Chapter 9
Conceptualizing the City of the Information Age

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Abstract Cities are among humanity's most important and most complex creations, and they have been steadily increasing in complexity since the advent of the digital age. Informatics, the science of information, has by now advanced to a point where high expectations of improved understanding and evidence-based actionable knowledge for urban researchers, managers, and planners appear justified. But while there is more information than ever before, many kinds of theories, models, approaches, and tools that we have relied on thus far may no longer be of much use in the city of the information age. This chapter provides an overview of the state of affairs in urban science and planning, pointing out the limitations of formerly reliable methods and tools in the face of dramatic developments in the life and function of cities in the developed world. The chapter closes with suggestions for data-oriented strategies that might replace the ways we have used urban data up until recently.

9.1 Introduction

9.1.1 Urban Complexity in the Age of Information and Communication Technologies

A defining characteristic of a complex system is that it can be seen from any number of different, even contradictory angles (Casti 1984). Cities are complex systems by this as well as by many other possible definitions. They are made of asphalt and concrete, but they grow and change; they are places, but also networks; they are spatiotemporal objects, but they are about people; they are physical structures, but also abstract institutions connected with the notion of *citi*zenship; they may fit within a square mile, or they are larger than many small countries; and more recently, they are also both actual and virtual.

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For some time now, cities have been responding to information and communication technologies (ICTs) while also helping define them, with or without the help of urban analysts, managers, or planners. Years of publications on the topic have shown that the results of mostly piecemeal urban applications of ICT have so far been mixed, with few spectacular achievements or transferable best practices. There are also many questions of time–space perspective, as we transition from the city of yesterday to the city of tomorrow. For example: the repurposing of urban structures and infrastructures for new uses at new times; the anticipation of new divisions of labor, of new forms of urban management, and of new urban decision-making pathways, whereby technology companies increasingly call the shots; the role of supra-local and global agents, and of new political alliances at any scale. And of course, also, the appearance of new technologies not yet on the horizon. Issues such as these are highly likely to arise within the next twenty to thirty years, most of them supported by the unrelenting spread of ICTs across the globe. How does one even begin to grasp what is really going on? But there is hope: this may be the moment when the data, tools, infrastructure, and analytic approaches of the informatics revolution are becoming mature enough to forge unprecedented opportunities for the betterment of cities.

9.1.2 A Different Kind of City

There is no question that ICTs significantly add to the fundamental complexity of cities. Also, the piecemeal nature of most urban applications of ICT to date is antithetical to the notion of complexity, which entails interdependence and interplay. One everyday example of the interdependent complexity contributed by ICTs is captured by the related notions of the disconnect of urban form from function (Batty 2018) and the fragmentation of activity (Couclelis 2009; McBride et al. 2019), which affect the macro- and micro-levels of the city. The former notion concerns the relationship between, on the one hand, the classic urban activities of residing, working, shopping, learning, recreating, etc., and on the other, the urban places where these activities take place. In the traditional pre-ICT city, there is a close correspondence between each kind of urban activity and the urban spaces adapted to support it. The correspondence used to be so reliable that knowing where someone was at some point in time made it relatively easy to guess what they might be doing—and conversely ("if working then at the workplace, if shopping then at the shopping mall, if getting an education then at school"). This match between activity and place was also at the heart of traditional urban land-use and transportation models and planning, since people's movement from place to place was largely dictated by the daily schedule of predictable activities, and urban form and function were tightly linked. In much of today's industrialized world, these close connections between urban activities and spaces are disintegrating, and as a result, model predictions of urban growth and change are becoming less reliable.

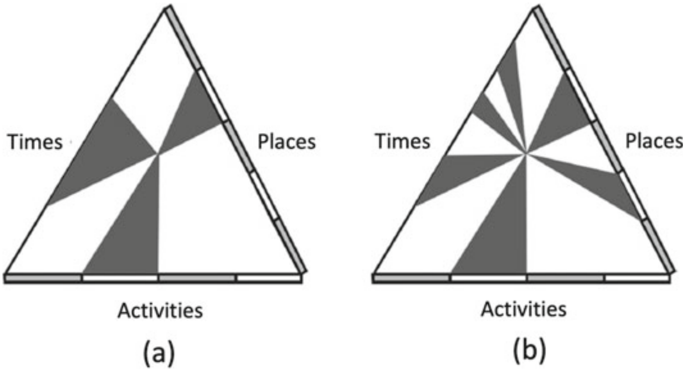

Fig. 9.1 Fragmentation of activity and ICT. **a** Before ICT: one of four activities is carried out at one place, during one time interval; **b** After ICT: that same activity is carried out at two different places, at three distinct time intervals (from Couclelis 2009)

The notion of the fragmentation of activity sheds light on the micro-level of this phenomenon. Indeed, for some time now, thanks to ICTs, increasing numbers of daily activities can be broken down into tasks and carried out consecutively at several different places and several different time intervals during the day (Fig. 9.1). For increasing numbers of people, gone is the compulsive Monday to Friday 8–5 at the office, or the family Saturday trip to the shopping mall. These traditional specialized places still exist, but we can also shop from home after a visit to the drug store, watch movies on our workplace computer during breaks from work, close an extra business deal from our car after the martini lunch at the fancy hotel, follow university lectures on our smartphone while in bed, before cycling to campus, or monitor our real-time health indicators on our smart watch at the gym to expedite the check-up at the clinic later.

9.1.3 The Smart City

The broadening international conversation about the coming smart city is certain to add several more layers of complexity to urban research and management. While the smart-city concept remains ill-defined and open-ended, and few, if any, generally accepted examples exist today, there is agreement on several of the anticipated (or desired) defining characteristics: smart cities will be sustainable, livable, equitable, innovative, and creative. Above all, they will be able to capitalize on the extraordinary possibilities that technology, especially ICTs, artificial intelligence (AI), and big data, are already unraveling before our eyes. Are all these hopes, assumptions, and anticipated characteristics realistic, or even mutually compatible? There is also the unavoidable gap between intention and reality. As Goh (2015, p. 169) asks: "What happens when intelligent plans encounter messy politics, social systems, and divergent scales of urban governance?" San Francisco, USA comes to mind. There, the world's most famous breeding ground of new information technologies coexists with sky-high property values and with some of the worst levels of homelessness and street squalor to be found in any city of the industrialized world.

Further: smart is not quite the same as intelligent. Smart, much like clever, has connotations of something playful, a bit superficial, not terribly serious, of no great consequence. A smart child. A smart dog. A smart answer. Street smarts. A clever trick. The smart city could easily be smart in this sense, with bright flashes of brilliance here and there (and then), but also with much that is technology for technology's sake, unhelpful, unneeded, wasteful, discriminatory, retrograde, ephemeral, or downright damaging—now, or a few years down the road. How can our cities be not just smart, but truly intelligent?

The smart cities phenomenon thus encapsulates many of the major new challenges of current urban research and management. At the one end of a spectrum, smart (urban) growth only recently meant wisely managed urban development, socially, fiscally, and environmentally sustainable, mindful of resource constraints, prepared to capitalize on comparative advantages and to seize opportunities as they arise, while attentive to community input, fairness, and the planners' recommendations. At the other end of the spectrum, a smart city is the bionic city of science fiction. At the moderate middle, we find mixed approaches of some of this and some of that, or even coexisting views that appear incompatible at first sight. As an example, the European Commission's website begins by defining the smart city as "a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business," but a few lines later, the European Partnership on Smart Cities and Communities is introduced as being primarily about governance, citizenship, wise regulation, and other such traditional soft imperatives going back to the Athens of Pericles (European Commission 2020).

Different authors also provide many contrasting definitions and descriptions of the smart city. Thus Caragliu et al. (2009, p. 50) consider "a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance," whereas Batty (2018, p. 178) emphasizes the technological aspects: "The nature of the smart city then lies in the very technology that defines it." Geertman et al. (2015) take a different approach, attempting a classification of smart cities into four categories, as follows: (a) Smart machines and informated [sic] organizations; (b) Partnerships and collaboration; (c) Learning and adaptation; and (d) Investing for the future. These categories are discussed in the above chapter, and they are interesting and plausible, but are meant more as alternative abstract types than as descriptions of possible, actual kinds of cities.

9.1.4 Urban Informatics

Informatics, the increasingly preferred term for information science, has been defined as "the study of the behavior and structure of any system that generates, stores, processes and then presents information; it is basically the science of information. The field takes into consideration the interaction between the information systems and the user, as well as the construction of the interfaces between the two." (Technopedia). The smart city is but one application area for urban informatics, albeit one of fundamental importance, considering the ever-increasing significance of the urban in the present world and in any conceivable near future. Not coincidentally, Batty's (2018, p. 176) notion that "Smart cities essentially enable computers and communications to be embedded in the very fabric of the city" is very close to the use of the term "system" in the above definition. But informatics is needed just as much in the still-traditional city, where so many taken-for-granted regularities are being increasingly challenged by ICTs.

The next section provides a broad overview of current approaches to urban research and planning, seeking to identify areas where modern informatics may have a key role to play.

9.2 Urban Research and Planning, Yesterday, and Tomorrow

9.2.1 The City as Place

A direct consequence of the complexity of the urban is the multitude of possible ways of approaching the study of the city. On the one hand, there is the vast range of disciplinary perspectives, whereby the word "urban" may be added as a qualifier to almost any empirical discipline. We thus have urban economics, urban sociology, urban history, urban geography, urban ecology, urban transportation, urban health, urban anthropology, urban planning, etc., and now also urban informatics. In addition, there are numerous cross-disciplinary and methodological viewpoints and approaches applicable to cities, such as post-Marxism, post-structuralism, gender studies, science and technology studies, quantitative social science, spatial analysis, computer simulation and modeling, the networks perspective, the design perspective, and so on. In "Key Thinkers on Cities," Koch and Latham (2017) collected 40 profiles of scholars who in one way or another have made significant contributions to the study of cities, the stress being on "one way or another," as the diversity of approaches represented is quite stunning. While there are significant affinities among cognate disciplines or approaches (urban sociology and urban anthropology, say, or spatial analysis, mathematical modeling, and computer simulation), others are so distant intellectually from one another that they hardly seem to be about the same general topic. One may say that the universe of perspectives and theories on cities is locally coherent but globally not coherent. The most creative new work on cities might be that which discovers and establishes important connections among intellectually or methodologically remote areas of urban research. An example is the work by Reades et al. (2018) on gentrification, which combined spatial analysis, qualitative research, and machine learning to show that it is possible to analyze existing patterns and processes of neighborhood change to identify areas likely to experience change in the future.

Theories of the city have existed since antiquity, but have flourished since World War II along with the establishment of academic units and journals dedicated to their study, and the fast-increasing number, size, complexity, and importance of cities in the modern world. At the same time, the quantitative and computational turns in the social sciences and urban planning have enabled more thorough and empirically relevant work, while also stimulating theory development, motivated by the newly available observations and informed discussions.

This trend toward more realistic empirical theory may now be reversing. We saw earlier how gravity-based spatial interaction modeling, one of the mainstays of quantitative urban theory and planning, risks becoming less and less relevant as urban activity becomes more fragmented in space and time, and as urban form is getting disconnected from function. The same seems true of urban cellular-automata-based modeling, another popular approach that also relies on assumptions of proximal relations among cognate places and land uses. It is true that the principle of distance decay, which underlies these kinds of models, is too fundamental to become obsolete as long as people and cities inhabit the physical world; but having to coexist with principles of the virtual world makes its theoretical utility more elusive.

Other ways of looking at the city, such as those involving cognition (think space syntax, the legibility of urban environments, finding one's way in an unfamiliar area, recognizing place in space) may be more resilient in principle. But faced with ubiquitous digital aids for navigation, point-of-interest (POI) location, place-related information, and environmental problem-solving in general, it is questionable whether human spatial abilities might not degrade over time. More optimistically, spatial abilities should improve in tasks involving ICTs, just as they degenerate where no longer needed.

Economy, demography, and technology remain among the handful of key drivers of urban growth and change, especially in the vast megalopolises of the world that are not yet steeped in ICTs. Increasingly, ecological conditions such as water availability and climate are added to the key drivers of urbanization. Most of these factors are slow-moving and can be accounted for relatively well with traditional data and methods. But the more a city becomes part of the information society, the more its study requires indicators on fleeting phenomena that vary during the course of the day, the hour, or the minute. Many of these may be local quality-of-life factors (noise levels, air pollution, traffic conditions, disturbances due to special events or incidents), while others, such as threats to community health and safety, or to the integrity of energy and information networks at any scale, may be of broader import.

9.2.2 The City as Node on a Network

The vast majority of urban research has approached the city as a kind of place, but an alternative, increasingly relevant way of thinking about cities is as nodes in a network. This idea has been around for some time, and is reflected, among others, in Christaller's widely known Central Place Theory, which views individual settlements as elements in a recursive regional hierarchy of population sizes centered on the largest settlement. The idealized model of the resulting spatial arrangement is a hierarchy of nested hexagons, the vertices of which are the smaller settlements that depend on the central larger one. While Central Place Theory emphasizes the notions of trade and distance, it also clearly describes systems of settlements bound together by networks of relations.

Christaller's notion of networks of interdependent cities also appears, at a much grander scale, in Doxiadis's (1968) vision of Ecumenopolis. This is the author's term for the coming network of cities of all different sizes that spans the entire globe, and which becomes, at the limit, a mesh of continuous corridors of urbanization ('Ecumene' is Greek for the inhabited world). Megalopolis—literally, the big city—is a more modest and better-known version of the same idea, of which there are multiple actual instances around the world. While the term had appeared in earlier writings of the twentieth century, it was popularized by Gottman's (1961) work on the north-eastern seaboard of the USA. The catchy name BosWash, for the urban agglomeration reaching from Boston, MA to Washington, DC is the best-remembered part of Gottman's ground-breaking study.

The most systematic contemporary approach to the notion of the city as node in a network of cities is quite likely represented by the work of the international research network on Global and World Cities (GaWC 2020). Scholars affiliated with the GaWC network sometimes describe their work as metageography—a geography of geographies—to emphasize the global-scale perspective on cities that they adopt. The group's focus is the world-wide hierarchy of cities of different degrees of importance and size (world, global, peripheral, and specialized cities), with an emphasis on the mutual dependencies and other relations that make up the international network of urban interactions. The socioeconomic, political, and physical characteristics of individual cities are examined to the extent that they reflect or promote the forces that bind the world's cities together, such as the global phenomena of capital flight, industrial dislocation, labor migration, trade and resource flows, innovation and technology diffusion, and so on. To study these networks of mostly intangible long-distance flows and their local implications, GaWC researchers must ask novel questions requiring new kinds of data and new forms of visualization—in other words, define a new agenda for urban research. The network's website provides a wealth of information about the work of the close to three hundred affiliated members, who include several prominent names in geography, urban studies, and a number of other fields contributing to research on the information society (e.g., Latham and Sassen 2005; Hoyler et al. 2018).

9.2.3 Planning the City

Urban planning—professional as well as academic—is another field that is being substantially affected by developments in the city of the information age. Like urban studies, planning deals with the city at several different scales, from that of the neighborhood park to that of the megalopolis. Unlike urban studies, the planners' approach is more that of the engineer than of the scientist, more synthetic than analytic, more action-oriented than knowledge-oriented. The major difference between these two fields, however, is the fact that planning is inherently and fundamentally about the future, whereas urban research and data are at best about the very recent past. Predictive models developed by urban researchers still go some way toward meeting the current needs of planning, but the assumptions, generalizations, and rules of thumb built into them may soon become obsolete. It is ironic that deep qualitative uncertainty, the kind that matters most to future-oriented endeavors like planning, might be substantially increasing at a time when the quantity and quality of available data are also increasing dramatically.

Urban management is also a form of planning, operating over shorter time frames and handling more specific sets of problems. Both professional planning and management directly contribute to urban governance, and their errors have consequences well beyond the threat of a research paper rejection. Despite the considerable overlap with urban studies, planning and management thus involve a very different take on the city, and information needs that are as complex but different from those of the urban researcher. For example, planning must now (by law, in many countries) take into account the often vague or conflicting input of the public, while also accommodating political interventions and juggling a myriad of local and regional regulations that may include mutually contradictory, obsolete, or otherwise unhelpful restrictions.

Things were not always as complicated for urban planning. In the modern era, planning was at first a straightforward engineering profession focused on urban sanitation and other infrastructure development, before embracing the systems approach and operations-research methodologies in the 1950s and 60s, and later also additional perspectives by the names of comprehensive, integrated, or strategic planning. It is only with the social movements of the 1970s, when the participatory era began, that the planners' tidy office spilled onto the streets. Planning was no longer carried out for the people but with the people. Opinion surveys, public hearings, story-telling, and politicking increasingly replaced computer models, especially in countries such as the USA that lack a strong planning tradition. However, geographic information systems (GIS) eventually came along to fill the technical void, and there was no way back.

The adoption of GIS in planning was at first not without problems. Critics were concerned about the possibility of disenfranchising those lacking the requisite digital literacy, of affecting societal priorities by focusing on what is easily measurable, of imposing a technocratic view of the world on other people's perspectives, of introducing new issues of privacy and surveillance, and so on. These concerns have been to a large extent resolved, to the point where most of those who used to be the critics are now often using GIS themselves.

In response to the critique, academic planners developed methodologies largely based on GIS for the age of public participation, creating the subfields of public participation GIS (PPGIS) and, for well-defined groups of stakeholders, participatory GIS (PGIS; Jankowski and Nyerges 2001). Planning support systems (PSS) emerged in the early 1990s as a response to the increasing complexity of planning in societies that value both the diversity of opinions and the scientific grounding of public decision making (Brail and Klosterman 2001; Geertman and Stillwell 2009; Geertman et al. 2015). PSS were enabled by major improvements in computational resources and geospatial data availability, and relied heavily on the rapid expansion and increasing sophistication of GIS. The main purpose of PSS is to integrate the societal and technical aspects of planning with the computational bonanza of our age, and are thus, at least in concept, one of the best incarnations of the idea of geodesign to date. Current forms of PSS successfully support public participation, allowing the collection and processing of a wide range of relevant data through crowd-sourcing methods. The adoption of PSS has been slow, but the field continues to attract considerable interest, now also from scholars and practitioners from beyond traditional urban planning.

9.3 Speculations

9.3.1 The Robotic Era?

Humanity spent millennia in the pre-industrial age, then the industrial age lasted some two hundred years, the post-industrial age has been with us for just a few decades, and already the term information age that followed appears too limited. Yes, this is the age of big data, but it is also the dawn of a still nameless era (let’s call it the robotic era) where big data become embodied in machines. There is now talk about the second machine age (Brynjolfsson and McAffee 2014), of systems that privilege information over energy as input, and which output intelligence as well as physical objects and physical work: brains added to brawn, thinking built into inert matter. The coming world of sentient machines—the autonomous vehicles, the Internet of things, the drones delivering our packages or fighting our wars, the satellites deciding which information to transmit to which city of the global urban network, and so much else we cannot yet imagine (let’s not talk yet about machines built around synthetic biology, or quantum computers)—define a reality that challenges ordinary theoretical treatment. Indeed, the Greek word theory literally means contemplation, viewing, looking at something from the outside. It will eventually be futile to try to develop theories of the traditional kind by “looking from the outside” at cities run at least in part by emergent networks of heterogeneous, interacting smart systems.

We are not there yet, and we still need to figure out how best to use the big data bonanza. It is not likely that data mining alone will ever give the answers that urban research, management, or planning need, especially when it comes to helping prepare for the future. But there might exist certain basic principles at the core of current quantitative theories that can be relied on to remain valid even if the superstructure of the theory (dealing with socioeconomic or other empirical processes) is no longer helpful. Batty and March (1976) called these effects residues, and Couclelis (1984) developed the related idea of prior structure. These principles owe their resilience to the fact that they are formal rather than empirical: they are abstract properties of systems qua systems, or of the formal languages used in their derivation, which constrain what a model can represent. In spatial systems, it is properties of particular forms of abstract space that get transferred to the model. Here are some candidates of such principles that are well-established in the urban and geographic literature: distance decay; spatial heterogeneity; spatial autocorrelation; scaling laws; the rank-size rule; network properties; possibly fractal growth. And so on. There may be additional effects deriving from properties of cyberspace that could be added to the list. One can imagine appropriate combinations of these principles forming the backbone of analysis in hybrid approaches to data mining and any other strongly data-oriented techniques. But this is another discussion, for another kind of book.

9.3.2 The City's Epistemic Planes

The speculations in this section continue, but more realistically now: how could we best capitalize on the wealth and promise of urban informatics—not in a few years, but today? If data do not speak for themselves, what elements of order, what structured approach could make the data sing? Here is a tentative suggestion.

Cities—and even more so, cities of the information age—are not only highly complex but are also made up of many highly complex parts. Moreover, these parts are so qualitatively different from one another that they may be viewed as different realities, partially incompatible. Consider: The smart city as technological achievement versus as home of humanity; the smart city as place versus as node on a global network of urban linkages; the smart city as integration of actual and virtual dimensions.

It is increasingly unlikely that the whole of today's urban reality can be tackled with current notions of modeling. No comprehensive theory or framework may be able to do justice to the growing information-age complexity of the city. What might be possible instead is the development of strategies to guide the selection of data, tools, and methods, so that, depending on the objectives of the research or decision problem, the relevant critical aspects of contrasting views of the city are integrated in the analysis.

To give a sense of what such an informatics strategy might entail, here is an illustrative framework for merging disparate views of the city in response to specific questions or problems. It is based on the notion of a sequence of epistemic planes, each of which would support data and methods for a qualitatively different part of urban reality, and for qualitatively different kinds of knowledge. As a quick example, for any reasonably well-defined problem, one might need to systematically glean and weave together specific relevant information of the following kind from four or five different epistemic planes, e.g.:

- Measurements of the physical, social, and demographic **spatial structure** of the city, including information from and about distributed sensors and associated physical infrastructure;
- Information on social, business, financial, government, etc. **ICT networks**, both local and long-distance, including data on the supporting physical infrastructure;
- Measurements and qualitative information on the level of **functioning** of key aspects of the city (local and long-distance), including transportation, energy production and distribution, commerce, business services, health and human services, government, etc. (local and long-distance);
- Information on the **agents and forces** (local and global) affecting or likely to soon affect city functioning directly or indirectly, including recent technological breakthroughs such as autonomous vehicles and the Internet of things, and political changes such as the power of private companies over personal data.

For each problem or objective (to do with efficiency, growth, social justice, sustainability, quality of life, public safety, governance, etc.), appropriate analytical methods, models, and tools should be selected or developed to allow the problem-specific integration of the highly heterogeneous kinds of knowledge that aspects of the truly smart city demand. Only the most tentative indications of what these tools might look like can be suggested here. Possibilities include some type of information-filtering system (similar to recommender engines) for traversing the set of epistemic planes, artificial intelligence (AI) techniques for formalizing the objective or research question motivating the search, semantic networks and ontologies, to provide structure and help guide the selection of variables from among semantically heterogeneous planes of urban reality. Indeed, the systematic decomposition of urban-system information tentatively sketched above is loosely based on the information ontology proposed by Couclelis (2010).

9.4 Conclusion

This chapter has presented several of the reasons why business as usual in urban research, management, and planning cannot continue for much longer in the information-age city. We will miss the traditional kinds of theories, models, approaches, and methods that have served us well in the past century when these can no longer be relied on, as long as operational new approaches and tools do not yet exist to help us get the most out of ubiquitous, high-quality urban data. As an example of what may be lost along with a good traditional theory or model is its role in restricting the space of possibilities, so that not everything can be the case. In this chapter, we touched in passing upon two notions that could at least in part play that critical possibility-focusing role: first, the residues, or non-empirical effects hiding in our more successful spatial models (Batty and March 1976), and second, ontologies, which provide structure and restrict meaning so as to help keep the semantics of data interpretations consistent. Combined with data-mining techniques in the broadest sense, a priori elements of order, reliability, and consistency such as these might shape the hybrid strategies that can do justice to our age's unprecedented data riches. If informatics is the science of information, we should look to it for answers to questions that go beyond big data and their role in ICTs.

And here ends the speculation. This book has a very concrete double objective, which is to provide a comprehensive overview of the methods that so far form the core of urban informatics, as well as a technical introduction to the research tools necessary for understanding and creating the smart city of tomorrow. This should help prepare the ground for answering two major questions that may be asked concerning the general subject of this book: (a) How can the new science of information lead to the new science of cities? and (b) How can big data lead to actionable wisdom under conditions of pervasive uncertainty and complexity? It is not within the scope of the present book to tackle these questions directly, though its original chapters contribute to the necessary discussion that has already begun.

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