RESEARCH AND PRACTICE

Metropolitan Development as a Complex System: A New Approach to Sustainability

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A major national debate is under way about the effects of the regulation of development and land use patterns on metropolitan economies. Because this is often framed around whether sprawling development patterns are harmful or beneficial to the economy and environment, we are seemingly presented with an either/or choice. This article asserts that the debate misses the reality that metropolitan development occurs as part of a complex system. If we view metropolitan development as a complex system, there is no fundamental conflict between environmental goals and economic development. Examining the case of California, the authors demonstrate how the relationship between these is part of a larger system involving fiscal policy, governance structure, infrastructure policy, and other factors. The authors propose three strategies for improving metropolitan system performance to ensure sustainable metropolitan economies and environments: developing and using indicators for self-organizing urban systems, collaboration and consensus building among metropolitan stakeholders, and metropolitan leadership.

> Buyers, sellers, administrations, streets, bridges, and building are always changing, so that a city's coherence is somehow imposed on a perpetual flux of people and structures. Like the standing wave in front of a rock in a fast-moving stream, a city is a pattern in time.
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> —John Holland (1995)

> Efficient firms cannot function for very long in inefficiently configured metropolitan regions.
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> —Richard H. Mattoon (1995), Federal Reserve Bank of Chicago

Debates over metropolitan development in the United States typically are grounded in the assumption that we must trade off between economic development and environment. They assume that economic growth causes environmental degradation and that environmental protection only cuts into the economy. The view that environment and economy are dichotomous is grounded in a concept of a zero-sum world. This way of thinking has led to bitter divisions among interests and scholars and has also made it virtually impossible to imagine a sustainable society in any realistic way. Either rich countries will have to reduce consumption drastically and poor ones be held back from wealth, or the environment will be destroyed. Cities will have to choose between clean

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environments and prosperity. They either will be developed according to the dictates of developers and the free market or according to the heavy-handed rule of regulators. But neither scenario is sustainable. In the first case, the metropolitan environment will become so undesirable that business will wither and people will move away. In the second, regulation will stifle entrepreneurship and reduce profits, destroying jobs and business. Increasingly in the United States, the more sophisticated businesses recognize that a quality environment is necessary to their own success (Mattoon, 1995; Myers Richter), and some environmentalists have concluded that a thriving economy offers resources to restore and protect the environment. But neither business nor environmental interests are unanimous or comfortable with such views; they go against too much that these players have assumed for too long.

New understandings of complex adaptive systems, however, provide an alternative view, in which environment and economy are no longer dichotomous. Complex systems thinking helps to dissolve this paradox while offering a workable approach to sustainability. This kind of thinking also provides planners with ways to understand the interrelationships of economics, public finance, and the environment in the metropolitan development system and to avoid the simplistic thinking that results in policies with counterintuitive and unanticipated negative consequences. Part of this new thinking involves accepting the surprising idea that control is neither possible nor desirable but that giving up the goal of control does not mean giving up. Certain strategies can make complex systems more adaptive and innovative and thus sustainable, but these are neither the top-down regulation nor the formal plan making and implementation that the current California legal system envisions. Conservative economists who argue for the wisdom of the distributed intelligence and parallel processing of information that markets represent are closer to the mark in understanding how to work within complex systems than are regulators who argue for tight control and attempt to enforce carefully crafted rules. On the other hand, such economists fail to take into account that economic motivations are only part of the many forces simultaneously at work.

In this article, we will build on insights emerging from the study of complex adaptive systems to reflect on how a multiplicity of institutions, practices, and motivations jointly interact to shape metropolitan development. We will rely on the example of California, where governance and interests are particularly fragmented and complex and where the failure to recognize the dynamics of complex systems has produced policies and laws with increasingly counterproductive and unsustainable results. We lay out some key ideas from complexity theory, illustrating their application in the California case, and then develop an alternative way to understand sustainability within a complex system framework. Finally, we suggest strategies to guide metropolitan development so that it can be more sustainable.

DEVELOPMENT DECISION MAKING IN CALIFORNIA

California is an excellent example for reflecting on the complex systems nature of metropolitan development. It is in constant change and evolution. With the exception of a few brief downturns, the state has been growing steadily so that it now is, based on its gross state product, the seventh largest economy in the world. Over the next decade, California's population is expected to grow by almost 20%, its job force by more than 17%, and its economy to more than a trillion dollars (Center for the Continuing Study of the California Economy, 1997). At the same time, it is renowned for a beautiful and diverse natural environment, which is at risk today as its limited water resources absorb the impacts of development, as its habitat for endangered species disappears, and as its air quality deteriorates. Although the state has long prospered, the path it is now on appears to be unsustainable. The state's governance mechanisms and incentive structures affecting the shaping of places are fragmented and confusing. How to intervene and effectively change the course of the state is not obvious to anyone. We will lay out here some of the factors that make California such a complex and challenging decision-making environment but that, paradoxically, also offer the opportunity to build a sustainable system—because of that very complexity and uncertainty.

In California, the state has land use control authority, but it has elected to transfer much—but not all—of this responsibility to local governments. Hence, cities and counties prepare general

plans, enact zoning and other land use regulations, impose development and impact fees, evaluate environmental impacts, and issue development permits. Simultaneously, a myriad of other special-purpose local governments carry out specific governmental functions, ranging from provision of water or transportation to education. A special-purpose local government may even do mosquito abatement. Hence, there are more than 7,000 units of local government (with 15,000 elected officials)[1] in California, many of which have independent decision-making authority that influences development. This maze of institutions makes public understanding of fiscal and governance responsibilities difficult. Moreover, each unit of government has challenges to operating effectively in such a fragmented context and little knowledge of what others are doing. There have been many reform efforts (e.g., California Constitution Revision Commission, 1996) but so far little success. Finally, land use decisions are also indirectly influenced by fiscal and regulatory decisions of federal agencies, such as the Environmental Protection Agency or the Department of Transportation.

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The state itself has no statewide general plan or strategy, but it does require every city and county government to prepare a general plan. The state sets the required content areas of local general plans and specifies processes for adoption, amendment, and adjudication. The general plan must be long range (20 years or more), comprehensive, and internally consistent. Land use planning and regulation are directed by city councils and county boards of supervisors, elected in nonpartisan elections, but much of the day-to-day decision making is carried out by appointed citizen planning commissions with the assistance of professional planners. There is little state oversight of the compliance of local governments with state planning law. Instead, the state relies on litigation by affected parties, such as developers, environmentalists, or neighborhood groups. The law requires that land use regulations be consistent with the general plan, for example, and this is often the subject of litigation among competing local interests. Another common subject for litigation is application of the California Environmental Quality Act, which permits challenges to environmental impact assessments of development projects when they are thought to be inadequate. General-purpose metropolitan or regional authorities do not exist, nor does the state review the content of plans for coordination purposes or for assessing the cumulative or interactive consequences of decisions.

California local jurisdictions as well as state agencies are subject to a wide range of competing pressures from organized interests, reflecting the diverse nature of the state. Particularly active groups represent agriculture, high technology, business, builders and real estate, nonprofit and affordable housing, labor unions, environmentalists, taxpayers, and neighborhoods. These interest groups make land use planning and development even more complex, as well as highly controversial. Dealing with them can make the process for development lengthy so that there is a disjuncture between the development action and the economic conditions that triggered the request. Approvals for a modest housing development routinely require hundreds of hours of meetings and 4 years of processing, whereas large-scale or complex developments can take much longer.

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Overlying this complex and fragmented institutional and political context is an even more complex and fragmented fiscal system that, in many cases, is the most important single influence on local land use decisions. State and local tax and revenue structures and program responsibilities are interwoven so thoroughly that most people have little understanding of which tax goes where and which government is responsible for which service. The three most important tax sources are the income tax (mostly going to the state), the local real property tax (the majority of which funds school districts, thereby relieving the state of some of this responsibility), and the sales tax (divided between the state and the city and county governments where it was raised). A mix of other tax sources is important too, including local utility and business license taxes, vehicle license taxes, state alcohol and tobacco taxes, and state gasoline taxes. Finally, fees on new development fund much local infrastructure. Other public facilities, both new and existing, are funded by benefit assessments on people within a special-assessment district. This is a proportional tax, based on providing a service to those people and businesses that will benefit (California Planning Roundtable, 1997).

The most important factor in the state's complicated fiscal structure is a series of constitutional amendments, written and placed on the ballot by citizens and passed by voters.[2] Proposition 13

started this trend in 1977 by capping property taxes at 1% of value and allowing only up to 2% per annum adjustment. It immediately resulted in an $8 billion loss in local revenues. It allowed property reassessment to reflect increased value only after sale. Hence, property taxes remain low for homes or businesses that do not turn over, regardless of property appreciation or increases in the costs of providing services. They also remain low for jurisdictions with stable populations. On the other hand, new owners pay a disproportionate level of taxes in a state in which housing prices have risen dramatically. They also may pay development fees, which often run as much as $20,000 per housing unit. Despite these high taxes, many local governments find that new developments do not provide enough additional revenues to fund the requisite public services; accordingly, they shy away from permitting any new housing (Dresch & Sheffrin, 1997).

Since Proposition 13, state and local governments have adjusted and created new devices to fill the revenue holes. These reactions have, in turn, caused citizens to put forward additional ballot initiatives, which do such things as place revenue and expenditure limits on all units of government, constitutionally protect a proportion of revenues for schools, require voter approval of all new or increased local taxes, and place stringent restrictions on benefit assessments. In 1991, the state legislature shifted an additional $3 billion in property tax revenues away from cities and counties to school districts to deal with a state revenue shortfall stemming from Proposition 13. The result is a fiscal system that not only challenges voter and legislator understanding and generates public frustration but also makes it difficult for any jurisdiction, including the state, to provide infrastructure or undertake other growth-related programs for environmental or economic improvement (Schrag, 1998).

With all these restrictions, the situs-based sales tax has become the most important local revenue source. As a result, cities and counties have been increasing their competition for land uses that generate sales tax revenues, decreasing their willingness to approve land uses that generate low property tax (such as affordable housing), and increasing their reliance on development fees to finance community facilities. Even employee-intensive manufacturing land uses are fiscally unattractive because income taxes go to state government and most property taxes go to school districts. As a result, communities are far more likely to approve large-scale shopping centers than to approve clean, high-profit industry. The large-scale discount shopping mall and "big box" retail[3] are massive land users, which typically drain the commercial energy from the town centers and existing malls to the regret of the local residents. These facilities are usually scattered around fringes of metropolitan regions in whichever towns happen to need revenues rather than in any efficient way (Fulton, 1997).

The consequences of this pattern are, first, high costs to the region for such infrastructure as roads and sewers, as well as automobile traffic and congestion and air-quality problems. Second, large-scale shopping facilities may provide revenues for one town, but they undermine the economies of neighboring towns; as their revenues shrink, their schools and services may also decline in quality. These areas then become less attractive as locations for business or middle-income residents, and the second- or third-order effect is to reduce the revenues further and increase neighboring towns' incentive to approve regionally inefficient land uses (California Planning Roundtable, 1997). Funds for infrastructure projects have grown increasingly inadequate as a result of both the sprawling patterns and the fiscal constraints so that by 1997, there was a projected $29 billion deficit in such funds (California Planning Roundtable, 1997). This deficit has, in turn, further increased housing costs, produced overcrowded schools, and closed or curtailed use of parks and libraries. Moreover, the sprawling pattern of development has increased dependence on the car, which, in turn, requires massive parking, causes air pollution, and reduces the potential for land use dense enough to support alternative transportation (Fulton, 1997). Other second-order effects include disturbing trends to the creation of high-priced, typically White, gated communities, protected from the costs associated with the poor or with crime (Blakely & Snyder, 1997). These trends, although damaging to the metropolitan system as a whole, increase the relative attractiveness of suburban low-density development to families with the resources to make the choice (Downs, 1994).

The overall unsustainable pattern in California is not one that can be blamed simply on popular explanations, such as Californians' love affair with the car or their preferences for large yards and

detached housing. Nor can it be blamed on economic growth itself. Rather, it is a product of a set of interacting factors that are locked into a complex, vicious-circle pattern. Efforts to intervene have been made by one or another set of interests—each grasping the elephant by only one of its parts and misunderstanding the whole. The effects of each new law and mandate have been not only to make the system more complex and less transparent but also to produce outcomes not intended by the proponents of the change. The system has, by now, become too complex for anyone to solve these problems with a simple reorganization or new law. The ramifications of any proposal are too many and too uncertain.[4]

GROWING AWARENESS OF THE COSTS OF SPRAWL

As the consequences of this complex array of conditions emerge, recognition is increasing in many quarters, including the business community, that compact development patterns are supportive of a state or region's economy rather than harmful to it. Business has often regarded development regulation as a cost and a hindrance to competitiveness. A number of recent studies have shown, however, that business functions as part of a complex system of linked factors in the physical environment and the governmental context, as well as in the economy. For example, Mattoon (1995) has shown that efficient metropolitan land use patterns have been closely linked to competitiveness and productivity in regions across the United States. Compact patterns also have been shown to save significant fiscal resources.[5] The Bank of America, along with the California Resources Agency, challenged conventional wisdom in the development industry when they released a report early in 1995, arguing that "unchecked sprawl has shifted from an engine of California's growth to a force that now threatens to inhibit growth and degrade the quality of our life" (p. 1). Another study, commissioned by the American Farmland Trust (1995), found that urban sprawl in the Central Valley of California, for example, would consume much more farmland, cause greater reduction in agricultural commodity sales, and dramatically increase the costs of public services than would compact growth. The state's Little Hoover Commission (1995), whose mission is to investigate government and make recommendations to promote efficiency, economy, and improved service, concluded that the current processes of decision making in land use are resulting in conflicts that are costly to the state because they are preventing the achievement of more efficient growth patterns "essential to the State's economic and environmental health" (p. 1). A U.S. Federal Reserve Bank report (Mattoon, 1995) documented the importance to the midwestern economy of achieving alternatives to the existing growth patterns currently "leading to urban sprawl and the inefficient delivery of public goods and services, that will ultimately undermine the economic prospects of entire metropolitan regions" (p. 20).

COMPLEXITY THEORY AS A FRAMEWORK

We can tackle the understanding of the shaping of places if we start with a conception of the social, political, and economic world as a complex, self-organizing, adaptive system, parallel to those that are being identified in the physical and biological sciences, and if we regard metropolitan development itself as a comparable, complex, adaptive system.[6] Complexity theory has particular application today because we are in an unstable time, in which much is unpredictable and change is constant. Existing structures and patterns of relationships and organization are in flux (Castells, 1996). Under such conditions, the predominant Western world view since the Enlightenment is no longer as useful as it once was. This view has been dominated by a Newtonian, mechanistic model (Capra, 1982), which, as a model of reality, is quite alien—not only to contemporary conditions but more generally to the way urbanists and planners understand what shapes urban patterns. The dominant, though tacit, metaphor was that natural and social systems are like machines: composed of separable parts that can be analyzed and understood individually.[7] Their ensemble is nothing more than the sum of these parts. Yet, nothing could be less like urban place making, which is constantly evolving and results from perpetual and complex interaction among many parts. In

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mechanical systems, the parts are interchangeable. The natural tendency is for their dynamics to move them toward an equilibrium state. Having been set in motion, this machine-like universe is driven by laws that, if we could uncover them, we could use to predict its behavior. Over time, this universe and the systems within it gradually lose whatever energy has been applied to them. The mechanistic perspective contends that, with an adequate theory, accurate observations, and appropriate inputs, we could control how a given system behaves (Hwang, 1996) and predict the results of an intervention. Yet, decades of trying to change the direction of change in urban places, using this sort of carefully developed intervention, have produced little to suggest that a mechanistic approach makes sense when applied to natural or social systems.

Over the past decade, however, a new view of how systems work has begun to emerge in the thinking of many scientists and mathematicians—a view that provides a far better analogy for understanding metropolitan development and how it works than does the mechanical conception. This model is based on the study of complex adaptive systems in a state "at the edge of chaos." It first emerged in the physical sciences (Kauffman, 1995; Lewin, 1992; Nicolis & Prigogine, 1989; Prigogine & Stengers, 1984; Waldrop, 1992). Some have argued that this model is also powerful in understanding the functioning of social systems (Hwang, 1996; Kauffman, 1995; Kiel, 1991; Wheatley, 1992).[8] Although understanding of this model is still in its infancy and we cannot, in any case, explain here the theory of complex adaptive systems, we can highlight basic features that are important for our purposes to distinguish it from the mechanistic view.[9]

The dominant metaphor for this new world view is, rather than the world as machine, the world as organism, with all the consequent implications of growth, feedback, and evolution. Complex adaptive systems involve networks of relationships among many components, which interact in both competitive and collaborative ways so that they coevolve and mutually adapt. It is perhaps easiest to see this by noting how, in a complex ecological system, plants and animal species evolve in their activities in response to changes in the patterns of those species on which they depend—and in response to changes in the environment or in the introduction of new species. This adaptation occurs without the agents in the system, such as individual animals or plants, necessarily having any conscious recognition, much less deliberate intent. Indeed, these complex adaptive systems are found in physics and computer science as well as in biological and ecological systems (Nicolis & Prigogine, 1989). They seem to be mimicking cognition in this adaptation process—to such a degree that Capra (1996) titles his book on the subject *The Web of Life*. This cognition is, however, less visible when we look at the individual agent than when we examine the ensemble, just as an ant colony has a level of intelligence that is far more than the sum of its parts.

This collectively intelligent, adaptive process is most likely to occur when the environmental conditions and influences on the systems can be characterized as being at the edge of chaos rather than involving either substantial continuity and equilibrium or fully chaotic conditions. Equilibrium occurs in either a closed system or in systems in a stable environment. In equilibrium conditions, a system adapts to external or internal change with modest adjustments, allowing it to maintain its comparative stasis. Such a system, however, has little capacity to respond to change or chaotic inputs with significant changes of its own that would allow it to adapt to the new conditions effectively. Chaos, on the other hand, is a set of relationships so turbulent that no meaningful order exists in them and no adaptation or response is of value. The less turbulent phase just at the edge of chaos, however, is one in which there is opportunity for experimentation and development of new and more productive patterns and activities—although often only after many failures. Functioning in a state at the edge of chaos, the participants or elements in the system can coordinate complex activities and are better able to evolve than those in chaos or equilibrium conditions (Kauffman, 1995).

In this view, the interactions in the network itself lead to the system's evolving to higher states of adaptability. Essentially through a process of tinkering or randomly experimenting and making further adaptations after feedback, the system as a whole "learns," rejecting ineffective pathways or actions and building on those that provide more desirable results. Thus, the IBM computer playing chess against Garry Kasparov learns from the play itself and develops continuously improved strategies the more it plays. In the process of play or interaction in a complex system at the edge of chaos, each participant or component influences the transformation of the others. Although the general pattern of these relationships may be predictable, the details of how the system will behave

cannot be predicted for any specific case or time. For example, in the case of malaria and a host immune system, one cannot predict how an individual will respond to infection—or even that a specific host will successfully adapt. There is both structure and agency at work in that the pattern or structure can have a strong influence on action by any component, but random or intentional acts by individuals can alter the structure.

A complex system is thus, in a basic sense, out of control (Kelly, 1994). It cannot be managed by any single mind or even by a complicated set of formal policies; there is too much going on at once, too many linked components, and too much feedback and adaptation. Research has shown that distributed rather than top-down intelligence works to deal with such situations and permits creative, coordinated action when many independent players are involved. Many agents, following simple rules for adjusting their actions, without seeing or understanding the dynamics of the larger system, can effectively coordinate for joint action. For example, flocking behavior of birds can be mimicked on the computer much better by applying to each simulated bird a few simple rules, like "do not bump into another bird" and "keep up with neighbors but not too close," than by trying to design the pattern a priori. The application of this distributed-intelligence concept results in patterns similar to the graceful and aerodynamically efficient patterns of flocking birds (Kelly, 1994).

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Top-down regulation and control strategy are far less effective than this kind of self-organizing approach, based on knowledgeable agents acting individually when systems are complex and operating in a fast-moving and unpredictable environment.[10] For example, Hutchins (1995, pp. 1-5) tells the story of a huge U.S. Navy ship that suddenly loses power in a narrow channel and, as a result, also loses use of the usual indicators and gauges. This sets in motion a series of activities and communications among people with different responsibilities around the ship as they endeavor to find a way to handle the problem without going aground or running over other boats. They make mistakes and have a number of partially missed communications. They come up with strategies to operate without reliable tools and gauges. The steering overcompensates wildly. They discover they have no whistle to warn an oncoming boat. But they manage to slow the ship and drop anchor without mishap. In this case, participants faced a situation that they had not faced before and for which there were no instructions. They had to invent quickly what to do. They could not consult or strategize and lay out the best approach. They had to use their experience and act, even without knowledge of all the other consequences on the ship of the loss of steam power or of all the other activities that were going on simultaneously. Sometimes, one person's judgment was wrong, but others compensated in what they did. They experimented and reacted collectively, and that collective response worked, albeit clumsily.

COMPLEXITY AS A PERSPECTIVE ON THE METROPOLITAN SYSTEM

We contend that the metropolitan development system in California is now like a ship without gauges and without clear communication among the participants.[11] Each can see only a part of the problem, and each can act only individually—or, at best, shout across the deck to someone else who is busily working on his or her crisis-management responsibility. Successful self-organization and adaptation do not necessarily occur in complex systems or may only be done inadequately. If no communication, feedback, or common purpose exists among the participants, or if one agency or individual tries to make rules and intervene in a deterministic controlling way, the results are likely not only to be inefficient but also to quite possibly fail entirely to address the problem or even aggravate it.

Four ideas from complexity theory that will help us think in new ways about how to improve the metropolitan development system are as follows:

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- Simplification results in fundamentally wrong answers, and focus on individual sectors separately will be counterproductive.
- Effects cannot be directly linked to causes because an intervention reverberates through the system in ways that can be only partially traced.

- Even small changes introduced into the system may produce discontinuous, unpredicted effects.
- Adaptive changes within a system can grow from learning generated by the individual interactions in the networks of system participants.

Metropolitan development in California demonstrates these principles. Attempts at policy interventions have not produced a smooth pattern of change; rather, they have made radical transformations that intervenors did not anticipate. The simple effort of apartment developers to control property taxes with Proposition 13 produced more fiscal uncertainty, increases in other taxes and fees, more restrictions on development, rent controls, and more state control over local governments. The effort of local government to focus on the fiscal sector alone produces land use patterns that undermine their own revenues over time and put heavy costs onto metropolitan infrastructure—which, in turn, means there are fewer resources to go around. We cannot pinpoint the causes of migration to suburbs because social changes, quality of public services, racial attitudes, lifestyle choices, transportation technology, and even economic prosperity may all be implicated, along with other factors (Fulton, 1997). Capital improvements in highways reduce congestion and improve air quality in the short run, just as improved gas mileage saves on nonrenewable resources. But both have second- and third-order effects, producing an expansion in automobile use far exceeding population growth, which ultimately increases congestion as well as adding to the attractiveness of low-density suburban housing and vast auto-oriented shopping malls. On the other hand, in a rare case of adaptive learning, automobile commuters in the San Francisco metropolitan area have developed practices of casual carpooling (some would call it hitchhiking) among the white-collar workers commuting to the city, so they can take advantage of special highway lanes for multioccupant vehicles. During a recent transit strike, public officials finally recognized the value of this effort and took steps to make such a self-organizing solution work better by creating special spots in San Francisco where cars can legally and conveniently stop to pick up riders.

The use of complexity theory in understanding the functioning of the metropolitan system tracks with new insights into the nature of changes in the social and political system, which have emerged over the past few decades. Charles Handy (1990) has argued that the changes society must cope with are different today because of the rapidity of economic and technological changes. Change is discontinuous rather than part of a pattern, and even apparently minor changes can have profound implications for our lives. Handy suggests that discontinuous change requires discontinuous thinking to manage it. We can no longer think in incremental, evolutionary terms but must instead be willing to think in terms of completely different options if we are to respond to change effectively. He also observes that the model of rational control with top-down, centralized direction will not be effective in this radically different world.

> We have tried to plan and control world trade and world finance and to make a greener world. There should be a rational response to everything, we thought; it should be possible to make a better world. It hasn't worked. Management and control are breaking down everywhere. The new world order looks very likely to end in disorder. (Handy, 1994, p. 11)

Anthony Giddens (1994) says these changes have produced "manufactured uncertainty," because the effort to use advances in human knowledge and controlled intervention has actually resulted in more unpredictability. This phenomenon is demonstrated by the example of California, summarized above. Giddens attributes this seeming paradox to three interlinked developments: globalization (by which he means action at a distance that affects each individual), emergence of posttraditional society (in which traditions are subject to justifications instead of accepted on the basis of faith or ritual), and expansion of social reflexivity (individuals filtering information and acting on the basis of the filtering), which is both condition and outcome of the other two.

Giddens (1994) explains social reflexivity by saying,

> Decisions have to be taken on the basis of a more or less continuous reflection on the conditions of one's actions. "Reflexivity" here refers to the use of information about the conditions of activity as a means of regularly reordering and redefining what the activity is. (p. 84)

Hence, individuals rely less on traditions or rituals in making decisions and more on information about their conditions of everyday life, the results of their activities in that life, their most important concerns, and expert information relevant to these. They also develop the habit of tuning into or out of specific issues based on this filtering of information. As a result, bottom-up decision making, autonomy, and decentralization increasingly replace centralized regulation and hierarchical organization. Indicators may become very important in influencing the activities of individuals. Social reflexivity also generates the extension of what Giddens calls dialogic democratization—autonomous communications among participants forming a dialogue in which all points of view can be heard to shape policies and actions rather than as an exercise in search of the "correct" answer. This presumably creates an important role for processes such as consensus building, which facilitate such dialogue.

In trying to manage metropolitan development systems to achieve sustainability in an era of uncertainty and discontinuous change, we are going to have to develop strategies that recognize and adapt to these conditions of complexity (Courtney, Kirkland, & Viguerie, 1997). These strategies will need to be based on a new understanding of sustainability; on the use of indicators to help guide actions and dialogue; on consensus building to enable dialogic democracy, joint learning, trust, and innovation; and on leadership to build common meaning and purpose.

COMPLEXITY AND SUSTAINABILITY

Complexity theory provides new insight into the elusive goal of sustainability and suggests that many popular ways of thinking about this have been moving in the wrong direction—a direction that would make sense if the world were like a machine rather than like a growing, evolving organism. Essentially, a sustainable complex system is one that is adaptive and self-organizing, with its components free to coevolve in response to changes in each other and, as a whole, changing in response to external conditions. It learns from the feedback it gets, as it randomly or deliberately experiments with new actions. It develops the actions and pathways in its network of agents that work most effectively. In doing so, the system grows and evolves. The character and quality of its results may change, and its productivity could eventually increase, even when the external change is one that at first appears damaging. There is unlikely to be any endpoint for an adaptive system or any ideal form; its adaptations are not predetermined but are the product of distributed intelligence and of experiments or even random events that open up new ways of doing things. The sustainable complex system not only survives but also continuously undergoes transformation.

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The implication of this concept is that sustainability is about process, not about a particular vision, pattern, set of rules, or criterion. We cannot know just what a sustainable world will look like or even whether the one we have is sustainable. If we unduly constrain our choices as we move forward, however (as California has done), or impose a particular vision on those who come after us, we will not allow the system to be adaptive and experimental as it encounters the future. Natural and man-made disasters will occur, technology will change, and these will have impacts and reactions that we cannot even imagine. Such disasters could be transformed into the impetus for the creativity that will be needed to develop a truly sustainable society.

Mechanical and dichotomous notions, like making trade-offs between the economy and the environment, moreover, are not likely to be part of a sustainable path. A metropolitan economy needs an adequate environment, and the environment needs an adequate economy to ensure that it can be protected and improved. Increasingly, cutting-edge businesses recognize that this is a symbiotic relation (Myers Richter). A sustainable world is also unlikely to be one in which people

consume less. Not only is reduction of worldwide consumption unlikely, but consumption reduction may not be the only approach to sustainability. Fossil fuels may or may not be important in a future sustainable development path. Under the right conditions, societies can develop alternative valued outcomes and different ways of meeting human needs. This can happen because of new technologies, but it also may result from societies organizing themselves in new ways, so that new and currently unanticipated values may emerge, and from dialogues that produce innovative responses.

The objection that many would surely make at this point is that it is simply too risky to let the system take its course. We can see disaster ahead, and we need to develop new rules and new forms of governance that will avert the disaster. Maybe people will wake up to this disaster, critics say, and change their values someday, but it is likely to be too little, too late. By the time they react, the resources will be depleted. People and species will disappear while we are waiting for societies to learn.

Our response is that the rules and mandates we create today will not avert disaster, although they may seem to help for a time. If we have too much hubris today and imagine that, from our limited perspective, we can solve this complex problem, we will end up having the same fragmented, counterproductive development system worldwide that we now have in California. We have no choice but to trust the intelligence and inventiveness of people everywhere to learn and to transform the system. Instead of trying to define a vision of sustainability—how to get from here to this ideal world—we need to find ways to make the complex system we have into one that will allow the players themselves to turn the metropolitan system into a collective intelligence that can sustain itself indefinitely.

WHAT ACTUALLY CAN BE DONE?

Policies fail to turn out as those crafting them desire—not only because of emergent technologies, unanticipated major events, or changes in the structure of the economy that are beyond their ability to predict or control, but also because there are so many players who make the city what it is. Businesspeople, residents, commuters, elected officials, and many others make millions of decisions on a daily basis that add up to the evolving form, structure, and character of the cities and that shape their economies, their vitality, and the direction of change. Yet, these decisions are largely beyond the reach of any formal urban policy or plan, much less any top-down regulatory strategy. The best planners can do is to help the players in these places to influence the direction of change.

We therefore propose three principal strategies for improving metropolitan system performance, each of which targets a different level or type of metropolitan decision maker. These include development and use of indicators and performance measures in new ways, the use of collaborative consensus building among stakeholders who best understand the different aspects of the metropolitan system, and, finally, the creation of new forms of leadership. Each of these strategies represents a way to make the whole system more informed, responsive, and transformative. Together, these strategies can help make the metropolitan development system more of a genuine learning system. The goal is to achieve not only what is known as single-loop learning, in which information can be used to keep the system on track in response to variations and external changes, but also double-loop learning (Argyris & Schön, 1974, p. 50ff). Double-loop learning involves not just maintaining equilibrium, but also reassessing goals, purposes, and processes. This kind of learning results in fundamental transformations in agents and in the system.

In this context, actions that will make a difference are related to the improvement of system performance rather than simply to the performance of one aspect for a short time. Sustainability is a characteristic of a whole system, and we can only work toward it by thinking in system terms, which are unfamiliar to most people. A well-performing, sustainable metropolitan system, for example, may be one that shows a high degree of adaptability to global and technological change and in which the economy moves to higher levels of productivity rather than stagnating or collapsing into chaos. It is one in which the various jurisdictions work together to meet regional needs for

water, transportation, housing, economic development, and revenues over the long term and in which they have the capability to look collectively at the interactions and relationships among these subsystems and to act at a system level rather than for their own parochial interests.[12]

Indicators

To create a sustainable system and enhance the reflexivity of its participants, feedback and conversation are essential. The agents in the system must have knowledge so they can learn, repair, and redesign their own system. They also must explore and discuss among themselves the meanings and implications of the knowledge as well as attempt to anticipate the consequences of various responses to it. For this purpose, we believe three types of indicators will be needed[13]—indicators that are the product of the collective intelligence of many agents, closely linked in content and design to the values and meaning systems of those agents, and directly relevant to the choices and opportunities that face them. These are not proposed to be all-purpose databanks but rather focused ways to extend the conversation and the knowledge of participants. These are indicators to provide feedback not only to planners and policy makers but also to residents, migrants, businesses, community groups, and public agencies so they can make simultaneous adjustments in their own tasks and move the system more in a desired direction. Getting the selection and design of these indicators exactly right (even the imperfect information and faulty gauges on the ship were useful as a starting place) is less important than engaging the players in the design of the measures, in the understanding of their meanings and limits, and in the development of responses to them. These measures and their implications must become second nature to the people who have to internalize them so they can respond appropriately and quickly. They will learn, through their own "praxis" as homeowners, planners, or elected officials, to react to what the indicators seem to show. They will learn by working together and communicating about what they think is happening and what they think is working. In trying to resolve their differences, these conversations have the potential for double-loop learning rather than simply reactive, single-loop approaches.

. . . system indicators are needed—a few key measures that reflect the central values of concern . . .

First, system indicators are needed—a few key measures that reflect the central values of concern to metropolitan players and serve as bellwethers for the health of the overall system. The design and use of these over time will help to form a common sense of direction and mission. The effort to develop two or three measures that really express the health and nature of the system will educate the participants about how the system works and what they collectively need it to accomplish. Preparing these is the closest to central guidance for a complex system, and they are likely to measure a broad mission, like "dock the boat without mishap" or "provide for the well-being of all urban residents." The effort will require developing some agreement among a wide range of participants on the kind of city they want and perhaps on what they mean by sustainability.[14] An example might be a measure comparing economic performance with a pollution or environmental cleanup measure.[15] Alternatively, a measure of the annual growth of sprawl might be developed.

Second, a set of performance measures reflecting specific outcomes of various aspects of the system—such as the street or park system, the state of the water resources, or the provision of social services—will allow policy makers, businesses, or others to assess whether they should adjust specific policies. Performance measures help the experienced policy maker or planner to make sense of many interlinked activities and ongoing events to figure out how to act. Performance measures, which have gotten international recognition in *Reinventing Government* (Osborne & Gaebler, 1992), are being widely promoted in the United States under the White House and Vice President Gore's leadership[16] as a crucial element in the reorientation of government to give attention to "customer satisfaction" and to ongoing monitoring of actions by bureaucrats, planners, and local, state, or regional elected officials. They are designed to provide feedback and accountability, but they are not evaluative measures for rewarding or punishing participants. Instead, they are collectively interpreted by experienced participants, who bring an understanding of specific events and unique conditions that affect the measure.[17] In the context of the California metropolitan system, for example, performance measures might include the number of acres of inner-city land vacant or abandoned, the acres of agricultural land used for housing, or travel times on key highway segments.

Rapid feedback indicators are the third type. These are designed to help individuals and businesses on a daily basis to get what they need in the most efficient or cost-effective way to help them make choices and daily decisions in a real-time context. In the final analysis, a community is what the individuals, businesses, and agencies in that place do and have done in the past. It is a product of the things they create, produce, and reproduce over time, whether buildings, practices, or institutions. It is in dynamic relation with the geographic, physical, political, and economic context in which it sits. Each of these agents reacts not only to others but also to perceptions of changes in the context and feedback on the results of their own actions. Today, the homeowners and renters, commuters, entrepreneurs, shopkeepers, clerks, laborers, service providers, and regulators have poor or limited information to guide their daily actions. They do not typically know much about the immediate consequences of their own actions—for example, how long it will take them to travel to a neighboring town for shopping if they take their intended route or how much money it costs to water their lawns. Yet, these are forms of information that we now have the technology to provide on a real-time basis so that these people could make choices that would be efficient both for them and for the system.

Consensus Building

. . . establish multistakeholder and interagency or even interjurisdictional consensus-building processes designed to address problematic aspects of the system . . .

A second strategy for helping create a more adaptable and sustainable metropolitan system is to establish multistakeholder and interagency or even interjurisdictional consensus-building processes designed to address problematic aspects of the system, such as air or water quality, downtown redevelopment, or metropolitan management of growth.[18] These can even be used to develop new strategies for statewide legislation that are not heavy-handed regulation but introduce changes to the incentive structures and opportunities for self-organization.[19] The type of consensus building to which we refer involves stakeholders on different sides of an issue, each with knowledge and experience. Typically, it involves facilitated, face-to-face, long-term discussions organized around a task, such as developing a transportation plan or an agreement on water use. It is a form of what Anthony Giddens (1994) calls dialogic democracy and results in the spread of social reflexivity as a condition of both the day-to-day activities of the participants and their collective actions as part of the consensus group. It also has the capability to create active trust among the participants (Giddens, 1994). This type of process is grounded in interest-based bargaining (Fisher & Ury, 1981) and the techniques of mediation. The method ensures that all feel comfortable and all are heard, that assumptions and boundaries are all legitimate for challenge, that technical information is provided to and tested by the group, and that consensus is sought on any actions taken. This model has been instituted for such controversial regional issues in California as growth management, habitat conservation, water supply management, and transportation.[20]

Experience has shown that many consensus-building processes have properties similar to complex systems—self-organization, decentralization, and inventiveness (e.g., Innes, Gruber, Neuman, & Thompson, 1994, p. 45). Because consensus building maps so effectively onto these complex systems, it can be a particularly powerful planning method (Skaburskis, 1995). Indeed, it is no coincidence that California is a state in which these processes are being created; they are a logical, pragmatic response to fragmentation and controversy, and they bring together those who know most about how the processes work "on the ground" and who are most in a position to change the system. These processes involve continuing dialogues to work out how to act, at what point in the system to intervene, and how to monitor and adapt in response to feedback. Typically, these groups become acutely aware of the need for flexibility in the future. They make proposals full of contingent strategies and establish new collaborative group processes to oversee implementation. As a result of their learning, they become sensitized to the nature of the complex system. As a result of their communication and, in some cases, of transformative learning, they can improve on the otherwise clumsy and imperfect self-organizing responses of the system. Like dialogic democracy generally, the learning, active trust, and future cooperation contribute to mutual tolerance and adaptability of the system, even if a final consensus product is not achieved.

LEADERSHIP

A new type of leadership is required to operate innovatively and appropriately in this complex, dynamic metropolitan system. We need to think of leadership in some of the new ways that are being identified in the literature of business and public management.[21] Leaders in a world of complex uncertainty have vision and focus; they are able to translate this into meaning and are capable of communicating this meaning; they are able to build trust through commitment, passion, and integrity; and they emphasize learning and risk taking in themselves and in others.

Leaders in a world of complex uncertainty have vision and focus; they are able to translate this into meaning and are capable of communicating this meaning; they are able to build trust through commitment, passion, and integrity; and they emphasize learning and risk taking in themselves and in others.

We believe Peter Senge, in his important book *The Fifth Discipline* (1990), has provided a good beginning to understanding the nature of leadership in this world of complexity and discontinuous change. The first of his five learning disciplines is systems thinking. Systems thinking is a discipline for seeing wholes and interrelationships rather than things. It is first because each of the other four disciplines is also concerned with seeing wholes instead of parts and with seeing people as active participants in shaping reality instead of as passive reactors. The other learning disciplines emphasize personal growth and learning, creating and learning to work with shared mental models, building shared visions, and team learning. Team learning has three critical dimensions. It requires insightful thought about the complex issues, innovative and coordinated action, and cross-participation of members in many teams.

Instead of the leader's identifying the answers and pushing through his agenda and program unilaterally or in combination with a few advisors, these leaders must be able to help the many participants develop a common sense of values and purpose, instill a sense of mastery and empowerment among all the players, and encourage and support them in organizing themselves, learning from one another, and innovating. These leaders must be able to draw on many disciplines and skills, to create and manage group learning processes, and to listen. They must help to identify the tasks to be done and the players to be brought together. They must themselves be self-reflective, like Schön's (1983) reflective practitioner or Soros's (1997) reflexive entrepreneur. Nothing can be assumed in the complex uncertain world we face. Those who help manage it best are those who can bring out the creativity in themselves and others.

CONCLUSION

The experience of California offers an example of the ineffectiveness of approaches to metropolitan development when based on centralization and control. In the face of rapid and often discontinuous change, globalization, the emergence of posttraditional society, and expansion of social reflexivity, we need to develop new concepts for metropolitan development and sustainability. Big governmental schemes, based on extensive rules and centralized direction that ignore the multiplicity and diversity of actors in the metropolitan system, simply do not work (Scott, 1998). We believe the emerging field of complex adaptive systems offers one model that may be useful in evolving more adaptive strategies for metropolitan development, resulting in more sustainable economies and environments. This model suggests to us that metropolitan development strategies require three elements to be successful: consensus building and other similar collaborative processes, use of a system of indicators to provide the various actors with feedback, and a new style of leadership that emphasizes collaborative learning, commitment, integrity, and passion. Indeed, our experience, although only partially documented at this point, suggests that these elements are already beginning to emerge in a self-organizing way in response to the discontinuous change in California. This gives us a sense of optimism about the future, despite the apparent turmoil of the present.

NOTES

1. These are elected in nonpartisan local elections, often by district. Thus, these elected officials are highly independent and certainly are not governed by party discipline.

2. The California constitution allows voters to circulate and place on the ballot proposals for constitutional amendments or statutory laws without the participation of the legislature. This power has become an important source of new fiscal policy with the result of an increasingly complex and piecemeal revenue system, with some funds earmarked for specific purposes and arbitrary caps placed on other revenue sources. To raise many specific taxes now requires a two-thirds vote of the public statewide or in a particular jurisdiction. This is often not obtainable.

3. These are large-scale discounted retail outlets for things such as hardware or home items, housed in massive warehouse-like buildings surrounded typically by acres of parking. Examples are Wal-Mart, Home Depot, and Orchard Supply Hardware.

4. One exception to this is a creative process taking place at the state level, in which representatives of the major stakeholder interests—from business and education to labor and poor and ethnic minority groups—are gradually developing a much more complex proposal involving a transformation of fiscal structures and accountability structures across the state. This proposal may be placed on the ballot for a vote in 1999. This would be, rather than a quick fix of one element of the problem, an adjustment simultaneously of a number of factors and incentive structures in the hope that the system will become more responsive and adaptive (Booher, 1997).

5. The impact assessment of New Jersey's State Development and Redevelopment Plan estimated that, if this form of growth management were implemented, it would save the state $400 million per year (New Jersey Office of State Planning, 1992).

We note that we are in disagreement with virtually every claim of Gordon and Richardson (1997), who argue that sprawl is not costly. We find the premises, evidence, and arguments deeply flawed, and we believe that Ewing (1997) makes a convincing case of denying their claims.

6. We might even think of it as a fractal—a smaller version of the complex self-organizing world, designed to function in that world.

7. Like human-made machines, the cosmic machine was thought to consist of elementary parts. Consequently, it was believed that complex phenomena could always be understood by reducing them to their basic building blocks and by looking for mechanisms through which these interacted. This view has become deeply ingrained in our culture and identified with the scientific method. The other sciences accepted the mechanistic and reductionistic views of the classical physics as the correct description of reality and modeled their own theories accordingly. Whenever psychologists, sociologists, or economists wanted to be scientific, they naturally turned toward the basic concepts of Newtonian physics (Capra, 1982, p. 47).

8. Interestingly, the Jesuit philosopher and paleontologist Pierre Teilhard de Chardin (1959) anticipated this connection a half century ago in his concepts of convergence and complexification.

9. Although the term *system* has many meanings, in this context it refers to dynamical systems as first conceived by Henri Poincaré (Devaney, 1989).

10. Many kinds of research converge on this point, from studies of parallel processing in computer science to brain research, which suggests that the brain operates across neural networks to pull together widely distributed information to understand and act.

11. Although we have focused on the California case in this article, there is ample evidence that similar trends are at work in other regions of the United States. For example, see Kirp, Dwyer, and Rosenthal (1995) regarding New Jersey.

12. A recent book by Dodge (1996), remarkably sponsored by the National League of Cities, focuses on a similar theme. He contends that a self-organizing set of links among cities to create new forms of governance and regional excellence is necessary because we are in a complex, constantly changing world.

13. Innes (1996) describes this set of concepts more fully.

14. In cases Innes, Gruber, Neuman, and Thompson (1994) studied, for example, they found that some collaborative groups trying to manage a regional resource were able to come up with one or two indicators that really measured overall system performance.

Although the step of determining mission and overall system indicator in a consensual way may be difficult, it is far from impossible, particularly with professional help at facilitating and managing the discourse. Places tend to have their own cultures and unique qualities as well as problems, and such strategic visioning can often be done consensually. But this must be an intensely collaborative effort, in which groups of leaders and stakeholders decide on the problems of the city and the direction they want to go.

15. Examples of such system measures that groups have developed in other cases include, for example, the unemployment rate as a measure of the U.S. economic performance (de Neufville, 1975) or the level and location of a salinity threshold value in the San Francisco Bay Delta Estuary system (Innes et al., 1994).

16. This is known as the National Performance Review and thus far involves a number of demonstration projects, including the Oregon Option.

17. Of course, they may at times be used in this more mechanistic way. Learning and adaptiveness are, however, the intent.

18. Examples of these are described in Godschalk (1992), Innes (1992), and Innes et al. (1994).

19. One example is the California Governance Consensus Project, which includes 35 of the most powerful interest group representatives, who have been working together for the past 2 years to craft a complex piece of legislation to change the fiscal incentives and accountability in the state in a way that will make sense from many perspectives simultaneously.

20. See Innes et al. (1994) for an account of several of these processes.

21. Leading examples of this work are insightful and useful books by Bennis (1989), Bryson and Crosby (1992), Farson (1996), O'Toole (1995), and Senge (1990), but many other examples abound in the organizational development literature.

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