SCIENCE AND PRACTICE FOR THRIVING CITIES

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The last decade has seen an increased focus on cities and urbanization in connection with tackling some of the most important but also most difficult problems of human societies.[1] Such issues range from sustainable development and resilience in the face of climate change to challenges of economic growth, justice, and inequality.[2] Not surprisingly, these issues have been part of the international and national political agendas for a long time. However, despite the relatively greater resources available at high levels of government, progress—almost always and almost everywhere—has been excruciatingly slow. Diverging ideological interests, greater distance from the problems on the ground, an inability to properly analyze the issues as they affect individuals, and greater difficulty in assessing proposed policy solutions as they are rolled out all contribute to making policies ineffectual when formulated at these high levels.

There are many illustrations of this sort of impasse. A particularly clear recent example deals with attempts to tackle the sources and consequences of global climate change. The issue has been gridlocked between developing and developed nations at the international level, and between environmentalist groups and conservatives within many nations. Meanwhile, cities throughout the world, regardless of their national or political contexts, have stepped up to the plate and are creating a peer-to-peer movement that is leading to fast, practical, and effective change.

The fact that cities may be able to address persistent social and environmental challenges more effectively than national governments should not be surprising, for a number of reasons. First, city and local governments are much closer to their citizens and to their struggles. In principle, this allows them to better understand the nature of their problems and respond faster. Second, local problems and policy solutions often are already in play, providing real-time, real-world experience and practical avenues for learning, taking action, and refining policy through multiple iterations. Cities and other local governments must stay with a problem over the long term and assess whether it is being solved effectively. This can promote a more gradual and more practical approach to problems over time, with a focus on discovering what works.

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Despite these advantages of local government, the reality is almost always much more constrained. Local governments are the principal providers of essential services to most people, such as water, sanitation, basic education, and emergency response. The daily operational demands of this essential and exacting work tend to take precedence over strategic planning that can address deeper problems over the long term. As a result, local government action is often limited in scope, with an emphasis on short-term objectives and aspirations that include simply "living to fight another day."[3] Local governments are therefore often shackled by attending to what is urgent, rather than to what is ultimately important.

Things are changing, though. A good deal of action, and hope, is presently empowering cities. What is emboldening local governments to take on more than their immediate work? What is making it possible for cities and local governments to tackle perennial problems of equity and sustainable development? If new factors are at play, what is their logic? How can they be better understood and used more effectively to create thriving cities all over the world?

This paper examines these questions from two different but complementary points of view as presented by its two authors, one a scientist leading the Cities Project at the Santa Fe Institute, an effort that has contributed to the recent emergence of a new multidisciplinary science of cities; and the mayor of Santa Fe, New Mexico, a small city known for its creativity and deep multicultural historical roots, which is now striving to create new solutions to its most pressing problems. Our dialogue and our work together in Santa Fe, as well as our expertise and contacts throughout the world, have led us to identify what we think is a new transformational movement—both intellectual and practical—of innovation in cities.

Our arguments are intended to clarify what we think is fundamentally new about the power of cities to create much-needed change in an age of global urbanization and pervasive information technologies. In this paper, we provide a rough guide to what can be achieved through a set of new collaborations involving city governments, scientists, technologists, civic organizations, and other stakeholders.

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THREE ELEMENTS OF URBAN TRANSFORMATION: KNOWLEDGE, TECHNOLOGY, ACTION

Worldwide urbanization and the growth of information and communication technologies are the two most important forces shaping change all around the world today, and will continue to be for the foreseeable future.[4] Although the two trends may seem independent, when taken together they create a perfect setting for pervasive (urban) change. They enable faster social and economic innovation, democratize knowledge creation, and subvert many existing structures, including economic organizations, bureaucracies, and traditional forms of government and urban planning. Such change is already apparent in cities throughout the world, but new models of urban planning that capitalize on these opportunities in the civic realm are just beginning to emerge. If a city is to thrive, it must help create new platforms and collaborations that lead to better knowledge of urban processes, exploit the power of new technologies, and combine these elements into a virtuous cycle of learning and action, which we describe later in this paper.[5]

Knowledge: An Emerging Science of Cities as Systems

An exciting development in our approach to cities is emerging from the fact that new technologies and greater global interest are generating new data and more fundamental knowledge about many important aspects of urban life.[6] Our past understanding of cities and urbanization relied on a number of relatively disconnected academic disciplines that did not address the city as a joint social, economic, and infrastructural system. For example, urban economics has emphasized problems of real estate and land rents by exploring how firm and individual productivity may be organized in space, subject to transportation costs and agent preferences.[7] Urban sociology, especially in the United States, has emphasized social structures, in particular social networks and their relationship to issues of inequity and exclusion, poverty, and crime.[8] Urban planning, engineering, and geography, on the other hand, have tended to concentrate on different aspects of urban built form, infrastructure, and services, typically from a more practical but not always empirically grounded perspective.

Although these traditional approaches have taught us much about urban phenomena, the crucial areas at the interface of these disciplines remain poorly understood. We need to know more, for example, about the specific chains of causality by which improving urban infrastructure and services may stimulate economic activity and reduce poverty. How should such improvements be rolled out? The neediest neighborhoods first or last? Can incremental improvements to services have predictable consequences in terms of changes in the local quality of life and business activity? Are they more sustainable financially? When are larger-scale public works essential? Despite their obvious importance, questions like these require the integration and synthesis of knowledge from several disciplines and have remained woefully understudied. As a result, much of the past science of cities has been constrained by its reliance on limited and often contradictory conjectures and assumptions. Thus, it did not amount to an empirically based framework for providing policymakers with much-needed systemic guidance for prediction and assessment of interventions.

But this situation is changing fast. The path to better and more actionable scientific knowledge of cities is being opened by a series of new developments. First, new empirical evidence in the form of a proliferation of data is making it possible to measure and assess many aspects of urban life. Second, new technologies, from mobile smart devices to collaborative mapping, are enabling not only such measurements but new ways to create planning interventions,

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for example, by helping people and city governments coordinate and pool information on urban services on an ongoing basis.

More fundamentally, these data and technologies are expanding our ability to create learning opportunities tied to each local intervention, thus building new platforms to test and systematically expand our fundamental knowledge of urban processes. As a result of these transformations, new models of planning and policy are emerging that are more explicitly enabled by scientific ideas, and thus are bringing practical action in cities closer to scientific methods of inquiry.

New data on thousands of cities throughout the world are creating novel opportunities for comparative quantitative studies of what is common and what is different between locations. Communalities speak to many basic but fundamental properties of all cities, big and small. Differences, on the other hand, only make sense when measured against the background patterns created by these common features: they exist at many levels, from individual and cultural characteristics to physical geographies, histories, and levels of wealth, equity, and development.

Recently discovered communalities provide a general platform for collaboration across cities, within nations, and internationally. First, regardless of the level of development or their history, all cities should first and foremost be seen as social and economic networks of people and organizations embedded in built physical spaces.[9] The main point of this simple observation is that the success of cities hinges on their ability to realize network effects, which are the fundamental processes responsible for the advantages of larger cities. They magnify economic productivity and promote faster innovation (civic and economic) and greater resilience within larger cities.[10] They also create interdependencies between cities of different sizes, which leads to an integrated urban system where small towns and large cities play complementary roles.

Network effects is a term borrowed from technology. Thus, to understand its meaning we look at technological networks such as the Internet, and at cities.

Network effects emphasize that the value of a system is proportional not to its number of elements but to the connections between them. This is natural when we consider a system made up of transactions, be it in terms of information over the Internet or in terms of, say, money within the physical space of a city. This emphasis on the connectivity between people and organizations means that the prosperity of cities depends not so much on how many people they have (which is important, of course) but, more fundamentally, on their ability to connect with each other for mutual advantage. This emphasis on connections embodies familiar economic arguments at the base of productivity and growth, such as the division of labor and knowledge and the exploitation of comparative advantage via trade and exchange. It also emphasizes fundamental ideas from sociology, such as collective efficacy (the means by which individuals in a society solve problems together), and the importance of heterogeneity and interdependence between individuals and organizations.

Seen in this light, thriving cities are places where millions of strangers come together to explore how they can create economic and social complementarities that can lead to new, generative civic and economic enterprises. Such combinations are unlikely, unique, and often very valuable. They are also hard to create in an environment other than a city, which is why cities and urbanization are necessary for fast economic growth. Thriving cities thus must facilitate social and economic interactions between different kinds of people by encouraging collaboration and accountability.[11]

In practical terms, for a city to thrive requires it having a systemic approach to physical infrastructure, services, and socioeconomic life. For example, it requires good

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transportation infrastructure so that people can move and meet across the city. It also requires basic services and education so that people, especially women and children in developing cities, can become creative and entrepreneurial socioeconomic agents. And it requires a safe and collaborative environment where people with different histories, religions, races, and cultures can trust each other and hold each other accountable without violence when things go wrong. Needless to say, we can all identify places and situations where things like this should work better than they do at present along any of these dimensions. The solutions, though, may take different forms in different places, as they depend on local situations and contexts that cannot be easily copied from other cities and nations.

The consequences of network effects in cities are quite startling and profound, as cities differ vastly in population and density. Network effects means specifically that the number and value of socioeconomic products per capita increases with city size in a rather predictable way (by about 16 percent with each doubling of the population), as connections between people increase faster than population.[12] This means that larger cities have larger per-capita economies as well as higher wages and rates of innovation, but also higher costs, by about the same amount. They are also on average denser in the same proportion.

This balance between higher pay and higher costs, and greater socioeconomic opportunities but less physical space, makes living in larger cities an approximately neutral proposition. This means that cities of all sizes have their own advantages and disadvantages but that the two are different: such complementarities should be embraced by policy. Whereas large cities often struggle with greater inequality and more crime, intense use of infrastructure and chronic need for repairs, and limited affordable housing, they suffer less than smaller cities from lack of innovation, slow economic development, or difficulty attracting young and foreign populations. The latter are the predominant problems of smaller cities, such as Santa Fe.

These comparative struggles affect people at different stages of adult life in distinct ways. Individuals often cycle through differently sized cities at different times in their lives. Young adults typically care less about space and safety, thus they tend to live in larger cities, where they first build their independent social and economic lives and acquire human and social capital. Older adults often move to smaller or less dense areas as they become more established, have children, and reach the prime of their professional lives.

But while much progress is being made in mathematically understanding many general properties of cities, many crucial issues still require better science. This includes understanding the incredible diversity—and inequality—that is immediately apparent in any large city. To what extent are these heterogeneities "features" or "bugs"? How does a city promote an attractive, creative, and level playing field for everybody? How can safety be enforced without brutality or injustice? How can cities create productive inclusion for newcomers? These issues are actively being studied in practice and in theory using new combinations of data, such as cell phone locations and detailed neighborhood censuses. Understanding them and finding new solutions for these age-old problems requires the kind of new tools and policies that bring science close enough to practice inside cities, which we discuss next.

Technology: Smart(er) Cities

We already have pointed out the crucial role technology plays (especially information and communication technologies) in promoting better knowledge and better practices in cities. These technologies, which are varied and fast changing, include traditional elements of computing now on every desk

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and in every pocket, along with new uses such as digital data retrieved from sensors, maps, and surveys. They also include the new possibilities being opened up by smart phones for such tasks as coordinating on-demand services related to transportation, emergency response, or assisted living. Other new technologies, which can synergize with information and communications technologies, are revolutionizing energy production (solar panels) and storage, transportation (autonomous vehicles), and health and environmental quality. Thus, the power of various technologies is best mapped in terms of their potential uses, the disruptions and possibilities they bring to urban life, and the capacity of local governments, businesses, and civic organizations to use them to improve their current practices.

Many of these possibilities have been summarized in the push to create Smart(er) Cities.

In their initial conception by IBM and other technology companies, Smart Cities were essentially "better-engineered cities."[13] Early prototypes, such as the now scaled-back Masdar City (in the United Arab Emirates), were thoroughly engineered urban environments where energy generation, transportation, water, sanitation, and other services were seamlessly integrated into an automated and "green" citywide system.[14] Visions of automated cities run by technology go at least as far back as Le Corbusier and the ideal modernist city, but these concepts have always failed to deliver livable cities from a human-centric perspective.[15]

Consequently, the concept of Smart Cities has itself been changing as the limitations of engineering approaches become more apparent.[16] In the United States, for example, the primary objective of a new White House initiative on Smart Cities is to improve socioeconomic life and equity.[17] Recent initiatives in India and other nations have also pivoted to increasingly capture this emergent systemic Zeitgeist and the primacy of socioeconomic issues.[18]

The use of technology at the interface of socioeconomic life in cities and their engineered systems requires an approach that is often fundamentally different from traditional approaches and applications of data. Most early Smart City concepts relied on the idea of engineered control systems.[19] The most familiar example is the thermostat: it is not particularly smart, but it automatically adjusts a building's heating and cooling systems to maintain a chosen ambient temperature. Smart City concepts follow a similar logic but strive to run more complicated systems. They would help keep buses running on time, trash collected, power on, and other basic services working seamlessly by continuously measuring levels of service and adjusting logistical management in real time. This may enable many city governments to perform their tasks more effectively and provide better service, but it also introduces some rigidity into the nature of services and may erode their ability to adapt to rapid changes or unexpected events.

Such rigidity is, of course, anathema to issues for which we still don't have good automated solutions (we give a couple of examples of our work in Santa Fe in the next section). Most such problems are socioeconomic and deal with issues of development, innovation, economic growth, justice, equity, safety and security, among others. In these cases, technology can still help in critical ways, but its use is less about automation and more about supporting existing activities and helping solve difficult coordination problems between diverse stakeholders.

Action: Act Locally, Learn Globally

The convergence between the need to solve pressing problems in real cities and to derive general knowledge from the aggregate of many such actions is what we call

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"act locally, learn globally." We propose this motto as a general principle for policy design and as a means to anchor needed action to a growing body of knowledge and technology created by researchers and businesses, and by other practitioners in other cities. The central idea is that each local intervention can at once benefit and contribute to growing our practical and fundamental knowledge of urban processes. Linking local proposals to the best science and practices is a process that can also help garner political support for actions and speed up consensus.[20] Recent initiatives in the city of Santa Fe have been designed in this spirit.

911 call data and emergency medical response. One issue tying together urban services is how emergency response—triggered by a 911 emergency phone call—is being used overwhelmingly to provide medical assistance, especially to more vulnerable populations such as the elderly, those with chronic conditions, and the homeless. A 911 response is handled by the city's fire department, but it typically results in taking a subject to a hospital emergency room. An analysis of 911 call records reveals that the vast majority of responses result from just a few callers with chronic problems: about 0.3 percent of the city's population made up 18 percent of the city's 911 calls in 2014.[21] As a result, fire department first responders are predominantly engaged in providing health assistance. Thus the city has initiated a systemic program that targets providing better care to frequent callers, who often qualify for medical assistance under the Affordable Care Act and other programs. The objective of the initiative is to measurably improve health standards in the city while also using the fire department more sensibly and saving on health-care costs. This solution includes many of the ingredients described earlier in this paper: it addresses a multidimensional systemic problem; it is a collaboration with other cities and fire departments (in New Mexico and neighboring Colorado and Arizona); and it is incremental but seeks tangible and constant improvement based on real-time data and the judgment of the people involved. It also benefits from a scientific analysis of these data from researchers at the Santa Fe Institute, who are creating assessment tests and predictive tools that support local action and embed them in simple open-source technologies. We hope the result of this collaboration will not only solve this issue in Santa Fe but also will create a system that can be used in any other city and be constantly improved as part of a peer network of cities.

Carbon neutrality by 2040. Like many other cities around the world, Santa Fe has recently passed a resolution to become carbon neutral by 2040. It also has joined the Compact of Mayors, an international network of more than four hundred cities formed to create standardized and comparable measures of current greenhouse gas emissions and associated energy use.[22] The compact involves the United Nations, New York City's former mayor Michael Bloomberg, C40 cities, the International Council for Local Environmental Initiatives, and many other organizations dedicated to understanding and fighting climate change.

Because Santa Fe's city government has limited resources and expertise to dedicate to this important issue, it created several working groups to address issues of sustainable development that include city officials, interested citizens with appropriate expertise, nonprofit organizations, and researchers from the Santa Fe Institute and nearby Los Alamos National Laboratory. The issue of how to measure carbon emissions from all possible sources (e.g., electricity, heating, garbage, transportation) accurately and consistently over time presents a number of practical complexities that may only be possible to address through a networked effort. For example, it is difficult to obtain detailed data from utilities and businesses engaged in selling fuels, as no mechanism presently exists for disclosure and these entities fear liability and competitive-

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ness issues. It is also difficult to attribute emissions to consumer goods. A finer assessment of the lifecycle of products is ultimately needed to create accurate measurements over time and to attribute them to various places of production, transportation, consumption, and disposal. For all these reasons, we believe that only a city-based and globally networked approach to energy use and accounting will ultimately reveal the necessary data and produce the knowledge to solve issues of climate change. An especially exciting set of developments in Santa Fe is the transition over the next few years between carbon inventory assessments and the design and experimentation of policies aimed at reducing them. We see tremendous potential for peer-to-peer learning on these tasks, tied to a quantitative scientific understanding of what works in these areas of local action and international impact.

INGREDIENTS FOR URBAN CHANGE

We now offer a few ingredients that can be used to exploit our growing knowledge about urban processes, as well as new uses of data and technology to create thriving cities.

Networks of Learning

City and local governments will always have limited financial and technological capacity. Therefore, being embedded in networks of other cities, nonprofit organizations, researchers, and businesses is key to their sustained learning and the creation of technological know-how and practical progress. It also may help to recruit and retain a workforce that is passionate about improving its city and has the technical skills so badly needed in local governments.

A peer-to-peer collaborative model between cities and other institutions is already playing out in several important problem areas. For example, C40 Cities and the Compact of Mayors are global initiatives intended to standardize the accounting of greenhouse gas emissions in cities and to promote innovations and collaborations to stop climate change.[23] In the United States, the "My Brothers Keeper" initiative was recently started by the White House to create a network of cities that addresses issues related to disadvantaged youth.[24] The recently created MetroLab network helps form partnerships between research institutions and city governments to develop practical solutions using ideas and technologies from scientific practice.[25] Several of the world's most prominent private philanthropic foundations, such as the Rockefeller and Bloomberg foundations, have recently created networks of cities dedicated to solving common problems. This includes the 100 Resilient Cities network and What Works Cities initiative.[26] Nonprofit organizations such as Code for America also rely on a networking model between cities, businesses, and technologists to promote local governments' adoption of new technologies and innovation to address persistent urban issues.[27]

Thus, much like the dynamics of cities themselves, it is crucial to create technological platforms that promote network effects between cities and other urban stakeholders in order to drive global innovation and sustainable development.

Models of Collective Knowledge Production

Central to networks of learning are new models of collective knowledge production, which came of age with the Internet. These models promote network effects that take the familiar online forms of Wikipedia, OpenStreetMap, Github, and others.

The idea common to all these platforms is that knowledge and action can be combined and magnified tremendously in environments that are open, have very low entry costs (mostly time), and can create knowl-

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edge incrementally by relying on small contributions from many people over time. Although some existing examples—Twitter and OpenStreetMap in particular—have become important tools by demonstrating the potential to democratically create, collect, and disseminate critical knowledge and information during recent international crises (e.g., earthquakes in Haiti and Nepal, the Ebola crisis in West Africa), much more needs to be done to create technological platforms that support knowledge creation and action in cities, especially for civic purposes.[28] The kind of collaborations we are developing with other researchers and governments require better mechanisms to exchange data that are often sensitive. These collaborations also require sharing simple technology-embedded solutions that can readily be modified to fit new uses and contexts. A set of proposals the Presidential Council of Advisors for Science and Technology recently presented to President Obama explores mechanisms for creating and managing a new set of enabling platforms for using technology in cities, as well as recommendations for how to facilitate the exchange of data and tools to create more effective local policies and produce aggregate knowledge.

Further innovation in sharing and aggregating knowledge will be crucial to capitalizing on the creativity and needs of billions of people living in urban environments, and to addressing urgent issues of sustainable development, justice, and equity everywhere.

Policy for Learning

Related to the collaborative use of technology is the issue of learning from each local intervention. The main goal of policy is to solve existing problems that affect particular people in specific places. The challenge is to ensure that knowledge of what works and what doesn't can accumulate so that effort is not wasted on repeatedly "reinventing the wheel." Thus, now more than ever before, each local intervention can also be formulated as a learning opportunity. In short, each intervention has a goal and requires an assessment. To the extent that such expectations can be stated clearly and assessments can test progress objectively, one is in effect testing a hypothesis. This is the only way we know to learn at a collective level. Thus it is essential to formulate policy as a mechanism for learning. Thousands of such tests that are taking place in neighborhoods and cities throughout the world hold the promise of accumulating knowledge much more quickly and creating a large portfolio of solutions and best practices, which in turn can be built on and adapted to new places and problems anywhere. This eminently practical logic is the way science has progressed, and it provides a path not only to more effective policy but to other opportunities.

The Role of National Policies

If cities are emboldened to solve many of the pressing problems of human societies, then what role should higher levels of government play? Should we think of a world increasingly governed in practice by city-states? Or should the capacities presently developed locally eventually be taken over by national governments and international agencies? We believe the answer is somewhere in the middle.

We alluded throughout this piece to the crucial enabling and coordinating roles played by higher levels of government but also distinguished them from the ability to create practical, adaptive solutions that directly affect people's lives. National and federal governments are uniquely positioned to promote collaborations between cities by enabling and funding integrative initiatives based on sharing local learning. They also can help set technology standards and best practices, as was done to some extent during the creation of the Internet. Higher levels of government can also create the legislative environment that promotes

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the appropriate disclosure of data and guarantees appropriate levels of privacy. Crucial current examples of need include how cities may obtain energy use data from utilities or how medical records may be shared to create more effective systemic health-care solutions that involve emergency responders, social support civic organizations, hospitals, health insurers, and other actors. Thus, national governments and international organizations are crucial to nurturing the effective bottom-up innovation and collaboration that is emerging from local governments, entrepreneurs, businesses, and civic organizations.

In summary, in order to succeed, cities must innovate and learn. This is no big news. What is news is that the means by which we learn and act as urban agents (as governments, citizens, or business organizations) are changing quickly, empowering local actors to collaboratively tackle problems of unprecedented scope and importance and creating the conditions for an urbanized planet in which every city can thrive.

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[1]. Increased focus on cities.

[2]. Good examples are the new sustainable development strategic plans put forward by many cities worldwide, such as New York, Los Angeles, Tokyo, and London.

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