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Simon Elias Bibri

Big Data Science and Analytics for Smart Sustainable Urbanism

Unprecedented Paradigmatic Shifts
and Practical Advancements

 Springer

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To Fatima Zahrae Gouttaya for her generosity and good nature, knowing all my story and living it with me, making the good times unforgettable, and becoming my family. What sheer bliss to have someone to lean on and to share daily experiences, intellectual passions, and life aspirations with. I admire her for her integrity, moral fiber, intellectual curiosity, native wit, and sense of humor, as well as for her distinct combination of optimism, passion, perseverance, and determination as to pursuing long-term goals in life.

Preface

Key Aims and Themes

This timely and multifaceted book is concerned with the complex interplay of the scientific, technological, and social dimensions of the city, and what it entails in terms of the ensuing systemic outcomes pertaining to sustainability as informed and underpinned by data-driven smart urbanism. In concrete terms, it explores the interdisciplinary and transdisciplinary field of smart sustainable urbanism and the unprecedented paradigmatic shifts and practical advances it is undergoing in light of big data science and analytics and the underlying advanced technologies. The scholarly, practical, and futuristic strands of this rapidly burgeoning field are currently at the center of debate due to the emerging paradigmatic shift in science development and epistemic shift in knowledge production brought about by big data science and analytics, coupled with their salience to the fundamental change in the way the city is operated, managed, planned, designed, developed, and governed. In this respect, big data science and analytics as a new area of science and technology is seen as a major factor that determines the way the city will tackle the kind of special conundrums, wicked problems, intractable issues, and complex challenges it embodies through a multitudinous array of alternative solutions in the form of novel applications and sophisticated methods informed by advanced scientific and scholarly research. This consequently determines how the city will evolve in the future under the multiple processes of, and pathways towards achieving, smart sustainable urban development. In a nutshell, developments in science and technology fundamentally alter the way people live, with profound effects on all spheres of society in terms of advancements and innovations.

This book aims to help view the challenges of sustainability and urbanization as well as the alternative approaches to tackling them from the perspective of big data science and analytics through the lens of smart sustainable cities as a leading paradigm of urbanism and a manifestation of social evolution. It also intends to facilitate the understanding of the fundamental principles of big data computing with respect to the automated extraction of useful knowledge from large masses of data for enhanced decision-making and deep insights pertaining to urban operational functioning, management, planning, design, and development for the primary purpose of addressing those challenges. Indeed, this book is about data-driven smart sustainable urbanism in the sense of exploiting, harnessing, and leveraging the unfolding and soaring deluge of urban data through advanced analytics to discover new knowledge in the form of applied intelligence intended for enhancing and optimizing urban operations, functions, services, designs, strategies, and policies across multiple urban domains in line with the goals of sustainable development in a rapidly urbanizing world.

This book involves innovative, up-to-date big data science and analytics research related to smart sustainable urbanism, that is, theoretical, technological, and interdisciplinary and transdisciplinary studies that make up the field of data-driven smart sustainable urbanism in terms of practice. Accordingly, it provides theoretical and applied contributions fostering a better understanding of this approach to urbanism and the synergistic relationship between the related practices. With respect to the latter, at the core of smart sustainable urbanism is the

synergy between urban operational functioning, planning, design, and development in terms of their interaction or cooperation to produce a combined effect greater than the sum of their separate effects. This entails using big data computing and the underpinning technologies as an enabler for such synergy and a determinant of its outcomes. Further, this book offers contributions pertaining to the ongoing development of urban intelligence functions and related simulation models and optimization and prediction methods as innovative solutions for how smart sustainable cities can be monitored, understood, and analyzed so as to be effectively operated, managed, planned, designed, developed, and governed in line with the goals of sustainable development. Applying urban intelligence functions as new conceptions of the way such cities function and utilize complexity science, data science, and urban science in fashioning new powerful forms of urban simulation models and optimization and prediction methods that generate urban forms and structures that improve sustainability, efficiency, resilience, and the quality of life is crucial to dealing with such cities as complex systems and dynamically changing environments. In short, it provides in-depth coverage of the latest advances in the field of smart sustainable urbanism in the wake of the big data revolution.

To facilitate embarking on exploring the field of smart sustainable urbanism and the unprecedented shifts and advances it is undergoing, I have designed this book around three related aims: to help readers gain essential underpinning knowledge about the topic of smart sustainable urbanism, especially in terms of its scientific, scholarly, and practical dimensions; to enable them develop a broader understanding of this flourishing field as they make connections between their own understandings of the current urban challenges and the ongoing urban transformations, on the one hand, and the emerging shifts instigated by big data science and analytics, on the other hand; and, more importantly, to encourage them to take part in the ongoing debate about smart sustainable urbanism in the big data era and the ensuing datafication of the city. The data avalanche is here.

Uniqueness and Subject Treatment

This book is the first of its kind with respect to the topicality of the issues it addresses, the contemporaneous phenomena it is concerned with, and the unprecedented shifts and advances it covers in the context of smart sustainable urbanism in the era of big data science and analytics. This unique amalgam is indeed deemed relevant and salient in light of the changes taking place in the urban world. We are currently in the midst of a new wave of enthusiasm for scientific urbanism of a historically unparalleled kind inspired by the big data revolution and carrying wide-ranging implications for the practice of smart sustainable urban planning, design, and development. This is manifested in us experiencing the accelerated datafication of the city in a rapidly urbanizing world and witnessing the dawn of the big data era not out of the window, but in everyday life. Our urban everydayness is entangled with data sensing, data processing, and communication networking, and our wired world generates and analyzes overwhelming and incredible amounts of data. This allows for, over sufficiently long periods of time, extracting changes to the structure and form of the city and the way people behave in the form of useful knowledge and valuable insights associated with applied intelligence. The modern city is turning into constellations of instruments and computers across many scales and morphing into a haze of software instructions, which are becoming essential to the operational functioning of the city. The datafication of spatiotemporal citywide events has become a salient factor for smart sustainable urban planning, design, and development.

This book is also unique in regard to the approach to studying the field of smart sustainable urbanism—based on a uniquely holistic perspective. Accordingly, it approaches the topic of smart sustainable urbanism from an interdisciplinary and transdisciplinary perspective while adopting a compelling approach to cross-disciplinary integration and fusion involving diverse scientific and academic fields, notably data science, urban science, urban informatics,

complexity science, environmental engineering, sustainability science, and systems science, as well as urban planning and design, sustainable development, philosophy, and the social sciences. This is meant to achieve a broader and more inclusive understanding of the phenomenon of smart sustainable urbanism by facilitating collaboration among and between an array of disciplines for the primary purpose of generating the kind of interactional and unifiable knowledge necessary for such understanding. This is a core contribution that supports the foundational ethos of interdisciplinarity and transdisciplinarity characterizing the research field of smart sustainable urbanism. Interdisciplinarity and transdisciplinarity have become a widespread mantra for research within diverse fields, accompanied by a growing body of scientific and scholarly publications. On the whole, this book offers a novel, fresh, all-encompassing approach to the exploration of smart sustainable urbanism as a holistic and integrated paradigm of urban planning, design, and development. In doing so, it combines scientific, academic, and practical relevance with philosophical, social, ethical, and environmental analyzes, supported with critical and reflective thinking.

Originality and Value

Up till now, no multifaceted book has, to the best of one's knowledge, been produced elsewhere—as to exploring smart sustainable urbanism and examining the historically unprecedented shifts and advances this blossoming field is undergoing as a result of the uptake and diffusion of big data science and analytics and underpinning technologies. Nor has any book approached the topic from the perspective of integrating and fusing these scientific fields: data science, urban science, complexity science, systems science, sustainability science, and environmental engineering—with a result that both yields new ideas by thinking across disciplinary boundaries as well as exceeds the simple sum of each discipline. This can be accomplished by combining different analyzes, using insights and methods in parallel and conjunction, and spilling over and blurring boundaries. Indeed, there is a growing need to fill the shortage urban research is facing nowadays in key scientific respects, and to advance urban sustainability science as to tackling the dilemma of the wicked problems associated with urbanism in terms of planning, design, and development. In particular, urban sustainability science requires a decisive, radical change in the way science is undertaken and developed. Such change is, in fact, what data-intensive science is about. Moreover, beyond the need for a stronger interdisciplinary and interdisciplinarity lens, urban research needs to be adequately directed to real-world problem applications pertaining mainly to sustainability and urbanization. Urban research is still segmented by disciplinary boundaries when urban transformations demand truly holistic urban research, and whereas solutions to global problems require integrated (cross-disciplinary) knowledge.

This seminal work provides the necessary material to inform the research communities concerned with the unprecedented shifts and advances that smart sustainable urbanism is going through and with the state-of-the-art research and the latest development in this area in light of big data science and analytics. It also provides a valuable reference for scholars and practitioners who are seeking to contribute to, or already working towards, the development and implementation of smart sustainable cities as a leading paradigm of urbanism based on big data computing and the underpinning technologies. In this respect, the upshot of this book enables researchers to focus their work on the extreme fragmentation and weak connection between sustainable cities and smart cities as landscapes and approaches, respectively, while embracing the emerging shifts pertaining to smart sustainable urbanism to mitigate or overcome such issues by realizing smart sustainable/sustainable smart cities. Practitioners can use the outcome of this book to identify common weaknesses, flaws, and drawbacks in smart sustainable urbanism projects and initiatives and then deal with them through devising alternative solutions on the basis of what big data computing and the underpinning

technologies have to offer as novel applications and sophisticated approaches. These pertain to new ways of optimizing and enhancing urban operational functioning, planning, design, and development in response to the challenges, or in line with the goals, of sustainable development.

While this book can best be seen as being aimed at those with a background in both urban science and sustainable urbanism, it is primarily from an urban science angle. That is to say, it would be more appropriate for giving urban scientists a vantage on sustainable urbanism than giving sustainable urbanists a vantage on urban science. Nonetheless, it contains value-laden knowledge and technology of high relevance to sustainable urbanists.

Intended Readership

Big Data Science and Analytics for Smart Sustainable Urbanism is intended for several classes of readers, including students, researchers, academics, data scientists, urban scientists, urban informaticians, philosophers of science, social scientists, futurists, technologists, ICT experts, urbanists, planners, engineers, architectural designers, built and natural environment specialists, and policy analysts and makers, whether they are new to or already involved in smart sustainable urbanism as a field for research and practice. It is also intended for all of those interested in an overview covering an extensive range of topics pertaining to the role of big data science and analytics in catalyzing the emerging shifts and advances that are of an unprecedented kind as related to both this field as well as the other fields or disciplines concerned with data-intensive science.

Specifically, I have written this book with two kinds of readers in mind. I am writing to students taking graduate and postgraduate courses or pursuing Master's and PhD programs in the areas of sustainable cities, smart cities, smart sustainable cities, urban planning and design, sustainable urban development, environmental engineering, urban informatics, urban science, sustainability science, and so forth. Those readers already familiar with sustainable cities and smart cities as leading paradigms of urbanism and their relationship as both landscapes and approaches in the context of sustainability and with the growing role of big data computing and the underpinning technologies in improving and advancing their contribution to the goals of sustainable development will certainly get much more out of this book and find much more that appeals to them in it than those lacking that grounding. Nevertheless, those readers with limited or without knowledge in this particular area are provided and supported with a detailed explanation and discussion of the relevant conceptual, theoretical, disciplinary, discursive, and practical foundations with reference to the integrated field of smart sustainable urbanism and the underlying scientific and technological components. This is meant to appease the uninitiated readers. Second, I believe that this book will be a very useful resource for all of those involved or with interest in smart sustainable urbanism (including scholars, scientists, practitioners, intellectuals, technology forecasters, decision makers, etc.) that are looking for an accessible and essential reference with respect to the interplay between big data science and analytics as a new area of science and technology and smart sustainable urbanism as a rapidly emerging field. Overall, people in many scientific and academic disciplines and professional fields will find the unique coverage of the scientific and epistemic shifts and scholarly and practical advances related to this flourishing field (as well as other fields and disciplines) as brought about by the materialization of big data science and analytics and the increasing adoption and use of the underlying core enabling technologies to be of great value and usefulness. My hope is that this book will also be of interest to people of other countries than ecologically and technologically advanced nations.

Perspectives and Prospects

This book benefits indirectly from the work of many people working within the field of smart urbanism, sustainable urbanism, smart sustainable urbanism, sustainable smart urbanism, or at the intersection of urban science and urban sustainability, and focusing on the transformational effects of big data science and analytics on urbanism. Thus, I am indebted to other scientific and scholarly writings in the sense of inspiring me into a quest for the great opportunities enabled by endeavoring to explore the emerging field of smart sustainable/sustainable smart urbanism along with the emerging shifts it is undergoing because of big data science and analytics. This has led me to espouse an intellectually distinctive approach into writing this book so that it can offer a tremendous value with auspicious effects in the field and be differentiated from other books on the topic of smart sustainable/sustainable smart urbanism, if any, with regard to their focus and scope of scholarship, as well as to their approach to exploration. While this book has an ambitious goal, clearly it is not possible to deal with every aspect of and shift in such urbanism in a single book, nor can it cover all of the chosen topics in equal depth. Nevertheless, it will be a great asset to the relevant scientific and scholarly communities, as well as to those who are simply interested in urban transformations enabled by technological innovations.

This book highlights the increasing urgency to merge big data computing and the underpinning technologies as recent discoveries and innovations as part of urban science with urban sustainability and sustainability science in the research and applied domain of smart sustainable urbanism. The strength of this integrated approach lies in using the most advanced strategies and methods for decoupling the overall wellbeing and health of the city and the quality of life of citizens from the energy use and concomitant environmental risks associated with urban operations, functions, services, designs, and policies. Indeed, the current and future investments in big data computing and the underpinning technologies ought to be justified by environmental concerns and socioeconomic needs, enabling livable and healthy human environments in conjunction with minimal demand on resources and minimal environmental impacts—rather than by sheer technical advancement and unjustified industrial competitiveness. What is mostly needed nowadays are urbanism approaches and innovations that are not driven by distant and overblown ICT of pervasive computing research agendas focused mainly on technological superiority motivated by short-term profits, narrow outlooks, and unsustainable disruptive effects—but rather by the pursuit of the persistent delivery of robust solutions for improving and advancing urban sustainability and stimulating research opportunities in this direction. Especially, big data science and analytics is a means for science and society to control uncertainty and to make discoveries in relation to sustainability, among others. As long as there is uncertainty and intractability in the world, there is a need for big data science and analytics,

In addition, this book expects to elicit novel insights and spark new perspectives as a result of integrating and harnessing the emerging shifts associated with smart sustainable urbanism. The primary intent is to bring scholars and practitioners closer together from different disciplines and professional fields, or who are working on cross connections of data science, urban science, sustainability science, and urbanism, to develop, concretize, and disseminate new ideas for advancing the field of smart sustainable urbanism as well as promoting related projects, programs, and initiatives based on big data computing and the underpinning technologies.

Furthermore, I consider that this book represents a basis for further discussions to debate the point that big data science and analytics and the underlying core enabling technologies have disruptive, substantive, and synergetic effects, particularly on forms of urban planning, organization, design, and development that are required for future forms of smart sustainable urbanism. In the meantime, this book seeks to encourage in-depth research, thorough qualitative analyzes, and empirical investigations focused on establishing, substantiating, or

challenging the assumptions and claims made by the advocates of big data science and analytics with regard to advancing sustainability.

Finally, I believe that I have achieved an important goal with this book—by creating a valuable, strategic resource for the scientific and scholarly communities and the industries involved in the field of smart sustainable urbanism. Especially, there is an urgent need for a multifaceted book on smart sustainable urbanism given that the field is remarkably heterogeneous with a large number and wide variety of unaddressed and unsettled questions and unexplored and promising opportunities. I will be pleased if this book contributes to a better understanding of the topic under investigation, and, more importantly, stimulates the development and implementation of smart sustainable cities on the basis of big data computing and the underpinning technologies and thereby mitigates or overcomes the extreme fragmentation of and the weak connection between sustainable cities and smart cities as landscapes and approaches, respectively. All in all, I hope that this book will be enlightening, thought-provoking, and making good reading for the target audience. And ultimately, the first edition will be well received.

Trondheim, Norway
October 2018

Simon Elias Bibri

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- Big data analytics and context-aware computing
- Data-driven smart sustainable urbanism
- Sustainable cities (e.g., compact city, eco-city, sustainable urbanism, green urbanism, etc.)
- Smart cities (e.g., real-time city, data-driven city, ambient city, ubiquitous city, sentient city, etc.)
- Sustainability transitions and socio-technical shifts
- Environmental innovations
- Philosophy and sociology of science
- Social shaping of science-based technology
- Technological innovation systems
- Sustainable business models innovation
- Technology, innovation, and environmental policies

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3. *Smart Sustainable Cities of the Future: The Untapped Potential of Big Data Analytics and Context-Aware Computing for Advancing Sustainability* (660 pages), Springer, 03/2018.
4. *Big Data Science and Analytics for Smart Sustainable Urbanism: Unprecedented Paradigmatic Shifts and Practical Advancements* (505 pages), Springer, 05/2019.