erase the first. Most important, we must not confuse the totally distinct characteristics of these two networks and apply them to the wrong one.

## Legislation Prevents or Encourages Reconstruction

There are presently in place neighborhood review boards, homeowners' associations, etc., that have some influence on new building and the rebuilding of the urban fabric. These oversight entities should begin to use our prescriptions for the regeneration of that suburb or region (abandoning their present guidelines, most of which lead away from a sustainable urban fabric). This concept should work no less in any conventional suburb than in a downtown, where the process of approval is now taken for granted. The idea is to implement all these proposed guidelines in practical form.

We certainly take the view that urbanists should not get mired in endless legal wrangling, possibly getting "shot down" by some hierarchical authority. But often it is impossible to make the kinds of design changes needed without at least suspending the present requirements. That may be a particularly bad problem in the United States, where Le Corbusier-style segregated zoning and unbelievably large building setbacks, wide roads, low densities, etc., have such a stranglehold because they are legislated into codes. Unfortunately, this postwar planning model is still being embraced by other countries who seek to achieve United States-style prosperity, and who are not yet aware of the model's growing disadvantages. But here, too, we need an incremental strategy. Our recommendation is that urbanists take whatever steps they can based on the local conditions and the local political will, and not waste time tilting at windmills.

In the above section entitled "The Small-Scale Approach," we prioritize coding and legal action. Regarding previous arguments about top-down and bottom-up strategies, immediate short-term interventions (as well as the possibility to impact the larger context with smaller economic interventions, etc.), there exists a definite dilemma here. Political work and legal strategies are often tedious, long, and depend upon triggering top-down effects. Also, the relationship between legal action, coding, and their implementation is an enormously time-consuming process, involving a lot of lobbying and long-term strategies. That's the reason why we do not insist on a definite sequence for the stages of urban action. Sometimes, the coding could be a priority; for example, the coding could be a limited project that depends on coding only. At other times, there could be a larger coding effort on the regional scale like the Traditional Neighborhood Codes developed by Duany Plater-Zyberk & Co.[8]

Physical urban and architectural changes can even happen without necessarily introducing new codes, or they can take advantage of legal ambiguities. Interestingly, most projects need to be accompanied by a written document including legal and code aspects, but one wouldn't say that the coding was the most essential—it is rather the integration of didactic physical design and subtle, integrated coding that empowers the project. We definitely agree with the incredible emergency and need for a full and comprehensive legal revision and recoding strategy. In the context of this paper, however, we clearly stress feasible, short-term, tangible policies and actions. We balance these goals within a larger context of more thorough political and legal objectives to be aimed at. We are more supportive of efforts on an intermediate time frame. It will be the combined actions at various scales and levels that will constitute an overwhelming challenge to the obsoleteness of legal planning inertia, and will finally accelerate massive and drastic overhaul.

Sometimes it is not even the local zoning that prevents suburban reconstruction. We and our associates have recently experienced enormous problems in Mississippi (following the devastation by hurricane Katrina) from onerous regulations. For example, the Department of Transportation refuses to budge on their wide-road protocols, including enormous building setbacks. The only way out of this impasse was achieved by New Urbanists marshalling the governor and other forces to come in and neutralize the stranglehold of the Department of Transportation. The United States Federal Emergency Management Agency (FEMA) has also required draconian building forms in order to get flood insurance: no street-level activities; everything up on stilts; all garages below, etc. If so much as *one* resident in a community builds their house in a nonconforming way, the *entire* community gets denied flood insurance. This effectively means that they get denied mortgages!

## Conclusion

The evidence already shows that the modern suburb in its current, disintegrated form (sprawl) is not a sustainable form of development, and needs to be reformed. This problem is particularly important as the developing world looks to the developed world for leadership in its own new, unavoidable suburban development. But this reform need not take away the characteristics that drove suburban expansion in the first place: a greener and more rural, livable environment, access to larger homes on larger properties, use of the automobile as an option (and not a necessity), and so on. Instead, reform needs to be aimed at creating a richer, more connected structure, allowing alternative modes of transport, greater ranges and locations for activities, and greater coverage of property. In this sense, the reforms presented here are less about limiting choice and more about expanding choice and diversity.





# COMPLEX SYSTEMS THINKING AND NEW URBANISM

T. IRENE SANDERS

This essay explores two questions: first, what have scientists learned about the structure, behavior, and ongoing development of complex systems that might be useful to architects, city planners, engineers, community leaders, and others working to revitalize fading urban areas, reenvision existing cityscapes, and cultivate the ongoing evolution of dynamic communities? Second, what can complexity science tell us about the characteristics, underlying dynamics, and patterns of interaction that encourage the emergence of beautiful vibrant cities that are alive with the qualities we recognize as community?

In exploring these questions, this essay responds to the strategic imperative of the New Urbanism to foster communities that are alive with the qualities that connect and nurture people and place. It provides an overview of complexity science; contrasts traditional planning, design, and engineering methods with the characteristics of complex adaptive systems; describes a new planning paradigm; and offers five food-for-thought observations for New Urbanists.

## What Is Complexity?

The challenges we face today, and those we'll confront in the future, require new ways of thinking about and understanding the complex, interconnected, and rapidly changing world in which we live and work. Complexity science provides a new theory-driven framework for thinking about, understanding, and influencing the dynamics of complex systems, issues, and emerging situations.[1] Insights from complex systems research also provide an exciting new lens for exploring the development and ongoing evolution of cities and neighborhoods, as well as their interactions with the larger environment or context of which they are a part.[2]

From the moment of the big bang to the present the universe has grown increasingly more complex; from a primordial soup of particles, we now have stars, solar systems, ecosystems, and human societies. In the last twenty-five years, rapid advances in high-speed computing and computer graphics have created a revolution in the scientific understanding of complex systems. The same technologies that have given us instant access to news and information from around the world—allowing us to think and act as one vast interconnected system—have made it possible for scientists to study the nonlinear dynamics of systems that were once either hopelessly inaccessible or took years to understand.[3]

As a result, we now have the ability to move beyond the old reductionist paradigm; to look at whole systems, to study the interactions of many interdependent variables, and to explore the underlying principles, structure, and dynamics of change in complex physical, biological, and social systems. From health care to city planning and international politics, the new science of complex systems is laying the foundation for a fundamental shift in how we view the world, and with it the need for a shift in how we think about, organize, plan for, and lead twenty-first-century organizations and communities.[4]

Simply stated, complexity arises in situations where "an increasing number of independent variables begin interacting in interdependent and unpredictable ways."[5] Traffic, the weather, the stock market, and the United Nations are examples of complex systems.

Complexity science represents a growing body of interdisciplinary knowledge about the structure, behavior, and dynamics of change in a specific category of complex systems known as *complex adaptive systems* (CAS). Most of the world is comprised of complex adaptive systems—open evolutionary systems such as a rain forest, a business, a society, our immune systems, the World Wide Web, or the rapidly globalizing world economy—where the components are strongly interrelated, self-organizing, and dynamic.[6]

In recent years, scientists have identified many of the basic characteristics and principles by which complex adaptive systems organize, operate, and evolve, leading to important insights and research implications in almost every field. As a result, we are witnessing the integration of knowledge across disciplines and the emergence of new concepts, tools, and a new vocabulary of complex systems thinking.[7]

Across the frontiers of science, this new, more complete, whole-systems approach is replacing the old reductionist paradigm, where scientists traditionally tried to understand and describe the dynamics of systems by studying and describing their component parts. Complexity science is moving us away from a linear, mechanistic view of the world, to one based on nonlinear dynamics, evolutionary development, and systems thinking.[8] It represents a dramatic new way of looking at things—not merely looking at more things at once.

Extending our understanding about the dynamics of complex systems into the domain of human systems is the new frontier. When understood and used as a sense-making framework, insights from complex systems research provide powerful new concepts, tools, and a set of questions that can be used to understand and influence *complex sociopolitical human systems*.[9]

Of the many insights arising from complex systems research, none was more surprising or useful to researchers than the finding that complex adaptive systems across the board—whether physical, biological, or social—share a significant number of the following characteristics.[10] When used together they provide a set of insights and questions that form the framework of a new planning paradigm—a complex adaptive systems approach to twenty-first-century urban design.

I think the next century will be the century of complexity.
—Stephen Hawking, January 2000

## Complex Adaptive Systems Characteristics (CASC 1–10)

1. Diversity among the components; heterogeneous parts or "agents;" sources of novelty in the system. Includes some sort of natural selection processes within agent groups that ensure ongoing evolution, regeneration, and adaptation.
2. Nonlinear interactions; widespread information flow and feedback loops.
3. Self-organization; results from attractors in the system, and from adaptation to changes in the larger environment and other agents.
4. Local information processing; local interactions among autonomous agents. Typically agents "see" only their part of the system and act locally; no global control.
5. Emergence; exhibits unpredictable global behavior or patterns; spontaneous order emerges from local system interactions.
6. Adaptation; open and responsive to changes to the larger environment or context and to other agents in the system; continuously processing, learning, and incorporating new information; making boundaries hard to define.
7. Organization across multiple scales; agents in the system organized into groups or hierarchies of some sort, which influence how the system evolves over time.
8. Sensitivity to changes in initial conditions; small changes can create big results at some point in the future.
9. Non-equilibrium; most interesting behavior/creativity found at the "edge of chaos;" healthy systems operate in a dynamic state somewhere between the extremes of order and disorder, making it easier for them to adapt to changing conditions.
10. Best understood by observing the behavior—activities, processes, adaptation—of the whole system over time; qualitative descriptions and understanding versus quantitative descriptions alone.

## Cities as Complex Adaptive Systems

Complex systems research has given us a promising new way to describe and explain how societies form, adapt, and evolve in response to changing conditions.[11] The characteristics of complex adaptive systems (CASC 1–10) identified above provide a new lens through which to see and make sense of the underlying dynamics and patterns of interaction that create the emergent phenomena we call cities and neighborhoods.

Through the lens of complexity we see that cities and communities are not linear cause-and-effect systems, but rather dynamic systems where the variables (people, businesses, governments, etc.) are constantly interacting and changing—for better or worse—in response to each other, creating nonlinear feedback loops that either promote or deplete the life energy upon which their futures depend. As complex adaptive systems, communities are organized, coherent entities in which physical conditions, decisions, perceptions, and the social order are constantly changing.[12]

## Complexity: Framework for a New Planning Paradigm

Thinking of cities as complex adaptive systems challenges us to review and revise our current planning, engineering, and design methodologies, which in most cases reflect a more linear, Newtonian worldview. In undertaking such a review we need to ask ourselves: first, which methods recognize the properties of complex adaptive systems? Second, what kind of knowledge about the system is provided by the method?[13]

As an example, figure 1 reexamines *futures research methodologies* through the lens of complexity in an attempt to answer these two questions for those focused on the future and others concerned with developing better foresight methodologies, as opposed to traditional forecasting methods, which are based primarily on linear extrapolations. It attempts to describe a landscape where futures research methods are used.[14] The underlying matrix is divided into four quadrants each representing a different system paradigm, including a view about how the future is created.

Differences in the basic assumptions between these four approaches can be described in the following way: the vertical dimension looks at the nature of our possible understanding of the system, and the horizontal at our means of controlling, directing, or managing the system. In the vertical dimension design is contrasted with emergence. Engineering approaches and systems thinking represent design, and mathematical and social complexity represent more emergent processes. Vertically, the matrix represents an ontological view about the nature of things defined in terms of causality, and horizontally in terms of epistemology, i.e., what kind of knowledge can be achieved by which methods.[15]

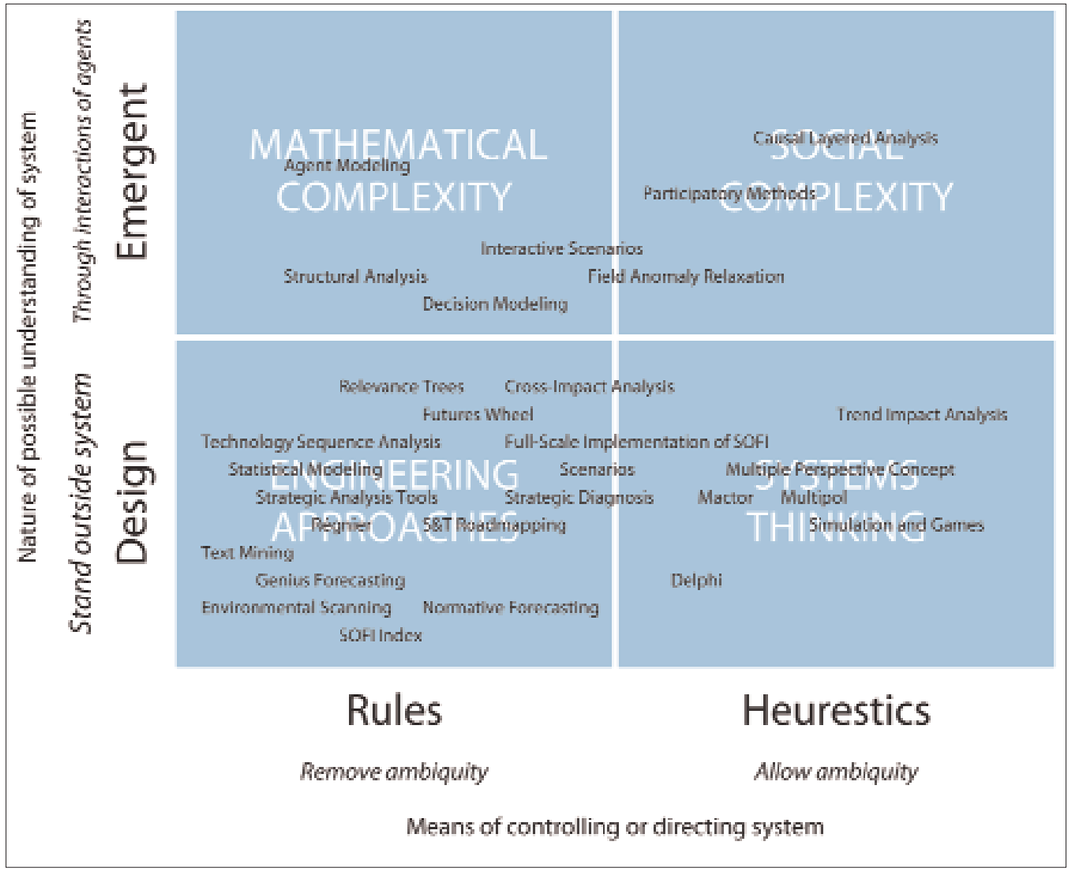


FIG. 1 Examining futures research methodologies through the lens of complexity.

Most methods designed to understand systems (and the future development of those systems) originated and are clustered in the engineering quadrant. Figure 1 helps us understand why we have difficulty using those methods to understand more complex, ambiguous, and emergent systems. It illustrates the point that most of the approaches we use today are inappropriate and ineffective in a complex and rapidly changing world, and it provides a template for rethinking and revising current methodologies.

## Summary: Food-for-Thought Observations for New Urbanists

These five complexity-based observations about cities and urban environments are offered as food-for-thought to those engaged in designing the communities of the future.

1. *Local interactions create self-organizing global patterns of community*. Emergence is one of the key insights from complex systems research. It refers to properties or a higher level of pattern created by the interactions of local agents in the system. What emerges does so naturally, and is not directed by a central commander or imposed by some outside source.[16]

The behavior of the whole cannot be predicted from one's knowledge of the parts of the system. In other words, the whole is greater than the sum of the parts. Complex systems often surprise us, and emergence is the process through which a system displays its creative and novel

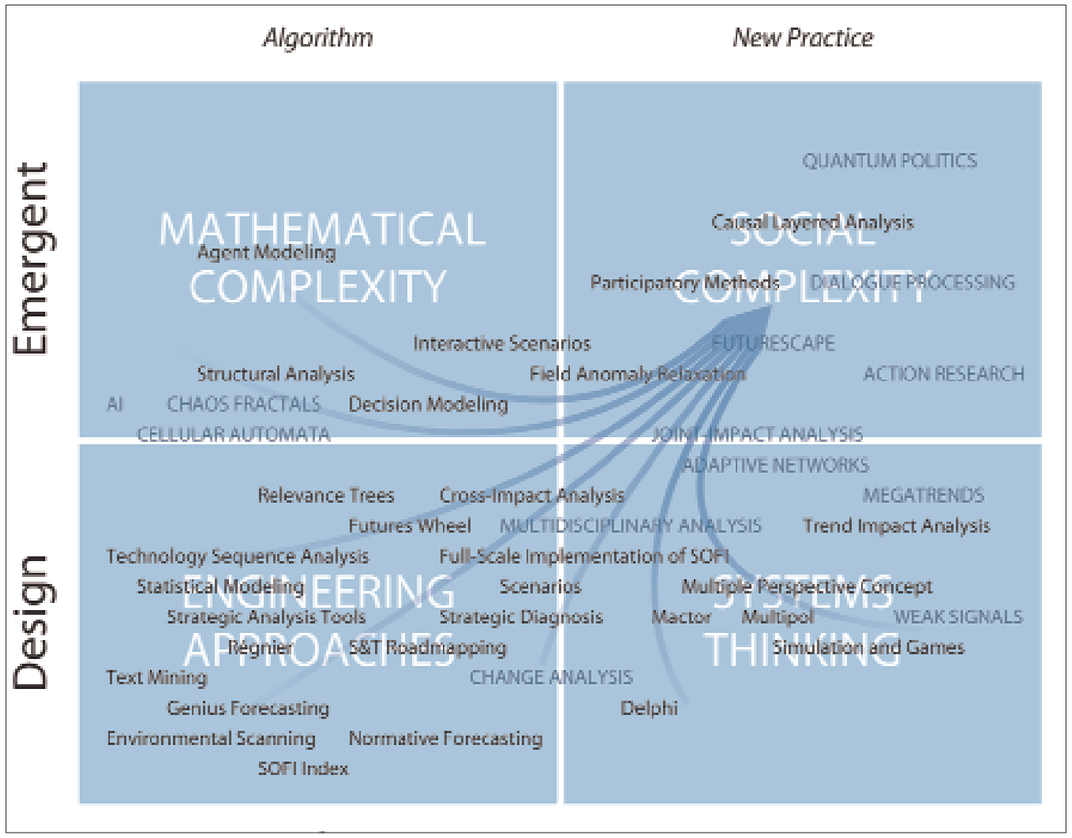


**FIG. 2** This diagram adds the Complex Systems Concepts–Tools Map, which is based on a complex adaptive systems view of the world. It provides an alternative, complementary causal view of systems and how things emerge (Aaltonen and Sanders 2006). Every discipline that adopts a complex systems view of the world needs to undertake this type of review.

behavior.[17] As an example, a computer program developed by Craig Reynolds in 1986 and known as "Boids" simulates the flocking behavior of birds by programming agents, or *boids*, to follow three simple rules: 1) maintain a minimum distance from other boids; 2) match the velocity of nearby boids; and 3) move toward the perceived center of nearby boids.

What appears to be very complex emergent behavior actually arises from a set of fairly simple underlying dynamics or rules. No central boid directs this process; the boids, acting only on local information gathered from their immediate neighbors and their environment, create the dynamic, elegant flocking patterns that are entirely unexpected; they cannot be predicted by just knowing the local rules defining what each boid does.[18]

Local, simple rules, motivations, and goals create complex self-organizing global behavior. Emergence helps us understand how community emerges from the local interactions of neighbors and neighborhoods with each other and with the larger environment of which they are a part.

How could positive interactions at all levels of a system be encouraged? When negative patterns emerge, how could the interactions be influenced in a more positive direction? What are the underlying rules and dynamics that encourage interactions and positive adaptation to changes in the larger environment or context?

2. *The vitality of living cities emerges from the interactions created by multiple, connected, diverse centers of activity*. As complex adaptive systems, cities are unique, in that they usually self-organize or form around some relatively stable attractor such as a geographic or climatic feature (river, mountains, seasonal temperature variations, etc.). Soon man-made structures or attractors (churches, schools, hospitals, farms, factories, etc.) add another layer of complexity as they create new patterns of interaction in an emerging community. These relatively stable geographic and man-made attractors serve as hubs of local activity, from which the emergent behavior or pattern of community arises.

The concepts of attractor and attraction are important to understand. Think about a tornado, for example. No external container or funnel gives a tornado its unique form. This dynamic, coherent, and focused system with a recognizable shape is formed by the interactions of the variables or attractors creating the tornado—moisture, heat, and wind rotation. A living city has many diverse and connected hubs or tornadoes of activity that give it its unique shape and personality.

What attractors can you identify in the old European cities we all love to visit? Most are characterized by multiple diverse centers of activity—cultural, commercial, educational, residential, and religious—connected by walkways, bridges, and most likely a central plaza where people spontaneously gather, celebrate, and protest.

Contrast these with the many lifeless urban renewal projects and downtown neighborhood developments where the concept of community includes Starbucks, Old Navy, a multiplex theater, a skateboard park, and restaurants surrounded by loft apartments and condos built in the midst of urban traffic and an uninviting cityscape. What's missing, and how could you encourage real interaction, connection, and vitality?

3. *Aesthetic coherence is created by recognizing and incorporating the fractal qualities of people, place, and environment*. The term fractal was coined in 1975 by mathematician Benoit Mandlebrot to describe a new concept in geometry. The word is derived from the Latin word *fractus*, meaning fragmented or irregular. *Fractal* geometry recognizes an order found within the irregular aspects of nature. It's an order that in the past we had not seen, because in a sense we didn't know how to see it—it doesn't fit the classical linear definition of order. The fractal concept helps us appreciate the orderly yet constantly changing world in which we live.[19]

There are two general characteristics that help us recognize this new type of order. First, *fractal forms are self-similar*.[20] Like ferns in a forest, bark on a tree, or the lines on our faces, patterns and shapes are repeated. Something in each new impression is familiar, a reflection of previous patterns and shapes.[21]

Second, *fractal forms are self-similar across scales*.[22]Patterns and shapes are repeated in finer and finer detail. The concept of self-similarity across scales has given us new ways to appreciate the special appeal of art and architecture. Patterns and shapes that are repeated in finer and finer detail add depth, texture, and a rich coherence to paintings and structures. The old European cathedrals are wonderful examples of self-similarity across scales, as are the paintings of Claude Monet and Vincent Van Gogh.[23]

There is an aesthetically pleasing quality to fractal forms in nature as they come together to create a beautiful whole. We respond positively to scenes where the buildings and landscape share a fractal quality. Frank Lloyd Wright had an intuitive feel for this concept, as do others who work to integrate their designs with nature. On the other hand, each of us could identify many buildings where the fractal quality is missing. These buildings jolt our senses and look like narcissistic, grotesque misfits in an otherwise richly textured city- or landscape.[24]

4. *A living city frames our interactions with subtle visual connections among people, place, and environment*. Every interaction takes place within a landscape that is captured in our unconscious mind, if not consciously recognized. If you put a picture frame around a quick conversation with a friend as you wait for the light to change at a busy crosswalk, what's in that picture frame around your interaction? Is it a park, a beautiful downtown cityscape, or buildings so high that you can't see the sky? Again, think about the cities you enjoy visiting or living in. What's in the picture? Living cities frame our interactions with views that invigorate our spirit and make us glad we're alive, too.

5. *A living city evolves within a larger context where emerging, new initial conditions will influence and shape its ongoing development*. As complex adaptive systems, cities are influenced and shaped by the larger context in which they operate. They must adapt to changes in the larger environment be they new traffic patterns, new hubs of activity, or the ups and downs of economic conditions.

The key to developing foresight about the future is to see and understand the dynamics of the big-picture context in which your decisions and designs are being made. What new initial or "perking" conditions are just over the horizon or under the radar that could dramatically influence the future of the cities you're working with? What local, regional, national, or international changes could go through your city like a bolt of lightning, rearranging its future overnight? How could you apply your thinking and planning resources now, so as to positively influence the future?[25]

## Conclusion

Cities are unique complex adaptive systems. New Urbanists need to know as much as possible about complex adaptive systems theory and research, and look for ways to apply the insights and thinking to their everyday work—our future depends on it.

## Note

The European Union report, "Business Knowledge Management: A Study on Market Prospects, Business Needs, and Technological Trends,"[26]uses the same model to assess organizational knowledge management in Europe, and to present a new initiative—Knowledge Management Made in Europe (KMME)—where the emerging opportunities for the European Union are seen to take place in the upper right quadrant—the field of social complexity.