Chapter 1
Introduction to 'Planning Support Systems and Smart Cities'

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1 Introduction

Since their emergence, digital information and communication technologies (ICTs) have been applied in many urban planning and management contexts. Not only do they have the capability for collecting, managing, analysing, and storing information about cities more efficiently than ever before, new technologies also present planners and managers with opportunities to draw on this information to improve city life. These applications have developed alongside the expanding use of ICT by all sectors in cities. Published in conjunction with an international conference of researchers and practitioners interested in planning support systems, big data, data analytics and smart technologies, this book contains a variety of chapters documenting the many ways in which ICTs are used to produce new knowledge about cities, improve decision-making, and change the very fabric of city life.

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S. Geertman et al. (eds.), *Planning Support Systems and Smart Cities*,
Lecture Notes in Geoinformation and Cartography,
DOI 10.1007/978-3-319-18368-8_1

The remaining sections of this introduction are organized as follows. First, we will elaborate on the two central concepts in the book—'smart cities' and 'planning support systems'—and explain our initial motivation in choosing these themes. Second, we provide an overview of the book's structure, providing summaries of each chapter and commenting on their contents. We close with observations about the nature of the research presented here, and some comments about the future of information infrastructure in cities.

2 Smart Cities and Planning Support Systems

In recent years, the concept of a 'smart city' has been taken up by many city leaders, IT companies and scholars worldwide, resulting in a flurry of professional (e.g., ARUP 2010; Washburn and Sindhu 2010), popular (Townsend 2013; Greenfield 2013) and scholarly (Deakin 2011; Glasmeier and Christopherson 2015) publications on the topic. As Hollands (2008) observed, the term 'smart city' and related terms like 'digital', 'wired', and 'intelligent' cities have been used in a variety of ways. One origin lies in the concept, developed by US-based scholars, of 'smart growth' (Harrison and Donnelly 2011; Daniels 2001; Burchell et al. 2000). Created as a reaction to excessive automobile-oriented urban sprawl which developed around many US cities, this sustainability-related concept promotes the adoption of urban growth management policies such as urban growth boundaries, rural land preservation and financial incentives to discourage growth at the urban periphery. On the other hand, the concept of smart cities also finds its origin in debates about how ICTs can contribute to the planning and management of cities (Goodspeed 2015). For some, a smart city refers to urban environments where 'pervasive' or 'ubiquitous' computing has introduced a range of digital devices for sensing, monitoring and managing the city (Kitchin 2013). This strand of research also emphasizes the digital infrastructure needed to collect and manage new sources of data, conduct analysis and ultimately use connected devices to manage cities in new ways (Batty et al. 2012).

Taking these two sources together, some authors have proposed a definition of a smart city that unites both ICT-based support and sustainability goals into one overarching concept. In line with this broader perspective, Caragliu et al. (2011, p. 70) defined the concept of smart city as: "*when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance*." These theorists see the key to a smart city lying not only in ICT, but also in human, social and natural capital (Neirotti et al. 2014). From this perspective, examples of smart city projects include not only the use of digital devices to monitor and manage cities, but also broader issues such as governance and sustainability. As described further below, the collection of chapters in the second part of this volume span the full range of the emerging field of smart city practice and scholarship, drawing on empirical investigations to explore promising new ideas in this fast-emerging field.

In contrast, the concept of planning support systems (PSS) refers to a well-defined scholarly and professional field which dates to the late 1980s (Harris and Batty 1993; Klosterman 1997; Brail and Klosterman 2001; Brail 2008). This volume's predecessors contain a diverse array of PSS research (Geertman and Stillwell 2003, 2009; Geertman et al. 2013). PSS can be defined as geo-information technology-based instruments that are dedicated to supporting those involved in planning in the performance of their specific planning tasks (Geertman 2006). Although scholars and practitioners had worked for many years on developing computer-based planning instruments, Harris and Batty (1993) proposed these efforts to be categorised under the concept of PSS, promoting the integration of geographic information systems (GIS) with various types of models to produce tools uniquely useful for planning. Thus, the PSS concept emerged as a related but distinct field from GIS. While GIS are general-purpose tools that are applicable for many different spatial problems, PSS are distinctive in their specific focus on supporting specific professional planning tasks. PSS are also related to so-called spatial decision support systems (SDSS), which are also designed to aid particular decision tasks. These two types of systems differ in that PSS generally pay particular attention to long-range problems and strategic issues whereas SDSS are generally designed to support shorter-term policy making by independent individuals or business organizations (Clarke 1990).

Given this definition, Klosterman (1997) argued that PSS should serve as a single information framework integrating planning-related theory, data, information, knowledge, methods and instruments. Examples of PSS include geographically oriented websites that show interactive land-use maps that inform users about formal regulations and building restrictions, communication-oriented map-based touch tables that provide groups of professionals a mutual workbench to discuss and assess sketches of future layouts (Arciniegas et al. 2012), and more analytical oriented PSS like What If, CommunityViz and UrbanSim, which offer planners the ability to consider alternative possible future spatial scenarios (e.g., see Geertman and Stillwell 2003, 2009). In recent years, we have observed a growing theme in PSS research. Even while overall adoption of PSS has lagged behind researcher's expectations (Vonk et al. 2005), several PSS have reached maturity and become used more widely in planning practice. These trends together have sparked the development of a growing body of research examining the application of PSS itself. Examples of scholars working in this tradition include studies which have sought to define PSS performance metrics (Te Brommelstroet 2013), analysis of the role of PSS in facilitating professional communication (Pelzer and Geertman 2014), and studies examining PSS and group learning outcomes (Goodspeed 2013). As elaborated below, the contributions in this volume illustrate this exciting and diverse field of PSS research and development, and include accounts of new PSS instruments as well as studies of their development and application.

To summarise, at the moment there is a tremendous diversity of smart city definitions, goals and approaches, characteristic of an emerging field of study, whilst PSS, on the other hand, are the subject of an evolving scholarly tradition that has been in existence for two decades at least. Our initial motivation for this volume and for the conference as a whole was to shed light on how these two themes might

be linked, for example a specific focus on PSS that are being developed or applied for use in smart cities around the world. In reading and compiling summaries of the contributions, it is apparent that whilst there is a tremendous amount of new research and development activity taking place in both of the theme areas, only a few researchers have tried to tackle the particular challenge of understanding their inter-relationship.

3 Structure of the Book

The chapters in this book are organized into four parts, the contents of which are summarised in the remainder of the chapter. We are of course well aware of the danger of imposing structure on such a diverse array of contributions. Nevertheless, we think that the structure provides some degree of organization on the basis of key themes. Part I is a collection of contributions that show the role of spatial data and ways in which these data can be transformed into useful knowledge. Part II contains chapters that investigate the concept of smart cities through theory, case studies and descriptions of new applications. Part III contains chapters in which PSS are used to support wider participation and/or assessment processes in planning practice. Part IV contains a series of chapters in which new methods and tools of PSS and their applications are described.

3.1 Part I: Spatial Data Analytics

Opportunities for urban planning-relevant spatial analyses have increased substantially with the advent of urban sensing, ubiquitous computing and the gradual standardization of embedded location information within administrative datasets about urban activities. The six chapters in Part I show how the new data can be captured, analysed and integrated into various types of PSS. In this way, the new data and related analytics can add to a city's capacity to be 'smart' by improving the data snapshots and behavioural models which feed PSS that enable everyday planning processes to be more intelligent. The first two chapters in Part I illustrate ways of tapping social media data streams to enhance the content and timeliness of PSS. In 'Development and Operation of Social Media GIS for Disaster Risk Management in Japan', *Kayoko Yamamoto* explores ways of integrating social media data streams into useful risk management tools for assisting with disaster awareness, relief and recovery. She presents several systems that her team has prototyped and tested, positions this work within the broader literature, evaluates the effectiveness of various system design and user interface features, and suggests development paths and user engagement strategies that can help integrate social media data into a practical PSS for disaster risk management. In the second chapter of Part I, 'The Role of Social Media Geographic Information (SMGI) in Spatial

Planning', *Michele Campagna, Roberta Floris* and *Pierangelo Massa* build measures of tourist interest in lodging and visitor attractions using volunteered geographic information (via Tweeter feeds, Instagram tags, TripAdvisor comments and the like). An Italian tourism planning example is used to demonstrate how data from these sources can be used to construct indicators for use in a PSS.

In the third chapter of Part I, *Michael Johnson, Justin Hollander* and *Eliza Devenport Whiteman* discuss 'Data and Analytics for Neighborhood Development: Smart Shrinkage Decision Modeling in Baltimore, Maryland'. The rapid spread of GIS technologies and related geospatial data have greatly enhanced the availability of spatially-detailed information about land use, urban infrastructure and the built environment. Johnson et al. take advantage of this new world of improved urban data by applying management science techniques to everyday community development questions. In their illustrative case, they help the US city of Baltimore, Maryland, to evaluate and prioritize alternative re-development options, showing how these methods might help the many communities which have experienced disinvestment and economic decline.

The fourth and fifth chapters of Part I integrate data about urban activities and preferences into dynamic models of urban change and resilience. *Lara-Britt Zomer, Winnie Daamen, Sebastiaan Meijer* and *Serge Paul Hoogendoorn* examine short-term questions of crowd control in 'Managing Crowds: The Possibilities and Limitations of Crowd Information During Mass Urban Events'. Through visitor surveys and behavioural models of events in the Netherlands, they calibrate and study alternative strategies for providing congestion and crowd control information to public participants at popular venues. *A. Yair Grinberger*, *Michal Lichter* and *Daniel Felsenstein* examine urban dynamics at very different temporal and physical scales. In 'Simulating Urban Resilience: Disasters, Dynamics and (Synthetic) Data', they examine the aftermath of natural disasters in terms of the changes in infrastructure and urban activity following natural disasters such as earthquakes. They use large-scale models of transportation and land-use interaction to explore disaster scenarios in Israel, simulating the long-term residential and work relocations that are likely to occur as a metropolitan area adjusts to the type of significant destruction and disruption that might result from a natural disaster.

In the last chapter in Part I, *Yi Zhu* and *Joseph Ferreira, Jr.* focus on the analytics and techniques that are required to translate the new, spatially-detailed data about urban activities into synthetic populations that are suitable for urban modeling and PSS. Their paper, entitled 'Data Integration to Create Large-Scale Spatially Detailed Synthetic Populations', uses the Singapore built environment as an example. They construct and utilize an ontology of building location, use and physical characteristics in order to make semi-automatic the integration of census and government statistics with real estate transaction data and other online sources. The approach is needed to construct a synthetic population of people and places with sufficient accuracy, spatial detail and reproducibility to support the next generation of urban dynamic models that are increasingly utilized in PSS.

3.2 Part II: Smart Cities

The next part of the book contains examples of the research on smart cities now underway. It begins with two chapters that consider the diverse theories that can be used to analyze smart cities. The next three chapters explore new infrastructures and new data sources often associated with smart cities, and the sixth chapter discusses a novel data infrastructure that links new data to analysis tools. Finally, the closing chapter in this part of the book considers how smart cities and PSS are related.

In the chapter 'Smart Cities: Concepts, Perceptions and Lessons for Planners', *Tuan-Yee Ching* and *Joseph Ferreira, Jr.* report the results of an empirical study of smart cities. To guide their study, they propose four alternative theories of a 'smart' city: smart machines; partnership and collaboration; learning and adapting; and investing in the future. Their detailed investigation of smart city initiatives in Boston, San Francisco, Amsterdam, Stockholm, Singapore and Rio de Janeiro reveals these cities are developing smart city practices appropriate to local capabilities and needs. For example, Boston has created new citizen-facing apps, San Francisco has created a new position in city hall for innovation, and Stockholm has invested in a broadband network. The chapter reminds us that while the idea of the smart city is a powerful inspiration for change, the ways cities use technology remain highly varied and are shaped by local capacity, needs and cultures.

The contemporary smart city debate often lacks connections with previous scholars who have considered how ICT might impact cities. *Kian Goh*'s chapter, 'Who's Smart? Whose City? The Sociopolitics of Urban Intelligence', addresses this gap by considering how smart city developments in Singapore and London can be analyzed from the perspective of two well-known urban scholars, Manuel Castells and William Mitchell. In some ways, she finds their theories are prescient, but concludes that neither adequately describes the heterogeneous developments in each city. In conclusions that echo those of Ching and Ferreira, the evidence suggests that cities are pursuing diverse goals with smart city technologies.

Shifting from theory to applications, the next chapters report on the technical details of several smart city projects. In the third chapter, 'Knowledge-Mining the Australian Smart Grid Smart City Data: A Statistical-Neural Approach to Demand-Response Analysis', *Omid Motlagh, Greg Foliente and George Grozev* present the Australian Smart Grid Smart City program and describe its use of big data. They present a novel statistical-neural approach to maximize knowledge extraction from large datasets, and demonstrate its use in evaluating the effectiveness of two different cost-reflective product offerings, named PeakRebate and PriceSmart. Their results show that users' energy consumption behaviour will change due to these offerings. In particular, participants changed their time of energy use behaviours after subscribing to these products.

In their contribution on 'Urban Emotions: Benefits and Risks in Using Human Sensory Assessment for the Extraction of Contextual Emotion Information in Urban Planning', *Peter Zeile, Bernd Resch, Jan-Philipp Exner* and *Günther Sagl* introduce their so-called 'Urban Emotions' approach. This method focuses on integrating

humans' emotional responses to the urban environment in both time and geographical space to be able to incorporate these into planning processes. To detect and analyze these emotions and perceptions, they extract contextual emotion information from technical and human sensors, as well as georeferenced social media posts. This results in novel information for urban planners. In addition to technical and methodological aspects, data privacy issues and the potential of wearable technologies are discussed in this chapter. With the help of two case studies, the authors demonstrate how this approach can be translated into planning processes.

Of course, not all information needed for smart city applications is available. As an example, one of the most noticeable developments in cities of the global south has been the proliferation of mobile phones. Although this technology has improved urban life in many ways, two of their most common uses in cities—wayfinding and trip routing—have often lagged in the developing world where transit systems are semi-formal and good data are lacking. The chapter on 'Leveraging Cellphones for Wayfinding and Journey Planning in Semi-formal Bus Systems: Lessons from Digital Matatus in Nairobi' by *Jacqueline Klopp, Sarah Williams, Peter Waiganjo, Dan Orwa* and *Adam White* shows that these hurdles can be overcome with savvy use of existing technologies. The authors report on a project in which new digital data were created using smartphones to describe Nairobi's system of *matatus*, or semi-formal mini-buses. They then publish the data in the form of standardized GTFS data, as well as a new paper map, both of which are eagerly adopted. The chapter suggests an exciting new era of public participation GIS (PPGIS), where the results of data creation projects are linked through standards and data sharing into a growing shared information infrastructure for cities.

The proliferation of novel data sources and data analysis tools associated with smart cities has created new problems for urban analysts. One innovative response to these problems is described by *Chris Pettit, John Barton, Xavier Goldie, Richard Sinnott*, *Robert Stimson* and *Tom Kvan* in the chapter entitled 'The Australian Urban Intelligence Network Supporting Smart Cities'. The network they describe includes researchers, planners, and policymakers who have developed the Australian Urban Research Infrastructure Network (AURIN), a shared online workbench of databases and PSS tools. With support from the Australian Government and leading Australian universities, this group has established an impressive network of data hubs making available to users over 1000 datasets. Much more than simply a system for data storage and retrieval, AURIN also contains more than 100 statistical tools, the Online What If? PSS, and a novel walkability tool.

Concluding this section is a thoughtful chapter by *Yanliu Lin* and *Stan Geertman*, 'Smart Governance, Collaborative Planning and Planning Support Systems: A Fruitful Triangle?' that directly addresses the connection between smart cities and PSS by drawing on examples from China, Finland and the USA. Scholars, companies and city officials each promote their preferred terms and definitions for smart cities. Too often, municipal officials and ICT companies alike are eager to avoid the links between these new concepts and the realms of governance and planning, two fields which are shaped by institutions and, inevitably, by politics. Yin and Geertman observe that often PSS forms a link between smart

governance and collaborative planning, and describe novel projects that seem to link the two, and therefore defy conventional categorization. In all three countries, innovative practitioners and activists are launching projects that integrate social media, participatory mapping and PSS to shape urban places. They make the important observation that technology alone is not enough—smart governance and collaborative planning each require well-designed institutions.

3.3 Part III: Planning Support Systems and Public Engagement

Continuing Yin and Geertman's focus on PSS projects, this section contains chapters on the development, application and assessment of PSS. This section reflects the new development in the PSS literature described above: namely, the growing body of research seeking to better understand social aspects of the development, application and use of PSS.

As discussions about smart cities focus on how ICT might be embedded within the urban environment, *Brian Deal, Varkki Pallathuchuril, Yong Wook Kim* and *Haozhi Pan* remind us in their chapter 'Sentient PSS for Smart Cities', that PSS also should be the focus for ongoing innovation. Inspired by theoretical and practical developments described by the term 'sentient computing', they argue that this concept should guide future PSS development. In the same way that smartphones dim their screens or zoom in or out of maps automatically, the authors of this chapter call for PSS that search the web for relevant data and adjust visualizations in response to user feedback, backgrounds and preferences. This concept provides a powerful conceptual framework for ongoing work to design PSS which match the high level of usability we increasingly take for granted in the consumer marketplace.

In their contribution 'Gaming, Urban Planning and Transportation Design Process', *Jayanth Raghothama* and *Sebastiaan Meijer* identify the discrepancies between two different approaches of using methods and tools for the analysis and design of urban systems. The first group is a technical-rational approach using computational and mathematical methods rooted in systems engineering. The second group is a participatory approach which uses qualitative methods to develop multiple narratives, values and perspectives. The authors propose integrating these approaches through gaming. They develop a framework to do this which they illustrate through two case studies in the cities of Paris and Stockholm. The authors conclude that games can create open spaces for dialogue, participation, experimentation.

The next contribution analyzes how ICT is changing the nature of planning itself. In the chapter, 'The Everyone City: How ICT-based Participation Shapes Urban Form', *Sara Levy, Karel Martens*, and *Rob van der Heijden* present a simulation model to explore how social media might change the planning process. Based on their modeling results, they conclude that ICT-facilitated participation will tend to bring building heights down and increase the number of buildings constructed.

The last two chapters of this part examine the issues of usability and facilitation, two key aspects of the participatory setting in which PSS are used. In their contribution 'Usability of Planning Support Systems: An Evaluation Framework' the authors *Patrizia Russo, Maria Francesca Costabile, Rosa Lanzilotti,* and *Christopher Pettit* recognize that previous research on PSS has shown that low usability of these tools is one of the reasons why they are not widely used by planning professionals. However, they identify a gap in the PSS literature for methods for evaluating PSS usability and performing usability tests. The authors develop a framework that aims at guiding usability evaluation of PSS. They then apply this evaluation framework to evaluate the usability of the user interface of three PSS, to determine how well the functionality can be used for specific circumstances and environments. The chosen PSS consist of CommunityViz, Envision and Online What If? Results of this user test are discussed, providing recommendations for the design of PSS.

In the final contribution in this part, 'Facilitating PSS Workshops: A Conceptual Framework and Findings from Interviews with Facilitators', *Peter Pelzer, Robert Goodspeed and Marco te Brömmelstroet* stress the importance of the facilitation of workshops where PSS are used in planning processes. They indicate that previous empirical studies have largely overlooked the important role of facilitation of workshops. By drawing on existing facilitation research, they identify four main categories of facilitation interventions: substantive, procedural, relational and tool related. Based on these categories, they propose a conceptual framework for the facilitation at PSS workshops. With the help of semi-structured interviews, they validate and develop this framework, concluding that successful facilitation of PSS workshops requires a careful balance of encouraging and limiting PSS use by participants.

3.4 Part IV: Planning Support Systems: New Methods and Tools

The evolution of PSS over the last three decades has taken place in tandem with the emergence of new methods and technologies. This final section of the book contains a collection of chapters that illustrate the application of new methods and tools in a range of contexts. The first three chapters are a continuation of the theme of Part III since they involve methods used to improve and assess the role and utility of PSS in public engagement but, collectively, they also demonstrate the value of particular tools designed for 3D visualisation, virtual reality and scenario planning in localities in different parts of the world. The fourth and fifth chapters contain descriptions of a system featuring graphical representation of spatial interaction data describing population changes in the UK, and a new tool for calculating and mapping the energy use of buildings in New York City. The final two chapters provide different perspectives on the use of new tools and systems in the context of transport planning in Boston, Massachusetts and in Perth, Western Australia.

The first chapter in this section describes a project featuring a PSS used to visualize climate change impacts. *Scott Lieske, Kari Martin, Ben Grant* and *Claudia Baldwin*, in 'Visualization Methods for Linking Scientific and Local Knowledge of Climate Change Impacts', consider the challenge of how PSS can be used to help communities in coastal areas of southeast Queensland (known as the Sunshine Coast) confront the combined effects of climate change, i.e. flooding, rising sea level, storm surges and other severe weather events. The chapter assesses the effectiveness of geographic visualization tools in aligning scientific knowledge with local knowledge by engaging with members of the coastal community in areas where residential development and infrastructure are vulnerable to the effects of climatic change under specific scenarios. The assessment of participants suggested that a combination of consultation techniques was important, including interactive 3D scenes, flood hazard maps, Photovoice, and interactive participatory mapping, but that 3D visualization was the most effective method for knowledge exchange about local climate change impacts. The chapter demonstrates that 3D geographic visualization is an important methodology for facilitating participation and the results confirm that despite certain limitations, there are clear benefits from this technology in promoting group understanding of environmental situations and coordinating actions and responses.

The value of using visualisation techniques is echoed in the following chapter on 'Virtual Worlds as Support Tools for Public Engagement in Urban Design' by *Anja Jutraz* and *Tadeja Zupancic* which explores the use of virtual worlds for public participation in urban design. In this case, the authors' research is based on the use of the Terf virtual world visualisation tool which provides an immersive environment enabling the participants to experience 3D models of neighbourhoods as though they were pedestrians. This tool is used to explore interdisciplinary collaboration in urban design. The context in this case is a suburban neighbourhood in Slovenia's capital city, Ljubljana, and semi-structured interviews were conducted with members of the public and with professional planners about their experience using Terf to assess alternative rearrangements for the urban area. The overall conclusion is that, when it comes to imagining the future urban landscape, people are served much better by tools that enable them to see the alternative environments in 3D and to experience those virtual worlds by walking through them. Moreover, the use of PSS featuring virtual reality helps improve the communication between the public and the urban design professionals.

The third chapter in this group is by *Jennifer Minner* and is entitled 'Recoding Embedded Assumptions: Adaptation of an Open Source Tool to Support Sustainability, Transparency and Participatory Governance'. The chapter tells the story of the development and application of an open source planning support tool, Envision Tomorrow (ET), to support the assessment of planning scenarios at district, community and regional scales in the metropolitan region of Austin, Texas. Envision Tomorrow is an open source PSS tool that is an extension to ArcMap (a component of the ArcGIS suite of geospatial processing programs) and uses a set of linked Excel spreadsheets to construct alternative futures based on different sustainability indicators. Minner reports on the use of a number of methods of public

engagement—visioning workshops, planning charrettes and open houses—in five different communities. Whilst these methods are not determined by Envision Tomorrow, the PSS role in this context is to provide planners with a method for performing planning from the modeling of individual buildings of different types through to constructing aggregate developments using Envision Tomorrow to develop and visualize scenarios in ArcMap. The use of spreadsheets means that the calculation of indicators (e.g. energy use, carbon emissions) is immediately transparent and the software has been recoded and extended to create new indicators to address equity and green infrastructure issues. The chapter provides a critical appraisal of transparency and adaptability and reveals that whilst there is much potential in the openness and flexibility of the PSS which is valuable for enhancing analytical capabilities, it also reveals some of the concerns associated with the application of Envision Tomorrow within planning processes. Balancing simplicity, transparency and ease-of-use versus the complexity, uncertainty, and sensitivity of 'real world' interactions is a continuing challenge for PSS designers, who risk hiding key assumptions and overstating the robustness of PSS-derived indicators.

The fourth chapter in Part IV shifts focus away from the public participation process and towards PSS tools themselves. 'Monitoring and Visualising Sub-national Migration Trends in the United Kingdom' by *John Stillwell, Nik Lomax* and *Nikola Sander* reports on work in progress on the development of a system for monitoring change in the components of demographic growth in local authorities throughout the United Kingdom. Whereas other chapters in this part of the book deal with systems and processes within regions, cities and particular localities, this chapter introduces a national system through which data can be extracted for the analysis of trends in population development over time and for the comparison of how the components of change (births, deaths, internal migration and international migration) are impacting on different urban or rural areas. The chapter describes a spreadsheet application which provides access to the data for analysis and visualization. In response to the problem of visualising flow data using conventional methods, the authors make use of the concept of circular plots and illustrate their application with examples of migration flows between city regions.

The next chapter describes a PSS to examine another pressing topic, urban energy use. Measuring energy consumption is a complex process, and in their chapter entitled 'Urban Data and Building Energy Modeling: A GIS-based Urban Building Energy Modeling System Using the Urban-EPC Engine', *Steven Jige Quan, Qi Li, Godfried Augenbroe, Jason Brown* and *Perry Pei-Ju Yang* explain the development and application of a GIS-based urban building energy modeling system, using the Urban-Energy Performance Calculator (EPC) simulation engine. Urban-EPC is a modeling system that is compatible with other planning tools and uses urban data related to the buildings, mutual shading, microclimate and occupant behaviour to generate the amount of energy used by every building in a city, which can then be mapped and analysed. The simulation method is applied to the Manhattan district of New York City to show its potential as an important PSS tool that can be valuable in assisting planners and policy makers in optimizing the urban energy system and achieving environmental objectives.

The final two chapters of the book are concerned with applications of PSS methods and tools in transportation management, a sector that is of critical importance in contemporary planning of sustainable urban areas and one with both a longstanding tradition of model-based PSS and is at the forefront in the adoption of smart city initiatives. One of the most important recent transportation developments has been the introduction of intelligent transportation systems that provide real-time information to transport operators, managers and travelers. These systems, used in combination with support tools such as traffic simulation models and decision support systems now provide traffic managers with the means to optimize the flow of traffic in real-time as well as prepare for various scenarios. Several metropolitan areas in the USA have joined up with federal agencies to adopt active traffic management (ATM) or integrated corridor management (ICM) approaches, including Seattle, Dallas, Minneapolis, Las Vegas and San Diego. In Boston, the Massachusetts Department of Transportation (MassDOT) is pursuing an innovative business model that provides real time travel time information to the public using dedicated highway signs covering over 700 miles of state highway. In the chapter entitled 'MassDOT Real Time Traffic Management System', *Russell Bond* and *Ammar Kanaan*, two transport practitioners, explain how MassDOT has invested in infrastructure to capture and archive real travel time data and freely provides these data to third party developers. In other states, these data are usually collected by and purchased from private companies. The authors explain how the development and operation of the MassDOT Real Time Traffic Management (RTTM) system has resulted in a shift towards new measures of system performance. There is also a commitment on behalf of MassDOT to expand how it interacts with its transportation network users through mobile technologies and social media, indicative of the extent to which the city is getting 'smarter'.

Land-use transport modeling (LUTM) dates from the 1950s when the first efforts were made in the USA to systematically study the relationships between transport and the spatial development of cities. Lowry's (1964) pioneering Model of Metropolis was the first attempt to model the interactions between land use and transportation systems. The number of applied LUT models has increased steadily and Wegener (2004) provides a valuable overview of the range of models developed whilst Hunt et al. (2005) offer a detailed review of six of the various alternative frameworks available for urban LUT interaction models in operation. LUT modeling in Western Australia is the focus of the final chapter by *Sharon Biermann, Doina Olaru, John Taplin* and *Michael Taylor*, in which the authors explain how three models were proposed and evaluated before PLATINUM (Perth LAnd and Transport INtegrated Urban Model) was selected as the preferred option. The chapter, entitled 'Pragmatic Incremental or Courageous Leapfrog [Re]Development of a Land-use and Transport Modelling System for Perth, Australia', considers the application of current theoretical insights into the critical success factors for PSS (Vonk 2006) to the design of PLATINUM as well as lessons learnt from other applications and from the development of the PSS in the particular planning and policy context of Western Australia.

4 Conclusions

The 25 remaining chapters included in this collection contain research with diverse theoretical and analytical approaches. Featuring contributions from scholars around the world, the chapters cover projects as varied as the cities they describe. In this way, this book continues a CUPUM tradition of drawing together a global scholarly community. However CUPUM has thrived not only because of a shared scholarly fascination with cities and their endlessly diversity, but also because of common connections among researchers. It is to these commonalities we will now turn. The conclusions first discuss the types of scholarly contributions contained in the volume before turning to some comments about trends in information infrastructure in cities.

4.1 Knowledge About Cities, Technology, and Planning

The scholarly contributions of the research included here fall into three distinct categories, and the chapters often contribute to more than one. The first category contains contributions that feature original knowledge about cities. Whether it is analyzing social media data (Chaps. 1, 2, 3, and 11), mapping their informal transportation infrastructures (Chap. 12) or visualizing population flows (Chap. 23), digital technologies have been indispensable for researchers to develop new insights into urban processes. In addition, with the growth of 'smart city' and other competing visions for how ICT should be used in cities, the book contains qualitative chapters analyzing practices in cities and their associated theoretical debates (Chaps. 8, 9, and 14).

The second category includes contributions to the evolving set of constructs, models, methods and instantiations which are the outputs of ICT research (March and Smith 1995). This category encompasses chapters featuring application of analytical techniques to urban problems (Chap. 4), new methods for data integration (Chap. 7), and urban modeling (Chaps. 6 and 26). The common purpose of these research outputs is to contribute to the evolving toolkit for urban research.

The CUPUM community has not been content to develop an in-depth understanding of cities through empirical studies and modeling as an end in itself. The third category includes contributions from research about the process of applying ICT to improve the planning and management of cities. As described above, this growing area of scholarship seeks to develop knowledge at the intersection of technology and social processes at the heart of planning and decision-making. Examples from this category in this volume include explorations of the potential for gaming and virtual worlds to improve communication among planning participants (Chaps. 16, 20, and 21), the role of facilitators in enabling stakeholder engagement with PSS (Chap. 19), and an analysis of the usability of PSS tools (Chap. 18). The results from this research is a growing body of knowledge practitioners can draw on when deciding where and how to apply ICT to a given context.

Surveying the contributions of the chapters, we next turn to an assessment of the two themes of this volume. So far as we have been able to tell, the concept of 'smart cities' remains an evocative slogan and is not a well-defined theoretical or empirical phenomenon. We hope this volume contributes to a robust dialogue among practitioners and scholars concerned with ICT and cities. We think the research traditions represented here can enrich the smart city debate, even as newcomers reinvigorate the field with fresh perspectives. PSS, on the other hand, has remained a remarkably durable concept for well over 20 years. The term has persisted despite shifting intellectual trends and rapidly evolving cities. We believe it has done so because the term's classic definitions contain a balance between specifics and abstraction. PSS is not a category of technology, but a perspective on what technology is asked to do. PSS should not only subject proposals to rigorous analysis (Harris and Batty 1993), but also facilitate the collective design and learning required by communities seeking to tackle long-range problems (Klosterman 1997). Most importantly, the term has served as a common reference point for researchers working in diverse planning traditions and has facilitated the development of the growing base of knowledge about how planning and decision-making can be improved with ICT in different ways.

4.2 Smart Cities and PSS: Towards New Information Infrastructures

In addition to illustrating the contours of research in this area, the chapters illuminate some broader trends as well. In particular, the chapters highlight the extent to which investment in urban information infrastructure has generated data streams that facilitate 'smart city' initiatives and PSS development in mutually synergistic ways. In Chap. 12, the digital cellphone infrastructure of Nairobi made it possible for researchers to generate a rich database from which the researchers could construct transit maps of the semi-formal matatus buses. More broadly, the evolution of digital standards for encoding road networks, street addresses, transit routes and the like has had a much broader impact beyond the census taking, navigation aids and traffic management applications that motivated and financed the original data collection and standardization. These new datasets have greatly facilitated the sharing and cross-referencing of spatially-detailed data about the urban facilities and the spatial-temporal activity patterns that constitute urban life. Current efforts to standardize additional records, such as land use information, are also impacting the quality, detail and accessibility of the types of data that make PSS much more affordable, timely and realistic.

We are only at the beginning of this virtuous cycle whereby improved data makes new uses practical in ways that generate yet more data, which enables yet more ways to understand how urban planning and management impacts urban activities and our quality of life. For example, Chaps. 2 and 3 illustrate how one can

take advantage of volunteered geographic information on social media sites to improve disaster response systems and improve tourism planning. Likewise, many of the 'smart city' initiatives discussed are generating new data that can be used for research and analysis. In this way, 'smart city' efforts, while quite different in motivation and structure from most PSS applications, are helping to provide the data, infrastructure and institutional capacity that are needed for PSS applications to be more affordable, timely, realistic and routine.

Of course, these synergies are not guaranteed and many difficult issues have emerged concerning boundaries between public and private data, confidentiality, infrastructure financing, and intellectual property. Addressing these issues will be increasingly important for the beneficial evolution of PSS. In general, PSS applications have tended to focus on making everyday urban and metropolitan planning processes more practical, routine and information-based. As a result, most of these applications have been within-agency efforts (or bottom-up inter-agency collaborations) without the big budget and top-down mandate that might be needed to acquire new data or build elaborate models (however useful) of land use, transportation and environmental interactions. Promoting urban information infrastructure as a public good is helpful to accumulate useable 'city knowledge' (Carrera and Ferreira 2007). Doing this and tapping the new data streams from 'smart city' efforts, open data initiatives and social media portals are already impacting the quality and usefulness of PSS efforts.

Even as our cities—and our technologies—seem to change rapidly, this volume reminds us of the incremental development of the bodies of knowledge about cities, the urban research toolkit, and PSS applications. In light of the trends we observe, the challenge before us is not only to keep up with the pace of change, but also to develop the knowledge necessary to empower cities to better understand themselves, and in doing so, better direct their collective futures.

References

Arciniegas, G., Janssen, R., Rietveld, P. (2012). Effectiveness of collaborative map-based decision support tools: Results of an experiment. *Environmental Modelling & Software*(0). doi:10.1016/j.envsoft.2012.02.021.

ARUP. (2010). Smart cities: Transforming the 21st century city via the creative use of technology.

Batty, M., Axhausen, K., Fosca, G., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., et al. (2012). Smart cities of the future. *UCL Centre for Advanced Spatial Analysis*, *188*.

Brail, R. K. (2008). *Planning support systems for cities and regions*. Cambridge: Lincoln Institute of Land Policy.

Brail, R. K., & Klosterman, R. E. (2001). *Planning support systems: Integrating geographic information systems, models, and visualization tools*. Redlands, Calif.: ESRI Press.

Burchell, R., Listokin, D., & Galley, C. (2000). Smart growth: More than a ghost of urban policy past, less than a bold new horizon. *Housing Policy Debate, 11*(4), 821–879.

Caragliu, A., Bo, C. Del, & Nijkamp, P. (2011). Smart cities in Europe. *Journal of Urban Technology, 18*(2), 65–82.

Carrera, F., & Ferreira, J. (2007). The future of spatial data infrastructures: Capacity-building for the emergence of municipal SDIs. *International Journal of Spatial Data Infrastructures Research, 2*, 54–73.

Clarke, M. (1990). Geographical information systems and model-based analysis: Towards effective decision support systems. In H. Scholten & J. Stillwell (Eds.), *Geographical information systems for urban and regional planning* (pp. 165–175). Dordrecht: Kluwer.

Daniels, T. (2001). Smart growth: A new American approach to regional planning. *Planning Practice & Research, 16*(3–4), 271–279.

Deakin, M. (Ed.). (2011). Creating smart-er cities [Special issue]. *Journal of Urban Technology*, *18*(2).

Geertman, S. (2006). Potentials for planning support: A planning-conceptual approach. *Environment and Planning B: Planning and Design, 33*(6), 863–881.

Geertman, S., & Stillwell, J. (2003). *Planning support systems in practice*. *Advances in spatial science*. New York: Springer.

Geertman, S., & Stillwell, J. (2009). *Planning support systems; Best practice and new methods*: Vol. 95. *The GeoJournal Library*. New York: Springer.

Geertman, S., Toppen, F., & Stillwell, J. (Eds.). (2013). *Planning support systems for sustainable urban development*. Heidelberg: Springer.

Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanović, N., & Meijers, E. (2007). *Smart cities—Ranking of European medium-sized cities*. Vienna: Centre of Regional Science, Vienna Universitat Technology.

Glasmeier, A., & Christopherson, S. (2015). The smart city [Special issue]. *Cambridge Journal of Regions*, *Economy and Society*, *8*(1).

Goodspeed, R. (2013). Planning support systems for spatial planning through social learning. PhD Thesis. Cambridge, MA: Massachusetts Institute of Technology.

Goodspeed, R. (2015). Smart cities: moving beyond urban cybernetics to tackle wicked problems. *Cambridge Journal of Regions, Economy and Society*, *8*(1), 79–92.

Greenfield, A. (2013). Against the smart city (The city is here for you to use) (pp. 153).

Harris, B., & Batty, M. (1993). Locational models, geographic information and planning support systems. *Journal of Planning Education and Research, 12*(3), 184.

Harrison, C., & Donnelly, I. A. (2011). A theory of smart cities. In Proceedings of the 55th Annual Meeting of the ISSS 2011, Hull, UK.

Hollands, R. G. (2008). Will the real smart city please stand up? *City, 12*(3), 303–320.

Hunt, J. D., Kriger, D. S., & Miller, E. J. (2005). Current operational urban land-use–transport modelling frameworks: A review. *Transport Reviews, 25*(3), 329–376.

Johnston, E. W., & Hansen, D. L. (2011). Design lessons for smart governance infrastructure. In: A. T. Balutis, F. Buss, Ink, D. (Eds.), *Transforming American governance: Rebooting the public square*. National Academy of Public Administration.

Kitchin, R. (2013). The real-time city? Big data and smart urbanism. *GeoJournal, 79*, 1–14.

Klosterman, R. E. (1997). Planning support systems: a new perspective on computer-aided planning. *Journal of Planning Education Research, 17*(1), 45–54.

Lowry, I. S. (1964). A model of metropolis. RM-4035-RC. Santa Monica, CA: Rand Corporation.

March, S. T., & Smith G. F. (1995). Design and natural-science research on information technology. *Decision Support Systems, 15* (4), 251–266.

Neirotti, P., de Marco, A., Corinna, Cagliano, A., Mangano, G., & Scorrano, F. (2014). Current trends in smart city initiatives: Some stylised facts. *Cities, 38*, 25–36.

Pelzer, P., & Geertman, S. (2014). Planning support systems and interdisciplinary learning. *Planning Theory & Practice, 15*(4), 1–16.

Te Brommelstroet, M. (2013, September). Performance of planning support systems: What is it, and how do we report on it? *Computers*, *Environment and Urban Systems*, *41*, 299–308.

Townsend, A. M. (2013). *Smart cities: Big data, civic hackers, and the quest for a new Utopia*. New York: W.W. Norton & Company.

Vonk, G. A. (2006). Improving planning support. The use of planning support systems for spatial planning. Ph.D. thesis, Netherlands Geographical Studies 340. Utrecht: Koninklijk Nederlands Aardrijkskundig Genootschap, Faculteit Geowetenschappen Universiteit Utrecht.

Vonk, G., Geertman, S., & Schot, P. (2005). Bottlenecks blocking widespread usage of planning support systems. *Environment and Planning A, 37*(5), 909–924.

Washburn, D., & Sindhu, U. (2010). Helping CIOs understand "smart city" Initiatives: Forrester Research.

Wegener, M. (2004). Overview of land-use transportation models. In D. A. Hensher & K. Button (Eds.), *Transport geography and spatial systems. Handbook 5 of the handbook in transport* (pp. 127–146). Kidlington: Pergamon/Elsevier Science.