https://doi.org/10.4324/9780203428054
21. Woodbury, R. (2010). Elements of Parametric Design. In Routledge (Vol. 1). Routledge. http://dx.doi.org/10.1016/j.asw.2013.04.001%5Cnhttp://journals.cambridge.org/abstract_S0140525X00005756%5CnLib scanned%5Cnhttp://www.br-ie.org/pub/index .php/rbie/article/view/1293%5Cnhttp://www-psych.nmsu.edu/~pfoltz/reprints/Edmedia99.html%5Cnhttp://urd.