# Chapter 1
# Overall Introduction


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**Abstract** Urban informatics is an interdisciplinary approach to understanding, managing, and designing the city using systematic theories and methods based on new information technologies. Integrating urban science, geomatics, and informatics, urban informatics is a particularly timely way of fusing many interdisciplinary perspectives in studying city systems. This edited book aims to meet the urgent need for works that systematically introduce the principles and technologies of urban informatics. The book gathers over 40 world-leading research teams from a wide range of disciplines, who provide comprehensive reviews of the state of the art and the latest research achievements in their various areas of urban informatics. The book is organized into six parts, respectively covering the conceptual and theoretical basis of urban informatics, urban systems and applications, urban sensing, urban big data infrastructure, urban computing, and prospects for the future of urban informatics. This introductory chapter provides a definition of urban informatics and an outline of the book's structure and scope.

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## 1.1 Defining Urban Informatics

Urban informatics is an interdisciplinary approach to understanding, managing, and designing the city using systematic theories and methods based on new information technologies, and grounded in contemporary developments of computers and communications. It integrates urban science, geomatics, and informatics: urban science provides studies of activities, places, and flows in the urban area; geomatics provides the science and technologies for measuring spatiotemporal and dynamic urban objects in the real world and managing the data obtained from the measurements; informatics provides the science and technologies of information processing, information systems, computer science, and statistics which support the quest to develop applications to cities.

The field covers many sectors that define city systems. Those sectors are often studied in their own right, such as transportation, housing, retail activity, physical infrastructure involving the distribution of waste, water, electricity, and other sources of energy, as well as demographic structure, economic location, urban development, and a host of related perspectives that pertain to cities and urban systems. What makes urban informatics different and complementary to these disciplinary approaches is the fact that computation is central to the way in which methods and models are used to generate a deeper understanding: of many problems that involve working out how cities function, how they generate different forms, how their dynamics reflects the ways in which they grow and decline, and how they mix, segregate, and polarize different populations and activities.

What makes urban informatics a particularly timely way of gathering together and fusing many interdisciplinary perspectives which involve computation is that in the last twenty years, computers have scaled down to the point where they can be used as sensors and embedded in a variety of physical infrastructures as well as being used in a mobile context by the population at large. This has meant that quite suddenly we are now endowed with streams of data about a city's functioning in real time, something that was not generally available hitherto when most of our methods of data collection were not automated through sensors. This has led to what is called big data—data that are generated in real time, with great variety, and hence almost limitless in volume. Such data may be the product of sensors that operate continuously and provide immediate updates to the system of our concern. For these data, we need new methods and models to help our understanding and to interpret old models that still have relevance. This has thrown the 24-hour city onto the agenda, and many of the chapters in this book reflect the fact that temporal dynamics is now a serious feature of this field of informatics. Time is now being deeply reflected in our models, whereas in the past the focus was more on spatial variety.

The field of urban informatics is still developing rapidly in its embrace of new sensing technologies, new kinds of spatial data science, new methods of analysis that range from traditional statistical methods as in spatial econometrics, all the way to new developments in machine learning, and multivariate analysis that enable analysts to explore big data in ways that have not been possible hitherto. In terms of the fields

that are distinct within the contributions we have collected here, it is worth noting that new approaches to the structure, form, and dynamics of cities using mainly physical approaches are being used to define a new kind of urban science. New methods of urban analytics are being fashioned using these ideas, and the fact that we are now able to exploit real-time movement data from sensors—either fixed to monitor traffic or mobile to do the same through telephone calls and other social media—means that we have a much richer understanding of cities than anything we have been able to develop so far. Mobility studies have thus become central to urban informatics, while developments in the dynamics of infrastructure, urban pollution, and waste—in short, the metabolism of the city—are coming to the fore through urban analytics. A large part of urban informatics involves sensing at many spatial scales from satellite remote sensing to indoor navigation, while the development of the third dimension in cities in terms of sensing and visualization is now becoming routine. Stitching all these ideas together is another important function of urban informatics, while the development of what was seen as rather disconnected types of urban models—land use and transportation, urban microsimulation, cellular automata, and agent-based models—is now part of the wider agenda. Last but not least, the field also has regard to how its theories, models, and tools relate to wider questions of governance, risk, security, crime, health, and welfare, as well as geodemographics. All these features are encapsulated in our definition of urban informatics here, and we hope readers will thus be able to piece together their own big picture of the field as they navigate many contributions in this book.

## 1.2 The Background: The Origins of Urban Informatics

The idea of publishing this book is rooted in the fast development of urban informatics in both academia and industry in the big data era. In academia, many universities have established programs to offer both undergraduate and postgraduate degrees related to urban informatics. Examples of such programs include a undergraduate program in Urban Informatics at Shenzhen University, an MSc program in Smart Cities and Urban Analytics at University College London (UCL), a graduate program in Applied Urban Science and Informatics at New York University, an MSc program in Urban Informatics at Northeastern University, an MSc program in Urban Informatics and Analytics at Warwick University, and an MSc program and a PhD research area in Urban Informatics and Smart Cities at The Hong Kong Polytechnic University (HKPU). These kinds of courses are rapidly expanding as different research groups recognize the importance of training and research in the ways in which urban informatics might be applied to contemporary urban problems. The common goal shared by these programs is to promote education and research activities to cope with various challenges in cities under the rapid global urbanization process. In industry, the smart city is a major new trend in urban development and management, and urban informatics is the core technology of smart cities. According to recent reports by Grand View Research and Zion Market Research, the global smart city market accounted

for USD 955.3 billion in 2017 and is anticipated to reach USD 2.57 trillion by 2025. Such a huge and increasing market is driven by many factors, such as rapid growth of urban populations around the world and the need to foster sustainable urban development. However, there are very few books systematically introducing the principles and technologies of urban informatics, including urban science, urban systems and applications, urban sensing, urban big data infrastructure, and urban computing. There is an urgent need to edit and publish such books to equip the current and next-generation workforce with the knowledge to tackle the challenges that cities are facing. Our contribution here is to address this urgent need.

The publication of this book is among a series of activities carried out by HKPU for promoting urban informatics internationally. Other activities include initiating and organizing the International Conference on Urban Informatics (ICUI) series, establishing the International Society of Urban Informatics (ISUI) and International Journal of Urban Informatics (IJUI), developing a new MSc program and a PhD research area in Urban Informatics and Smart Cities, and founding the Smart Cities Research Institute for conducting cutting-edge research.

Hosted by the Department of Land Surveying and Geo-Informatics (LSGI), HKPU, ICUI provides a platform for leading scientists, young scholars, and researchers worldwide to share an interest in urban informatics. The first conference in the ICUI series was held in 2017, with around 40 presentations on topics in urban systems, urban sensing, spatiotemporal big data, urban computing, and urban solutions. The second conference was held in 2019 with the theme "Toward Future Smart Cities". Over 280 participants from 18 countries and institutions such as MIT, Harvard University, the University of Cambridge, UCL, ETH, and the Alan Turing Research Institute, joined the conference and delivered over 120 presentations on 18 topics. Also introduced in ICUI 2019 was the International Society of Urban Informatics (ISUI). ISUI aims to promote the international exchange of knowledge and experience in the field of urban informatics, helping its members to succeed in their professions through regional and international academic exchange programs, publications, and networks of cross-disciplinary experts.

A number of other universities in Hong Kong have also contributed to urban informatics and smart city development. For example, the University of Hong Kong has formed the Hong Kong Urban Labs, the Chinese University of Hong Kong has established the Institute of Future Cities, and the Hong Kong University of Science and Technology has developed the GREAT Smart Cities Institute. HKPU has been conducting research on various topics in urban informatics and has accumulated numerous theories, methods, advanced technologies, and successful application cases that provide updated materials for this book.

The book is based on invitations to over 40 world-leading scholars and their teams across a wide range of fields in urban informatics who were asked to write the chapters of this book. In the book, they not only give comprehensive reviews but also share their latest research achievements in various topics within urban informatics, as well as vivid examples of employing emerging urban informatics technologies for solving urban problems. Some of the chapters have been contributed by the participants

of the ICUI series, but include new material rather than the presentations at these conferences.

This book is intended for use by researchers and students from a wide range of disciplines related to urban informatics, urban science, urban systems and applications, urban sensing, urban big data infrastructure, and urban computing. It will serve as a textbook for those undergraduate and graduate students majoring in urban informatics, studies in smart cities, transport and civil engineering, geography, geosciences, urban planning, geographic information science, environmental science, resources science, and land use. It can also be used as a reference book for practitioners and professionals in the governmental, commercial, and industrial sectors, such as urban planners, computer scientists, data scientists, geographers, policy makers, architect designers, surveyors, urban governors, and environmental scientists.

## 1.3 Structure of the Book

This book has six parts that cover the latest developments in a wide range of topics in urban informatics. These topics include the conceptual and theoretical basis of urban informatics, applications of urban informatics in understanding and managing various urban systems, urban sensing, urban big data infrastructure, and urban computing. While the parts are related, they can be read in any order except Part I, which intends to provide an overview of the backgrounds of urban informatics and thus should be read before the other parts.

After the overall introduction, Part I (Dimensions of Urban Science) focuses on the conceptual and theoretical basis of urban science as it has evolved in the examination of the city as a system. It highlights contemporary theories of urban interactions, human dynamics, metabolisms, and the urban economy, and relates these to the wider vision of a new urban science for examining cities in the twenty-first century. The chapters in Part II (Urban Systems and Applications) discuss applications of urban informatics in understanding, analyzing, and managing various urban systems. These include applications in urban travel and human mobility, urban freight systems, crime and security, pollution monitoring, energy systems, health and well-being, risk and resilience, as well as urban governance. The state-of-the art urban informatics are used to identify the problems and provide viable solutions for those problems. The chapters in Part III (Urban Sensing) describe existing and new methods of urban sensing, including remote sensing, ground-based sensors, global navigation satellite systems (GNSS), mobile mapping technologies, indoor positioning technologies, user-generated content, and other developments that have a considerable potential for advancing urban science.

Part IV (Urban Big Data Infrastructure) focuses on issues related to the new developments in urban big data infrastructure, including those concerning big data, geoprivacy, 3D city modeling, 3D cadastre, rule-based modeling, cyber infrastructure, spatial search, and urban IoT. These new developments will likely contribute

to significant progress in urban informatics and in urban science more broadly. The chapters in Part V (Urban Computing) cover various topics in urban informatics from the perspectives of computer science and urban modeling. Specific research or application areas examined include visual analytics, cloud and mobile computing, data mining, artificial intelligence (AI) and deep learning, agent-based modeling, microsimulation, Cellular Automata modeling, and transportation modeling. The chapters highlight the development and use of computing technologies, principles, and models for urban contexts and applications. Part VI (The Value of Urban Informatics) concludes the book with a broadly based and forward-looking discussion by Michael F. Goodchild on the goals of urban informatics, the potential for unintended consequences, and possible approaches to accountability.

## 1.4 Retrospective and Prospective

In the third decade of the twenty-first century, we find ourselves with a well-developed ability to acquire vast amounts of information about the city and with the tools to perform a wide range of analyses. Projects under way in world cities such as Beijing, London, New York, Hong Kong, and Singapore are described at many points in the chapters of this book, and there is every reason to believe that the burgeoning field of urban informatics will continue to grow. But while the reader will find rich detail in the pages that follow, he or she will also recognize that what is being described is a first-world activity, largely confined to the Global North. What all of this means for the Global South remains an issue that is scarcely addressed, and we can only speculate as to what is likely to happen if this omission continues.

Urban informatics is a young field, and not surprisingly it is difficult to organize into self-contained subfields. The reader will become well aware of this issue as he or she navigates the parts of the book and encounters issues such as urban mobility or urban heat islands in different chapters and parts and in different contexts. Hopefully, a better and more robust conceptual model of urban informatics will emerge in time, as the field matures and as its principles become more clearly articulated. We look forward to one or more future textbooks that distill the field into a simple, concise, and theory-based structure. For now, however, the approach has to be more encyclopedic.

What else is missing? First is a sense of history, of how earlier cities dealt with their limited information resources and their lack of the tools to make sense of what they had. John Snow's map of the London cholera outbreak of 1854 was a masterful exercise in inference (Johnson 2007); while the concept of the smart lamppost has a fascinating precursor in the Pluto lamps that were installed in London in the late 1890s (https://www.british-history.ac.uk/survey-london/vol47/pp52-83). We should be able to learn much from a counterfactual approach from earlier times. Second is a sense of what the future may hold in the way of unintended consequences, gaming of technology, and subversion. The history of information technologies is rich in examples of breakthroughs gone astray, finding application for purposes that are malicious and dystopic. Many of the chapters are full of enthusiasm and excitement

for the positive potential of urban informatics and understandably do not dwell on the negative. These possibilities are addressed at the end of the book in Part VI. Finally, as in any data-intensive field there will always be a need to address uncertainty, and associated issues of data provenance and measurement error, especially given the spatiotemporal focus of the field. Dealing with uncertainty is not simply a matter of putting a plus or minus on each item of data, given the strong existence of statistical dependence in both spatial and temporal domains. To quote Korszybski (1933), the map is not the territory; the data are only an approximation and representation of reality.

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