

**INDICATORS FOR SUSTAINABLE COMMUNITIES**  
**A STRATEGY BUILDING ON COMPLEXITY THEORY**  
**AND DISTRIBUTED INTELLIGENCE<sup>1</sup>**

by

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and

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## ABSTRACT

Indicators and performance measures have become an important element in the evolution of policy initiatives relating to sustainability and to reinvention of government. This article reviews the research and practice of indicators and summarizes several key lessons from this review. One of the key lessons is that, to be useful, indicators must be developed with the participation of those who will use and learn from them. The article then proposes a strategy for community indicators based upon the conception that cities are like living organisms functioning as a complex adaptive system. Three types of indicators are needed. System performance indicators are required to provide feedback about the overall health of a community or region. Policy and program measures are required to provide policy makers with feedback about the operation of specific programs and policies. Rapid feedback indicators are required to assist individuals and businesses to make more sustainable decisions on a day-to-day basis. There is no formula for how to develop a system of indicators. Each community and region should develop a system based upon their own circumstances and needs.



**Indicators for Sustainable Communities**  
**A Strategy Building on Complexity Theory and Distributed Intelligence**

*Buyers, sellers, administrations, streets, bridges, and buildings 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.*

*—John Holland (1995)*

**The Community Indicators Movement**

In the 1990s, a virtual social movement has emerged, focused on community sustainability. Both spontaneously and with the urging and financial support of foundations, nonprofit national and international organizations, and public agencies, citizens and stakeholders have been gathering in the U.S. city by city for several years to develop their own approaches to making their communities sustainable.<sup>2</sup> In the U.S., Sustainable Seattle (Sustainable Seattle, 1995) is probably best known, but dozens, if not hundreds, of cities have their own versions.<sup>3</sup> These efforts are part of a world-wide movement for sustainable development, each working independently, though linked through networks and collaborations, at and across national, regional, and local levels.<sup>4</sup> While there remain disagreements about how to define, much less to reach, a sustainable society, there seems to be agreement that indicators will play a key role. Indeed, much of the work of these sustainability projects has been devoted to the development of community indicators, often collaboratively designed and by and for the people in each place.<sup>5</sup> Handbooks have appeared to assist local efforts (Redefining Progress, Tyler Norris Associates and Sustainable Seattle, 1997; Hart, 1999) and a newsletter has started<sup>6</sup>. This movement is developing so quickly that little has as yet been published in the academic literature documenting, analyzing, or evaluating these practices.<sup>7</sup> The Internet is a better source than the library for finding out about much of this work, though its descriptions are sketchy.<sup>8</sup>

While practices and ideas about the design, production and role of community indicators seem to vary widely, it appears that much of the effort has been devoted to developing the numbers themselves rather than focusing on how they will be produced over time or how they will influence action. Dozens of articles can be found describing ideal indicators on one issue or another, and substantial public resources have gone into defining sustainability indicators.<sup>9</sup> Similarly community indicators projects appear to focus on getting out an indicators report, as if the numbers themselves would be enough to make changes happen. They sometimes produce reports with dozens, or even hundreds, of indicators and then are stumped about what to do next.<sup>10</sup> They know they want the indicators to become part of a public dialogue and somehow to help communities and regions become better at self-management and more self-conscious about the direction they are going. They want the indicators to be influential.

While these projects have ambitious objectives, they are not intrinsically unrealistic or inappropriate. Indicators can help with public dialogue and community self-management. Unfortunately, these projects are typically not building on the substantial experience with indicators and efforts to use technical information in public policy at the state and national level over the last fifty years. This history shows that millions of dollars and much time of many talented people has been wasted on preparing national, state and local indicator reports that remain on the shelf gathering dust (Innes, 1990a; Caplan, 1977; Caplan, 1975). These efforts, like many technical reports for public policy, have relied on unrealistic expectations and a simplistic model of how information drives policy and public action. On the other hand, a few indicators and related kinds of quantitative information have had impacts on action and one can learn much from how and why these processes worked while others did not. The influence came through a much more complex and less observable process than many recognize and only occurred when a variety of conditions were in place. Indeed, it was not really the indicators themselves or the reports that mattered, but the learning and change that took place during the course of their development and the way that learning led to new shared meanings and changed discourses (Innes, 1990; Innes, 1988a). This learning and changes in practices, however, was highly contingent on the way the information was developed and who was involved.

The purpose of this article is to outline a strategy for community indicators which we believe will assure that such indicators can be influential and can contribute to sustainable communities. The broad ideas build in substantial part on the empirical and conceptual work of a variety of scholars who have studied the development and use of indicators and technical information over the last 20 years (Innes, 1990; Ozawa, 1991; Weiss and Gruber, 1984; Innes, et al, 1994; Weiss, 1979; Weiss, 1977; Dutton and Kraemer, 1984; Caplan, 1977; Caplan, 1975; Sabatier, 1978; Innes, 1988a; Innes, 1998). They also build on Booher's learning from his practice in which, as a consultant, he works to influence public policy. We are also influenced by a literature and emerging set of practices on performance measurement and performance-based government. Our proposal builds fundamentally on the emerging thinking of complexity theorists. Urban plans and policies have fallen short in great part, we believe, because policy makers have applied a model of decision and action that is too simplified and mechanical. They operated on the belief that experts could produce answers and appropriate policies, which in turn could be implemented, and finally, if all the steps went as intended, the desired results would emerge. When such results did not emerge, professionals tried to design better policies, gather better information, work harder on implementation, or simply threw up their hands and blamed "politics" or the "power structure." For a long time, no one questioned the idea of city as machine that could be fixed, much less the expert-based analysis that lay behind the command and control approach.

Our proposal is based in the idea that the city should be seen not as a machine, but as an organism which evolves and changes its direction in response to external events and to its own internal dynamics. Urban policy and accordingly urban sustainability, needs to be seen as a product of many actions of the many participants in the city rather than uniquely of public action. A city is composed of thousands, perhaps millions of players whose actions form a pattern in time and space, though they do not follow coordinated instructions. If we want to change aspects of the city — its land uses, travel patterns, or use of resources for example — emerging theories of complex systems suggest that a top-down intervention or implementing a formal a priori plan will either not make much difference or have an unpredicted and perhaps counterproductive effect. Such a system is capable, however, of improving itself in ways we could not

predict, but which are more effective than what the most sophisticated analysts could create. Such self-improvement and adaptation however requires feedback — various kinds of information — to flow among the players who make the city what it is. This is where indicators come into the picture: to inform those players as they go about their business.

Our definition of sustainability grows out of our use of complexity theory as a principal metaphor for understanding the city. We believe that the sustainable community is one where many players in many different roles and with widely differing interests and values are all provided with a flow of meaningful information, and where they have the opportunity for joint learning and innovative responses to this feedback from the environment and internal changes. It is this distributed intelligence which allows players in a community to anticipate and constructively address the systemic problems it continually faces and to deal with the threats and opportunities of natural and manmade disasters, the shifting global economy, and inequitable distributions of resources. What exactly those responses will be or should be, we do not know. Nor do we presume to know what a sustainable community of the future will look like, nor even what are the best indicators of it. We do think, however, that those who come after us will have the best chance to create sustainable communities if we create the information system to make it possible.<sup>11</sup>

This article will lay out some of the lessons that came from efforts to design and use indicators and other technical information in the past to influence public policy, outlining the conditions in which such information can really make a difference. The gist of this will be to show that indicators that are influential are developed with participation of those who are to use them; their meaning comes to be shared in the relevant community and linked to the context and issues. The article will argue that the joint learning process around indicator development and use is far more important in terms of impact than are the actual indicator reports. It is this process that assures that the indicators become part of the players' meaning systems. They act on the indicators because the ideas the indicators represent have become second nature to them and part of what they take for granted (Innes, 1998).

While our proposal is consistent with the findings of the last thirty years about what makes indicators influential, we are introducing a new way of thinking about indicator purposes that is grounded in the recognition of the city as a complex, adaptive, "out of control" system made up of many independent agents, rather than primarily as an object of formal policy making. Indicators can only assist in a creative and adaptive urban process if those who design them come to the task with different conceptions of indicators, of policy making, and of cities themselves than they have mostly applied until now.

We propose that three types of indicators should be developed to assist in creating self-organizing, sustainable cities and regions: 1) a few carefully designed, highly visible, consensually agreed on, system indicators reflecting key issues that can frame public discussion and help the city's players to agree on the direction they want to go; 2) a larger number of policy and management indicators designed to help design and redesign policy, keep programs working effectively and evolving appropriately, and respond to unexpected challenges and change in the environment, for use primarily by professionals, elected officials and those citizens who follow urban policies closely; and 3) rapid feedback indicators for all who are part of a city, including residents, businesses, and commuters, designed to help them make better choices about their own actions and in the process make better use of the community's limited resources.<sup>12</sup>

## Indicators as Typically Conceived

Although those who propose or develop indicators are typically vague about how they are to have an influence, the literature and the experiments around the country implicitly offer several models. One conception is that all-purpose indicator reports should be prepared, including often dozens, or even hundreds, of indicators, listed by category. These are to be published and widely distributed. These might be produced by experts or by collaborative community based groups or some combination. The tacit idea is that these compendia, once available, will inform the public and assist analysts and decision makers, who will consult the reports, learning from whatever information is relevant to the problem they happen to face. A second idea is to design one indicator to sum up the quality of life in a place or the value of its output by combining important features of a place in a single composite, aggregated measure. The GDP is one such example, as is the Rand McNally Index to rate cities (Places Rated Almanac). The more recent effort of Redefining Progress to develop an indicator — the GPI (Genuine Progress Indicator) — that reflects real progress as opposed to including and weighting equally polluting and clean-up activities, is another example (Cobb et al, 1995; Anielski and Rowe, 1999). Another approach is to focus indicators on reflecting the status of particular problems (rather than try to be all encompassing) so we can be aware of how they are changing, like the unemployment rate, crime rates, or poverty levels, or housing affordability. Some hope for such indicators to motivate policy or assist in monitoring or evaluating policies and programs. Finally a movement to “reinvent” government (Osborne and Gaebler, 1992) emphasizes the development of performance measures and customer satisfaction. This spreading movement emphasizes the importance of dialogue in the design and use of measures and the interpretation of these in a complex, changing context. It does not advocate the use of indicators to guide a top-down control system, but rather to facilitate the work of many players in government to make better choices, solve problems, and improve their ability to respond to context and change.

Many of these ideas have turned out in the past not to make much sense. The all-purpose indicator report is seldom influential in itself. It may provide rhetorical points for speech makers and general education for those who know little about an issue (de Neufville, 1986), but typically influential players do not read it, much less act on what they find out from it. Moreover, it is enormously expensive and is not usually repeated. Without trend information, indicators have little meaning, and in any case, an indicator report goes quickly out of date. Often, aggregated measures like the Rand McNally Index have no meaning because to combine, for example, air quality, housing prices, and school quality in a single index requires a weighting system for which there is no clear basis (Landis and Sawicki, 1988). Sometimes such indicators are popular because of their simplicity and because they seemingly allow comparisons between countries or cities. They usually cannot withstand modest critiques, however, and accordingly they have not been widely used to actually influence policies, allocate funds, or guide other decisions. While indicators like the GDP are more thoughtful and meaningful and reflect more of a theory about the nature of the economy, they combine so much in one measure that it is not possible to use them to identify what is problematic or going well so that one can design a policy reaction to changes. Any aggregated measure reflects a particular theory or set of value judgments about the society and what is important, and that may not be shared.<sup>13</sup>

The idea of indicators to evaluate or even monitor how policy is affecting the world does not work because of the impossibility of holding the context constant so that changes can be associated with the

measure. In the midst of the ebb and flow of a complex world, it is impossible to isolate the "outcome" of a policy except in the most trivial sense of how many people were processed by the organization or program that was set up. What the impact may be on the world, or even on those people, one can never measure with much confidence, even with the most scientific evaluation. Researchers cannot make the world and/or people's lives stand still long enough. They cannot find and measure all the factors and activities that contribute to the "outcome," much less determine how much they contribute or in what way. The result of using societal indicators for evaluation is that all too often the public or analysts declare that some policy has failed when in reality we would be worse off without it, or when we would have different results if we just changed it a bit.

The most promising of these indicator approaches is the focus on issue or problem areas because this can be readily understood and used, and the method of using indicators that Osborne and Gaebler (1992) outline as a way to track the gauges and activities of public agencies while also developing sophisticated ways of diagnosing and responding to problems. The successes that have been observed relate more to such indicators than others. Broad indicator reports can be of value, but only if a number of conditions are met in that they are produced collaboratively and become an institutionalized part of the work of an agency and of the interests and players associated with it (de Neufville, 1986; Weiss and Gruber, 1984; Innes, 1988a). But then it is not the report that is the critical thing.

## **Lessons from Experience**

Some indicators have been influential in ways that have been clearly identified, including the national unemployment rate, the GNP, and the consumer price index (de Neufville, 1975). Information on human rights abuses has had an impact through the U.S. State Department's Country Reports (de Neufville, 1986) and data on race in schools has had an effect on policy related to discrimination (Weiss & Gruber, 1984). Technical information has had an influence in collaborative decision making in certain science intensive disputes (Ozawa, 1991; Innes and Connick, 1999) and in development of growth management plans (Dutton and Kraemer, 1985), in broadly enlightening decision makers about the issues (Weiss, 1977) and undoubtedly in many other ways that have not been documented. A significant literature however shows how many indicators, reports, and technical analyses have not been influential.<sup>14</sup> While indicators of crime rates, for example, may be cited a lot, it is not clear if they are actually influencing any public decision, providing enlightenment, or changing anyone's mind about how to fight crime or how to train police. These indicators are not closely linked to action (de Neufville, 1975). If we look at experience with both information which is influential and which is not, a number of conclusions emerge.

- Indicators do not drive policy. People are not suddenly converted because they are confronted with data, no matter how expertly or how collaboratively designed. Compendia of indicators are not used by policy makers as aids to decision. Conversion and learning requires more than reading a report or seeing an indicator.
- Indicators can be influential under certain conditions. They must measure something publicly valued. Their users must be involved in their design. Their meaning must be understood and shared among those

to whom they are relevant. They must stand up to expert critique. They must be trusted by all players. They must be linked conceptually and practically to actual policies or potential actions. There must be a place in the decision/action process where they are to be discussed and linked to action.

- Indicators' main influence is not primarily after they are developed and published, but rather during the course of their development. The process of debating the design of indicators shapes the players' thinking about the policies. Agreement on indicators helps get agreement on policy. The production and discussion of indicators in an agency or in the public arena focuses organizational and political attention on the issues they represent and gives them legitimacy. Their use can change the terms of public discourse over the long term (de Neufville, 1975; Innes, 1988a).
- If an indicator is to be useful, it must be clearly associated with a policy or set of possible actions. There will never be agreement on an indicator unless there is agreement on policy. The indicator does not lead to the policy, but agreement on policy can be advanced by discussion of how to design suitable indicators. The ideal method may be to develop the policy in the process of developing the indicator.
- Indicators influence most through a collaborative learning process. This learning occurs in the design and production effort as well as in the process of making sense of what the indicators later show. Indicators will not be influential just because they are well designed or because they show something surprising or even because they focus on a topic that is of public and policy interest. They only influence when they become part of the thinking and ordinary decision making of the players. This can only happen when the players are involved in developing them, so they can integrate them into their own perspectives and relate them to their own contexts and perspectives.
- It matters how the indicators are produced. Both anticipated users and participants in the production must be involved in the design of the measures and in planning for their implementation and use, as well as representatives of those with different stakes in the issues, if the indicators are to be influential. They need to reach agreement on both methods and concepts. If all this is done by experts alone, not including actual players, indicators do not influence action. If it is done without experts, on the other hand, the indicators are not credible and not used. The agency that produces the indicator must have both incentive and mandate if they are to continue to do so over time. Moreover, there must be safeguards to assure the indicator will be produced accurately and honestly. The users must develop a shared understanding of the implications of the indicators before they are even willing to support production on a regular basis.
- For indicators to be used, there must be not just opportunity, but a requirement to report and publicly discuss the indicators in conjunction with policy decisions that must be made. If this sort of required linkage is not made and followed, the indicators will never really become part of the debate. If the indicators start moving in a direction that is politically problematic, the producing agencies may even stop publishing them or avoid calling attention to them.
- The development of an influential indicator takes time. Five to 10 years is an estimate for an important indicator to be developed in these collaborative ways, linked into policy, and start to make a difference.

A set of somewhat parallel lessons has been derived from the history of indicators by two Redefining Progress researchers. This list includes: 1) having a number does not necessarily mean you have a good indicator; 2) effective indicators require a clear conceptual basis; 3) there is no such thing as a value free indicator; 4) comprehensiveness may be the enemy of effectiveness; 5) The symbolic value of an indicator way outweigh its value as a literal measure; 6) Don't conflate indicators with reality; 7) a democratic indicators program requires more than good public participation processes; 8) measurement does not necessarily induce appropriate action; 9) better information may lead to better decisions and improved outcomes, but not as easily as it might seem; 10) challenging prevailing wisdom about what causes a problem is often the first step to fixing it; 11) to take action, look for indicators that reveal causes, not symptoms; 12) you are more likely to move from indicators to outcomes if you have control over resources (Cobb and Rixford, 1998).

Participants in policy making do not use indicators in the simple way that has long been envisioned for good reasons. They realize that the world they face is complex and constantly changing, that opportunities and problems evolve, players change, and that understandings of that world change. They know that indicators represent, at best, only a small part of what they need to pay attention to. What we need to do to develop indicators that will make a positive difference is, first, to understand something of the theories of complexity that are emerging from science. These provide insights to allow us a much more productive strategy for indicators than has guided indicator work thus far.

### **Complexity Theory as a Way of Thinking about Cities**

Complexity has become a respectable scientific idea. Today mathematicians, scientists, and computer programmers have discovered that not only is the natural world fundamentally complex, nonlinear, evolutionary, and not fully predictable even with powerful methods, but also that simplifying and partitioning this world into discrete parts for rigorous measurement and analysis can produce misleading descriptions and fundamentally wrong predictions. What these researchers show us is that ignoring complexity and so-called random variations or "noise" misses the essence of the natural system. It is these variations that produce the changing world we know. The changes are not without pattern, but the patterns are so complex they can often only be detected with the aid of powerful computers (Gleick, 1987; Waldrop, 1992). These studies show that small perturbations of a complex system may make a great deal of difference in some cases — may even change its whole dynamic, while large perturbations or interventions in other cases may make little observable difference. They show us that networks and relationships among nodes matter and are essential to understanding these systems. Moreover, "learning" can occur in a system whether it is made up of molecules, computer code, or ants. Complex systems can adapt and self-organize in the same way we associate with organic or living systems in response to cues from the environment, particularly when that environment is at the edge of chaos. Complexity theory tells scientists what planners and other professionals working in the city have always known: everything is interrelated and is continuously changing, and unpredicted results of interventions are normal.

Social science has only just begun to reflect this new world view from the natural sciences, and the professions which rely on social science are thus handicapped. Social scientists often assume that their goal is to link well defined causes to well defined effects — a view that emerges from the machine metaphor of the world rather than the living system metaphor. In turn, urban planners, policy analysts, and political leadership search for tight links between policies and outcomes. They may try, albeit with great discomfort, to isolate their policy area, whether it is housing or transportation, and analyze it and the policies in use as if nothing else were happening in the city.

Instead of trying to control city development with carefully crafted policies designed to produce a particular amount or type of housing, for example, or trying to get a greenbelt by creating rules to prevent development in a defined area, they can look for a new way to frame the questions, generate strategy, and mobilize action. Policies fail to turn out as those crafting them desire not only because of emergent technologies or changes in the structure of the economy that are beyond their ability to predict or control, but even more importantly because there are so many diverse players who make the city what it is. Business people, residents, commuters, elected officials, and many others make millions of decisions on a daily basis which add up to the evolving form, structure, and character of the cities, and which 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, even if political support were forthcoming. The best planners and others can do is to help the players in these places to influence the direction of change.

### **Self-Organizing Learning Systems**

A complex system is in a basic sense out of control (Kelly, 1994). It cannot be predictably 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 intelligence works well to deal with such complex situations and to encourage creative, coordinated action. Many individual participants, following simple rules for adjusting their actions without seeing or understanding the dynamics of the larger system, can deal with complex reality. Indeed, top-down regulation and control strategy is far less effective than this kind of self-organizing approach when systems are complex and operating in a changing and unpredictable environment.<sup>15</sup>

Several examples suggest ways for us to see how such a distributed network of information and actors, each with little knowledge individually, works to produce outcomes that are coordinated and which demonstrate more intelligence collectively than any individual. For example, flocking behavior of birds can be mimicked with a computer by applying to each simulated “bird” a few simple rules like “do not bump into another bird” and “keep up with neighbors but do not stay too close.” The application of such rules results in patterns similar to the graceful and aerodynamically efficient patterns of flocking birds, and algorithms built on these rules are used for computer animation in films. The results are so realistic that biologists have concluded that real birds also operate by some such algorithms rather than use communication or other more complex strategies (Kelly, 1995; p. 11).

In another example, ant colonies are made up of hundreds of thousands of creatures with tiny brains, yet they form into complex social systems with hierarchies and specializations of labor. The ant colony as a whole has an intelligence none of the ants has individually. Each ant plays a part, and the result works for the group collectively to survive, reproduce, and adapt to changing environmental conditions.

Computer simulations now made possible by powerful parallel processing have expanded our understanding of the important idea of emergence (complex forms and structures that emerge from simple rules) and evolution. They help us to see that dumb or relatively dumb parts of a large system can work together to improve the system, so long as they get feedback from it and so long as they have a capacity to respond. Experimenters have found that simple algorithms and programs designed to reproduce themselves, but programmed with some random variations, begin to produce new forms. With some way of killing off the destructive forms, these programs tend to evolve more and more efficient or effective versions. Programs which incorporate ways to learn from mistakes and from the responses from the environment can be more powerful than programs an individual can design. A clear case in point is chess-playing programs, which became noticeably more powerful after they were designed to improve with practice. These programs can play much smarter games of chess than their programmers can because they learn by doing and evolve to develop strategies the programmers did not anticipate (Holland, 1998).

In another example of a how a self-organizing system can work when the individual agents get feedback, picture a large computer screen sitting in front of a large audience in which each member is equipped with a paddle which is red on one side and green on the other. The screen depicts members of the audience as points of red or green light depending which side of the paddle they display. The speaker instructs the audience to make a green letter Z in the middle of the screen. At first a fuzzy unintelligible pattern appears, but in a few minutes it shapes itself into a Z as members of the audience decide they are in or out of the Z by looking at the screen and at their neighbors. They try then to make another letter, but this time they do it faster (Kelly, 1994; pp. 8-9). Finally, Hutchins (1995) offers the example of a huge U.S. Navy ship which suddenly lost power in a narrow channel. The usual indicators and gauges did not work, and all power was lost for several minutes. This set in motion a series of actions and communications among people with different responsibilities around the ship as they endeavored to handle this problem without going aground or running over other boats. They made mistakes and had, at best, partial communications. They came up with inventive strategies to deal with not having their usual tools and with gauges working improperly. The steering overcompensated wildly. They discovered they had no whistle to warn an oncoming boat. But they managed to slow the ship and drop anchor without mishap.

In both these examples all players had a general goal — in one case, to make a Z and, in the other, not to go aground — which they knew and shared. In both examples, the task could not be accomplished without the participation of many players. In both examples, no one told the players what to do. It would have taken longer to get people to understand and follow instructions to make a Z than it took people doing it themselves. In the case of the ship, participants faced a new situation for which there were no instructions. They had to invent quickly what to do and work out how to coordinate their actions. 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 or of all the other activities that were going on simultaneously. Sometimes one person's judgment was wrong but others corrected it with what they did. They experimented

and reacted collectively. They learned how to stop the ship safely as they acted. Both these examples represent cases very like the urban world in which action takes place every day and few have the opportunity to consult or strategize quickly.

### **Indicators for Managing in Complex Urban Systems**

If we want to shape a city instead of a Z, each person must do his part. If there is some unforeseen but all too normal disaster, like an economic downturn, an earthquake, a riot, or just an unexpected reaction from citizens to a proposal, players have to wing it, and they have to do so with a minimum of consultation or formal plan making.<sup>16</sup> There is no time to make new rules, so people have to build on what they already know how to do. Maybe the players know how to steer a city when the economy is going well and the demographics are not changing and when structural change is not occurring. But when the changes start, many people will have to respond quickly and in parallel if they are to avoid running aground. Today cities are under stress and it can be argued that political, economic, and social change are so rapid that urban players operate in an environment at the edge of chaos, in a parallel sense to the complexity theorists' view.

Even if we accept the idea that complex systems can be managed by many players following simple rules and acting on their own limited knowledge, however, it is not obvious how this distributed intelligence can be created. If we look at the experience, we see central cities that are filled with deteriorating infrastructure, afflicted by crime and lacking in jobs. Suburban sprawl creates costly demands for new infrastructure and generates colossal traffic jams and air pollution even in low density areas. Economic restructuring has left many with little hope of work and a growing gap between the haves and have-nots. Much of what happens in metropolitan areas is counterproductive and far from sustainable. Hasn't this occurred as a result of the participants making independent decisions largely in a self-organizing way? Certainly the formal plans and policies were not intended to produce such outcomes.

The problem is that individual players have been acting with little sense of the big picture, any shared objectives, or of immediate effects of their actions even on their own welfare. What is needed is a set of indicators to provide feedback about how the system is doing, not only for the policy makers, but also for the residents, migrants, businesses, community groups, and the public agencies, so they can make simultaneous adjustments that will move the city in a desired direction. None of the self-organizing responses described above would have been possible if the participants did not have feedback from the environment on which they could intelligently and purposively act. What therefore will be important will be less to get the selection and design of the indicators exactly right (even the imperfect information and faulty gauges on the ship were useful as a starting place), than to engage the players and participants in designing the indicators, in developing an understanding of their meanings and of the workings of system which they are supposed to reflect, and in developing responses to changes in the indicators — and accordingly, to changes in the urban system. These measures and their implications have to become second nature to the people of the city. Players have to internalize the concepts and their importance so they can respond quickly and appropriately. Over time they can learn how best to incorporate feedback and adjust their actions, just as the audience learned how to make the letter Z faster on the second try. They can learn, through their own "praxis" as

homeowners, planners, or elected officials, to react to what the indicators seem to show. They can learn by working together and communicating about what they think is happening and what they think is working.

### **Indicators for a Complex, Adaptive Urban System**

To accomplish this task — to build a system of urban indicators that can truly help a city to be a self-organized learning system which can adapt and respond to change and opportunity and can effectively address problems — we propose that three tiers of indicators be developed. In the top tier, a small number of system performance indicators are needed, a few key measures which reflect the central values of concern to those in the city and which can serve as bellwethers for the health of the overall system. The development of these, if done collaboratively, can help to create a shared sense of purpose. In the second tier is a set of policy and program indicators. These reflect the activities and outcomes of various elements of the system or subsystems and allow policy makers, businesses or others to assess whether they should adjust their programs or policies and help with troubleshooting when results are not moving in a desirable direction. In the third tier are rapid feedback indicators to help individuals, agencies, and businesses to make the best choices for their own daily actions.

### **System Performance Indicators**

A handful of indicators of overall system performance should be selected and designed for each place. Perhaps one of these is a measure that reflects the overall quality of life or some broad value in the community. Such a measure need not be an aggregate that is ambiguous and difficult to interpret. An indicator can be selected which varies with the outcome variable of interest. For example, instead of measuring quality of life as a composite of housing, weather, economy and the like, one can develop an indicator of satisfaction from a survey of people's perceptions and attitudes. Or alternatively, a measure like immigration levels or the numbers of people that are moving out of a city might give a good indication of quality of life changes. Total waste generated could be a simple but valuable indicator of resource consumption, while also reflecting public attitudes and responses to the challenge of sustainability.<sup>17</sup> Whatever is chosen, it should be a measure of system performance, as opposed to merely of one problem area or another. This is a difficult concept to grasp, but a system indicator can help the community to see how the system is working and anticipate potential system breakdown or changes in direction. For example, in the San Francisco Estuary Project, the consensus building group which had the task of developing a management plan and the experts they chose selected the salinity level of the Bay at a certain key location as the indicator of the health of the Bay because this level was critical to the biodiversity of the whole system. If this indicator was going in the wrong direction, it would mean that biodiversity was about to drastically decline (Innes and Connick, 1999). Another example of a system measure might be VMT (Vehicle Miles Traveled) as an indicator of the sustainability of the transportation and land use patterns of a metropolitan area because it reflects the complex relationship of the use of transit, sprawling land use patterns and the potential for air pollution.<sup>18</sup> Another city concerned about a lagging economy might select an indicator of business startups, and another with a major focus on social equity might measure the number of children in poverty.

To establish such system performance indicators requires developing broad agreement among a wide range of participants on the kind of city the community wants. Is it a thriving economy without great extremes of income distribution? Or perhaps it is a civic community where all are engaged in the political and civic life? Or maybe it is a humane city where education and opportunity thrive? This mission must be shared if it is to guide the city's ship and prevent it from going aground. While determining a shared mission 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. The need to develop measures can be the opportunity for creating such a vision.

In this process it is critical to involve stakeholders, players, and experts in a joint effort to understand how the urban social, political, spatial, economic, environmental system works. These people should also develop ideas about how the choice of a particular indicator will have implications for policy and action. There is no point in having an indicator for which no policy or action response can be imagined, nor for one where no one can agree on a response. For example, if VMT is selected as an indicator, how is that likely to reflect on policies for supporting transit or highway development, or for local control of land use decisions? Indeed, this is a debate currently raging in the San Francisco Bay Area. There will be no agreement on VMT as an indicator until key players understand and accept what the next stage consequences will be of using it. But on the other hand, if the players do largely accept this indicator, and if it comes to be equated in most players' minds with discouraging sprawl, encouraging transit or simply providing sound transportation policy, it can be a very powerful and often tacit motivator of action. The trick is to stick to a simple and conceptually clear indicator that can be widely understood and which can be accepted by both the experts and the stakeholders as appropriate, reliable, valid, and methodologically sound (Innes, 1990). It is also important not to avoid controversial discussions and end up with lowest common denominator indicators that have few implications.

These system indicators, more than the other two types, require substantial public discussion and, ultimately, consensus among important players in part because they should reflect, or even help create, shared community values in a way no expert-driven design can do. Unless they are developed consensually and with ample discussion, they will not serve such purposes as framing public discourse and joint learning that will assure that the indicators and the ideas and information they represent become integrated into actions of the community and its leadership. Community members have to equate these indicators with the things they value and use them routinely as part of their language and guides to action if they are to have influence (Innes, 1998). If they do, then the indicators influence the players in pervasive ways, many of which may not even be conscious.

It is important, however, not to use these, or the policy and program indicators described in the next section, in a simplistic way to argue that a policy is not working or to punish any player or agency. Indicators cannot and should not serve such a purpose for reasons noted above — they simply do not show the causes of problems, only the existence and change in conditions. They are indicators, not answers. They are the starting place for discussion and exploration of potential action. Moreover, if one tries to use these measures as criteria to reward and punish cities or agencies, the result will be to undermine the entire indicator system. No agency will produce accurate data if they are going to be used to punish or criticize the agency. On the

other hand, an indicator developed in a thoughtful, informed way by the stakeholders and agencies to help them find out about conditions and to communicate with the public and with leadership about problems, needs, and opportunities is an indicator that will continue to be produced over time because the people who produce and use it know it is valuable to them.

### **Policy and Program Indicators**

A second needed type of indicator is one that will allow policy makers, whether in the public or private sector, to see both what the outcomes are of policies and programs and what is the state of particular subsystems. These will also show those who are responsible for the activities how to analyze what is going on and diagnose causes of problems. For example, these indicators might focus on the quality of parks in a city or on the transit systems. They would look both at customer satisfaction measures as well as various other indicators that help the agency staff, elected officials, and interested members of the public to understand how park maintenance is being done and give some clues about why some parks are in deteriorating condition. These are indicators which allow responsible actors to make adjustments in their daily actions and to set priorities. These indicators provide feedback to the leadership so they can say whether a policy is moving in the right direction, at the right pace, or identify problem areas where city staff or others need to work on solutions. These are not definitive performance assessments of a policy or program, but part of a set of information that the experienced policy maker or public manager uses in an effort to make sense of many interlinked activities and ongoing events. For example, the numbers of vacancies or length of the waiting list for public housing might be performance measures for housing officials, along with monthly maintenance costs. If these were getting unacceptably high, elected officials can say so and ask that more investigation be done of associated indicators that could provide clues as to whether the causes are poor janitorial service, vandalism, poor management, or changes in the population. Other indicators, like complaints from residents, time needed to respond to them, turnover among employees, or crime reports might be used to further diagnose problems and provide guidance for response.

Unlike system indicators, there can be dozens of these policy/program indicators on any given topic. While these should be selected with the participation of those who have to use and learn from them, these do not require the degree of consensus, reflection and system understanding that system indicators do. There will be many indicators of different activities used at the same time so inadequacies of one can be compensated for by others. They will be used by those who are knowledgeable about the programs and interpreted in the light of a variety of kinds of information and probably not by a very broad public. Most do not have to be specially designed because they will be ordinary outputs of the daily activities of an agency. Sometimes special surveys of satisfaction or outcomes might be done however, or new ways of compiling or tabulating information might be required. The goal in designing policy/program indicators is mainly to assure that the measures chosen are meaningful and that they will be timely, useful and relevant to the decisions and questions that face these players.

If the design of these indicators is assigned by an outside technical consultant, it will virtually guarantee they will remain unused. In any case, as with system indicators, the process of selecting as well as

using the measures is all part of the learning that is essential to assuring that the indicators have shared meanings and become a focus for discussion. This, in turn, will help the participants internalize their implications and make them more likely to take informed action. The point of indicators in a complex world is to help participants make adjustments and to adapt actions to rapid change, to fine tune policies to fit local conditions, to identify opportunities, to become creative about possibilities and new actions.

Many opportunities for the development of policy/program indicators exist that have as yet been little explored, but with imagination and ingenuity a great deal is possible. Given the importance in cities of spatial patterns, for example, one can take advantage of the fact that so much administrative byproduct information is now available with geocoding. Computer mapping of many types of information can provide powerful indicators comprehensible to the lay person, which will show the spatial patterns of change. It can be available on almost a real-time basis and allow anticipation of change and a proactive rather than a reactive stance. For example, the location and number of building permits and housing sales in a city could be mapped and produced on a frequent basis to help local officials to see where in the city development is occurring and to respond with services and infrastructure or changes in their investment plans. The speed of turnover of housing can be an indicator of where speculators are at work, so it may be important to protect low income homeowners. Business permits or sales tax revenues could provide neighborhood based information on changes in economic and commercial activity. Such indicators can also be developed out of the experience of residents in a community, as was done in an experiment in Lancashire which looked at public perceptions of sustainability (McNaghten, 1996).

### **Rapid Feedback Indicators for Individuals, Agencies, and Businesses**

In the final analysis, a community is made up of homeowners and renters, commuters, entrepreneurs, shopkeepers, clerks, laborers, service providers, regulators, and so on. A city is the result of what all these individuals, businesses and agencies do. A city is what they produce and reproduce over time, whether these are buildings, practices, or institutions. The physical, social and economic form of a place is the result of millions of individual actions and interactions in dynamic relation with the context of the larger society, the natural environment, and global economy. Each of the actors reacts not only to others but to her perceptions of changes in the context. A community is a complex system where players are constantly navigating the best way they can. People in their different roles act on the information they have to try to accomplish their own missions and in the process the city evolves.

These participants in the city typically have very little information to help them optimize their own welfare or do their jobs effectively. While they, like flocking birds, can look at the person or business next to them or down the street and adjust their actions accordingly, they can see little of the larger system. They cannot easily tell how it is evolving — if business conditions, for example, really are making it a good time to open a new upscale restaurant. They cannot easily determine where in the city they can find the goods they need at the current lowest prices or the ideal package of housing, school quality and costs for their needs. This requires a lot of research, so most act with only very limited information. If they could act in a more informed way for their own interest, complexity thinking, like classical market theory, would predict they will

also make the urban system work better. If they can choose intelligently from more options, they can use their own and the city's resources with greater efficiency. Individual access to better and more timely information is crucial to this process.

There are already a few examples of rapid feedback indicators that improve the workings of a city as a self-organizing process. The best example (besides the weather report, which helps us decide whether to walk or ride, or whether to go to the park or a movie) is the way information is used and reported about the location and speed of traffic on a metropolitan's freeways and about the delays on public transit. Each morning in major metropolitan areas one can tune in the radio or TV to get detailed information on the location of accidents and the length of tie-ups. This information comes in from police departments, news helicopters, and individuals with cellular phones. It is up to the minute and generally accurate. Thousands of people then make their decisions about routes to take or whether to take public transportation. The result is that traffic spreads more widely over the system, using it more efficiently, air pollution is minimized, and individuals save both time and aggravation and thus have more energy to apply to more constructive purposes. Emerging technologies will allow us soon to improve on this by electronically counting cars as they enter freeways and measuring their speed. Some roads now have changing signs at on-ramps reporting how long the commute on the road will be to give people the chance to take another route. In many places, this information is also on a web site that drivers can check before leaving and which will be accessible in the cars and buses of the not too distant future. In the San Francisco Bay Area, all this is supplemented by a system of call boxes for drivers to call on roving tow trucks for rapid response to accidents that would tie up traffic. Each of these is just a way of providing for communication and feedback and allowing each person or agent in the system to act in an informed way without central direction. This kind of system is likely to become increasingly important, not only to individuals, but also to business and the economy as just-in-time production puts a premium on the ability of firms to deliver goods on short notice as part of flexibly linked industrial sectors like the high technology sectors.

Other indicators to assist people, agencies, and businesses in managing their activities are technologically within reach. In water-starved California, for example, where the cost of water is high, residents could have daily information on their water use and its cost available in their kitchens, so they can discover when they have leaks or recognize when a particular water-using practice is wasteful and expensive. Similarly, it could be made easier for a household to monitor its own daily or even hourly electricity or gas usage, so they can make more informed decisions about how and when to use these resources. Water districts in Sacramento, which have recently installed residential meters, have been able to use information on water usage to identify where water mains have been leaking and wasting a substantial percentage of the water supply. Bar codes on supermarket packages could be used to develop indicators on what is being purchased where in a city, both to help businesses to identify market changes or even short-term needs, and to help planners identify demographic shifts that will not show up in the official statistics for years. Emergency calls to 911 in the U.S., which come in with the address of the caller, have proved useful for mapping crime and fire danger areas. These spatial indicators are already used by police and fire departments for deployment of manpower. All of these rapid feedback indicators can create a system of distributed intelligence which can support a more sustainable city, without central direction or regulation.

## **Recommendations for Action**

There is no formula or even a simple strategy to accomplish these proposals. The task will be different in each city, depending on the local culture, issues, players, practices and institutions. It will be essential for each city to design its own indicators in its own way. While communities can learn from each other's work and ideas and they can and should use the work of experts as inputs to their discussion, what they do has to be their own if the indicators are to help make theirs a self-organizing, adaptive system. The main ingredients of the effort are several.<sup>19</sup> The community needs to develop a way to bring its key stakeholders, agency players, experts and citizens into a process to select a set of system indicators, perhaps 3 to 5 at most. The number must be limited because too many will cause information overload otherwise. In any case, the development of each one will be time consuming and challenging if it is done properly. Shortcuts will simply make these measures useless. One should be prepared for this to take 2 or 3 years. Local universities can often help provide the technical knowledge in an inexpensive and politically unbiased way. It is important for the discussions to address the difficult, controversial issues because these will present the greatest opportunities for learning and change. Professional facilitation assistance can be helpful in many communities. It will be sensible to begin by focusing on those issues and topics where a substantial amount of interest and commitment to some kind of action is already in place. This commitment can mean the energy, interest and funding to develop the indicators will be forthcoming, and the indicators can be associated with actual proposed policy. This means they can be designed to be relevant and to get attention. Starting with such topics is more likely to help people become interested in indicators for topics not so high on the agenda.

At the same time a community is working on the system indicators, the participants in a particular program or policy network or issue area should be gathered to identify the policy and program indicators that could help them to see how things are going, whether outcomes are good or not, and to diagnose causes of problems and identify opportunities for improvement. This must include the public agencies involved in producing the good (and usually also involved in producing the data) as well as the private players who depend on the good or service, and the interest groups who pay attention to it. Many of the indicators are likely to be information collected in the course of doing the city's business, like measures of business licenses or traffic tickets, but data might also be collected by and from nonprofit agencies or businesses as well to get a meaningful picture of the issues and to engage these other players in the problem solving aspects of examining the indicators. Special surveys of community or user satisfaction or activity might also be needed.

There will need to be some funding to develop these policy/program indicators, as there will for the system indicators, because it will take time and resources to gather and tabulate data, to reorganize reporting systems and implement them. It will require staff to organize the discussions and follow up ideas. This cannot just be done as part of the regular duties of already overtaxed city staff. Leadership will be required to help assure that the new indicators are actually used and discussed. In particular, the city council, planning commission and other city boards and commissions should be introduced to the key indicators and asked to agree on the ones they want to have reported regularly to them. Workshops with staff and citizen leaders can help make sure this is not solely an internal exercise that may be ignored over time by some city staff who may not be interested in change or in the greater oversight of the elected officials.

For rapid feedback indicators, the process of development need not have all this public discussion. The main task at this stage is to explore the opportunities that have become available because of new

information technology and to try to get utilities, home builders and transportation agencies to incorporate feedback data in the new facilities they build.

This three-tier indicator system should be ultimately designed to help the individuals and players in the city to go about their business in a way that helps assure the city can be more sustainable and adaptive, that it can be an “intelligent” urban system. The indicators can only have these effects if they become part of everyone’s understanding and action.

## Notes

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1. An earlier version of this paper was presented at University of Newcastle, Department of Town and Country Planning, 50th Anniversary Conference, 25-27 October, 1996
2. Dozens of definitions have been proposed for sustainability or sustainable communities. Most of these involve a concept of a development that provides for current needs without compromising the health of the ecosystem in the longer run. Many of these focus on the three “e’s” — environment, economy, and equity — contending that all three must be addressed in a community that is truly sustainable.
3. The Urban Institute several years ago launched the National Neighborhood Indicators Project (NNIP) to help a series of cities across the U.S. develop indicators of neighborhood conditions so residents, public officials, and civic leaders can better plan appropriate strategies to improve their communities (Sawicki and Flynn, 1996), and a national Community Indicators Project, led by Redefining Progress, a nonprofit devoted to improving social measurement, assists 125 projects around the country (Redefining Progress, 1998). Some of the projects use the term “benchmarks” rather than indicators.
4. For example, The Bay Area Alliance for Sustainable Development has representation on it from the other major cities, each of which has its own sustainability project. In Detroit, May 1999, a national Town Meeting was sponsored by the President’s Council on Sustainable Development while dozens of regional conferences were held simultaneously around the country. Sustainable Seattle was awarded a United Nations Citation for Best Practices in Community Indicators as the U.N. and other international organizations promote this kind of work. A set of international guidelines for indicator development and communication were developed as a consensus statement at a global meeting convened by the International Institute for Sustainable Development based in Winnipeg Canada. This set of ‘best practices’ is known as the Bellagio principles, available as Appendix G in the Community Indicator Handbook (Redefining Progress, et al., 1998). What we propose in this article is consistent with these principles which propose, for example, that the indicators should look at the whole system, deal with economy, ecology and equity, involve a limited number of issues with indicators linked to goals and assessment criteria, have methods and data accessible to all, involve broad representation, and be continuing over time, institutionalizing the capacity for ongoing local assessment.
5. These efforts seem to be converging with other related efforts to improve communities in a broad ranging way, including the Healthy Cities initiatives, and efforts to develop quality of life measurement. One of the earliest in the present set of community indicators projects seems to be the Jacksonville, Florida effort to develop indicators for quality of life (Andrews, 1996; Jacksonville Community Council Inc., 1996).
6. Urban Quality Indicators, TBC Publishing Co., Box 6283, Annapolis, MD.
7. Exceptions include an article assessing Neighborhood Indicators Projects (Sawicki and Flynn, 1996) an as yet unpublished article (Unknown, 1999) which surveyed 16 community programs, a report on two

cases (Besleme, Maser and Silverstein, 1998) a brief description of projects in Colorado (Conner, et al. 1998), a report on 5 programs in Washington State (Miller, 1997). Very little has appeared in the academic literature on this subject. A special issue of the Journal of the American Planning Association in Spring of 1996 focused scholarly attention on the need and issues around the development and use of community indicators but much of that work is think pieces and proposals for practice rather than documentation of the practice.

8. Some of the better web-based resources to learn about community indicators projects include the National Partnership for Reinventing Government report on Best Practices in performance measurement, <http://www.npr.gov/initiati/>; The Sustainable Communities report of the President's Council on Sustainable Development, <http://www.npr.gov/library/papers/benchmrk/nprbook.html>; [http://www.whitehouse.gov/PCSD/Publications/suscomm/ind\\_suscom.html](http://www.whitehouse.gov/PCSD/Publications/suscomm/ind_suscom.html); <http://www.whitehouse.gov/PCSD/index.html>; Redefining Progress list of Community Indicators projects on the web [http://www.rprogress.org/resources/cip/links/cips\\_web.html](http://www.rprogress.org/resources/cip/links/cips_web.html); The U.S. Dept of Energy Center of Excellence for Sustainable Development describing urban sustainability projects in which indicators play a key part, <http://www.sustainable.doe.gov/>; and the US.DOE list of top sustainable development web sites, <http://www.sustainable.doe.gov/hotspots.htm>; U.S. EPA's web site on sustainable community, <http://www.epa.gov/ecocommunity/>, focusing on community based environmental protection and livable communities and offering sustainable development challenge grants; and The Green Mountain Institute Resource Guide to Indicators, <http://www.gmied.org/irguide.html> .

9. For example, the U.S. Interagency Working Group on Sustainable Development Indicators set up by the President's Council on Sustainable Development has produced a thick packet of proposed indicators (U.S. Interagency Working Group on Sustainable Development Indicators, 1998) and comparable work is being done around the world (Bossel, 1996; Hammond, et al., 1995).

10. For example, at a conference of community indicator project participants attended by one of the authors, many expressed frustration. Having produced the indicators, they thought this would be enough to start change happening. This bears out both authors' personal experience participating in efforts to develop indicators. The numbers substitute for the goal.

11. For this purpose, of course, it is useful for scholars and analysts to develop and propose specific indicators that can be used in these community based discussions as starting places, examples, or even measures they will select.

12. We have outlined these three types of indicators briefly in an earlier paper (Innes and Booher, 1999).

13. It should be noted that most indicators represent aggregated measures to some degree — that is, apples and oranges have to be added together to get some measure of fruit. The problem is that in many cases the underlying scale on which to do the aggregation in many cases is not adequate.

14. A review of this literature can be found in the Introduction to *Knowledge and Public Policy*

(Innes, 1990).

15. Many kinds of research converge on this point from studies of paralleling 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.

16. A new movement in California, for example, is to organize neighborhoods to respond in case of earthquakes. The federal agency responsible takes days to get on the scene and often follows standard operating procedure inappropriate for the particular problem in the particular place. But individuals trained and organized by blocks can, like the sailor on the Navy ship, figure out what to do based on the specific problems that arise, whether they are losses of power, injuries or fires. They can protect each other and share emergency equipment. They can create their own survival system (Simpson, 1996).

17. This one was proposed by the Sustainable Community Roundtable of the South Puget Sound Region in the State of Washington and selected by Hart Environmental Data as their indicator of the month in July 1998.

18. This is a controversial indicator now under discussion in the San Francisco Bay Area with transportation agencies resisting its use because they fear its being used to hold them responsible for land use patterns and for decreasing the legitimacy of investment in new roads. On the other hand, social equity advocates want to see transit get a larger share of the fiscal pie. The controversy over the measure is also due to lack of agreement on how the system of transportation and land use works and what a good system would be like.

19. Our proposed process is largely consistent with the ideas laid out in the *Community Indicators Handbook* (Redefining Progress, Tyler Norris Associates and Sustainable Seattle, 1997).

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