1. Planning support science: challenges, themes and applications

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1. INTRODUCTION

This *Handbook of Planning Support Science* aims to present new and innovative contributions by key players in the field of planning and decision support systems, with particular attention being paid to applications in different countries around the world. The main reason currently underlying this work is that there has never been a more important time for community citizens, planners and policy-makers to work more closely with researchers and to access new streams of data and utilize evolving information and communication technologies (ICT) to address the pressing issues facing the cities in which we choose to live in increasing numbers and their surrounding hinterlands.

The world is changing rapidly and the context in which planners and policy-makers have to operate is evolving across a range of physical-environmental and socio-economic systems and at a number of different spatial scales. Large-scale or global trends have been identified by various international organizations including the United Nations (UN 2014; 2016), the Organisation for Economic Co-operation and Development (OECD 2016) and the US National Intelligence Council (2017). These mega-trends include: global population growth (from 7.4 billion in 2015 to 8.5 billion by 2030 and 9.7 billion by 2050); increasing demand for resources (for example, water, energy, food and consumption goods); globalization; greater poverty and inequality between rich and poor; impacts of increased demand that result in climate change (for example, emissions of greenhouse gases) and environmental degradation (for example, soil degradation, loss of biodiversity and species diversity and increases in pollutants such as plastic); and global health crises (for example, obesity pandemic and associated diseases such as type II diabetes as well as famine and undernourishment).

Governments have to contend with the consequences of factors such as demographic restructuring through ageing and/or migration (both internal and international), increasing numbers of people living in slums or conditions of multiple deprivation, declining air quality and increasing traffic congestion at a time when government debt is increasing significantly (resulting in severe austerity measures in some countries) and when governing is getting harder owing to the complexity of the driving forces that increasingly result in black swans, that is, highly consequential but unlikely events that are easily explainable – but only in retrospect (Taleb 2007), such as the attacks on the USA on 11 September 2001 (9/11), the global financial crisis, migration into the European Union or freak weather conditions. While the identification and analysis of past mega-trends is critical, it is also important to look forward, to contemplate what the future will look like and to estimate the risks that arise under different conditions. The potential for risks to occur owing to the interaction of drivers and events has been

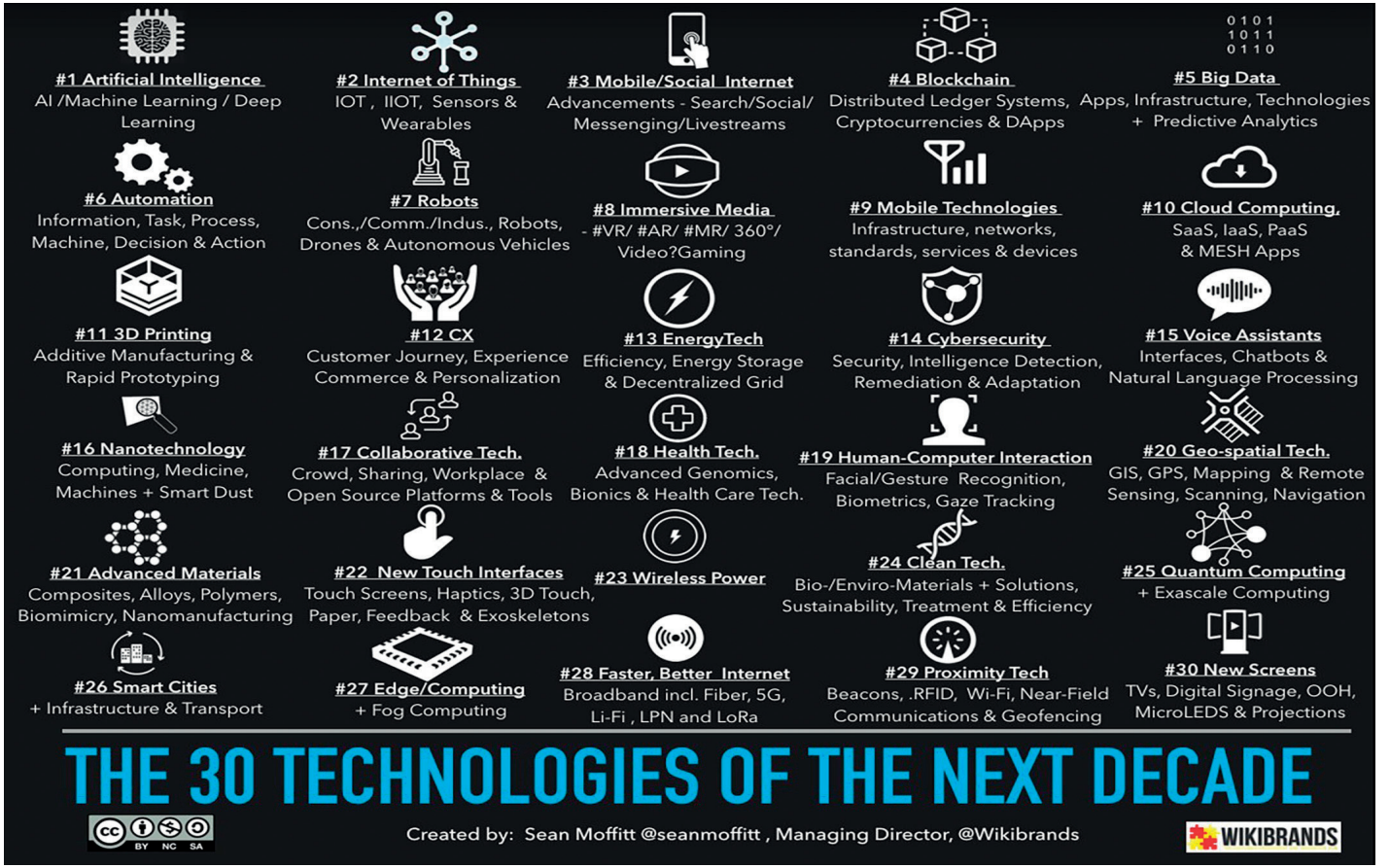
summarized in the World Economic Forum's (WEF's) annual global risks report (WEF 2018).

These major global challenges, together with the changes that are evident in people's behaviour (for example, more people working from home) and attitudes (for example, distrust of politicians) sit alongside the more routine requirements to produce solutions to physical, economic and social problems associated with urban and regional development and the drive towards more sustainable environments. Envisioning the impact of alternative scenarios at an urban or regional level is an activity that has traditionally fallen under the remit of planning support systems (PSS[1]), particularly in the field of land-use planning. However, PSS are also applicable for a variety of other tasks at different stages in the planning process, including the analysis of problems and the routine monitoring of indicators of development or development control. In the latter, many local authorities now have online systems to support routine planning activities as well as the delivery of basic services. One example is the planning explorer used by Barnsley Council, a metropolitan local authority in the north of England, whose mapping interface, which is open for anyone to observe the locations of planning applications across the district, can be viewed at https://www.barnsley.gov.uk/barnsley-maps/planning-explorer/ (accessed 8 September 2019).

There is strong consensus across the literature on mega-trends about the power of modern computer technologies to be the enabling agent that planners and policy-makers can utilize to effect transformation. Several encouraging signs have emerged in this current era of digitization, big data and smart cities, indicating that new ICT and data-driven approaches (data science and informatics) may be brought to bear to support researchers and practitioners in confronting some of the grand challenges as well as the routine tasks, many of which might be undertaken more effectively. Particularly important for PSS among the 30 technologies likely to have most impact on culture, the marketplace and society over the next decade (Moffitt 2018), and summarized in Figure 1.1, are artificial intelligence, the Internet of things, collaborative technologies, cloud computing, geospatial technologies, big data and smart cities, all of which are mentioned in several of the chapters in this *Handbook*. Digital technologies such as these are increasingly enabling new ways of living, working and communicating in society, as well as providing the mechanisms through which greater knowledge and understanding of human systems such as cities can be analysed, monitored and simulated. The potential benefits arising from technological developments are substantial but there is also the real possibility of regulatory and social problems, such as enhanced security risk, including the potential misuse of personal data, as exemplified by the recent accusations that Cambridge Analytica and Facebook used data about individuals to influence democratic elections.

At the core of PSS are computer-automated tools which can assist planners to more effectively undertake their day-to-day professional jobs. In the broadest sense, they are tools which add value to the planner's work processes and include components such as spreadsheets, websites, geographical information systems (GIS), visualization methods and modelling systems (Couclelis 2005). There are numerous definitions of PSS available in the literature (see, for example, Batty 1995; Geertman 2006; Klosterman 1997). While

[1] Throughout this *Handbook*, acronyms are used as both singular and plural.



Source: Adapted from Moffitt (2018).

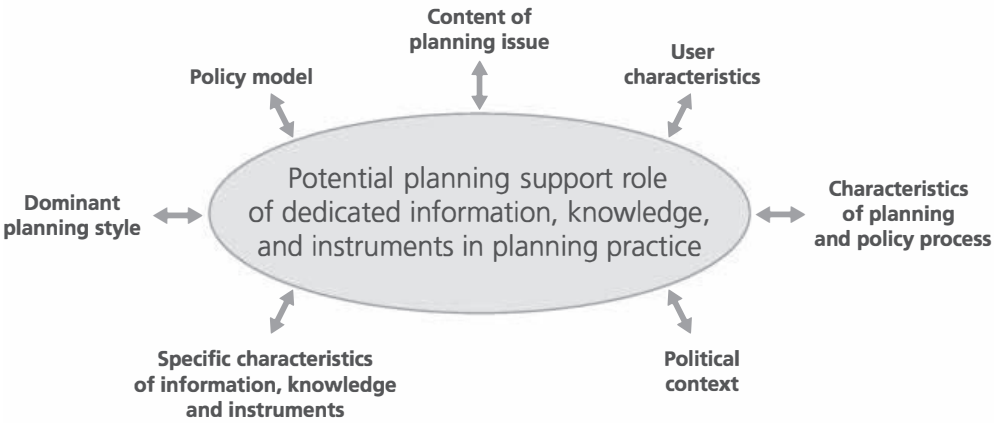
Figure 1.1 Emerging technologies that may influence the next decade

definitions vary, the common thread in each case is that PSS are computer-based tools that can be used to support planners in undertaking planning-specific activities.

Planning support systems came into being in the late 1980s, as described by Harris and Batty (1993). They arose through a convergence of efforts being undertaken in the areas of GIS, large-scale urban models and decision support systems (DSS). Planning support systems were in some ways a response to the backlash from planners and policy-makers to the top-down, black-box models which were being run to optimize city development. This is resoundingly articulated in Lee's famous 'Requiem for large-scale urban models' (Lee 1973). Planning support systems are those tools that *support* planning activities, not *replace* planners in undertaking strategic planning and other activities. This is an important distinction from the black-box, land-use and transport interaction (LUTI) models developed in the 1970s, some of which are still used today to optimize planning outcomes through a series of mathematical equations. In the 1990s, a number of PSS were developed which enabled planners to interact and use these tools themselves through graphical user interfaces (GUIs). Planners could change parameters through the use of slider bars and other means, and explore the likely implications of these changes through map visualization, bar charts, and so on. Thus planners could begin to explore 'what if?' urban scenarios; for example, *what* would happen to commuting flows *if* the economically active and employed population increased for a defined urban geography by 3 per cent per annum instead of 1.5 per cent?

Early PSS included systems for modelling land use such as What if? (Klosterman 1999) and UrbanSim (Waddell 2002), systems for measuring conditions and change such as INDEX (Allen 2001, 2008), and systems for encouraging community participation such as CommunityViz (Kwartler and Bernard 2001). Several of these PSS, and others, have stood the test of time and, in their various incarnations, are still used in planning practice 20 years later, such as the open source online version of What if? (Pettit et al. 2013, 2015a) and the cloud-based UrbanSim. There has also been increasing attention to improving the user experience for planners interacting with PSS through studies and experiments undertaken with more engaging interfaces such as map tables (Arciniegas et al. 2013) and the beginning of empirically driven PSS user studies (Russo et al. 2015).

However, as Vonk et al. (2005) and others have noted, including several of the contributors to this *Handbook*, the implementation of PSS has not been without its own challenges, with the adoption in practice not being as widespread as the PSS developer community might have hoped for, resulting in the PSS implementation gap (Geertman 2017; Geertman and Stillwell 2003). This entails planners and decision-makers needing more or better support from planning instruments to be able to cope with the ever-increasing complexity of current real-world planning problems; PSS instruments are required that utilize technologies which are becoming increasingly more widespread in their availability but which have not yet been recognized as being useful in planning practice. The emergence of digitization, big data, smart cities and the opening of government data repositories have all created new opportunities for PSS to embrace this shift towards the digital paradigm and increase their visibility and uptake as geo-information toolkits which can support a number of urban and rural planning tasks at national, regional and local scales. It is owing to this much widened perspective on PSS that we prefer to refer to the emerging scientific field of planning support science with an emphasis on the *goals of support* instead of focusing just on the system-side of PSS, the *means of support* (Geertman 2013).



Source: Geertman (2006).

Figure 1.2 Contextual factors influencing the support role of information, knowledge and PSS in practice

In planning support science, it is envisaged that research, education and practice work together cooperatively to attain mutual goals and cooperate to bring support for practitioners a step closer to reality. Thus, PSS developed in the computer laboratories, frequently by individual or small teams of academic researchers, need to be adapted to the specifics of planning practice, to the intended application and to the context of that application. This adaptation, the intended needs and context of the application and its associated context-sensitive methodology have become a field of research in its own right (Geertman 2006, 2013). Of particular relevance therein is an agenda that calls for context-sensitive PSS research which pays more explicit attention to the influence of contextual factors on the support role of PSS in specific planning processes (Figure 1.2).

A range of specified factors – which have mutual interactions – influence the support role of PSS. This was revealed at a PSS workshop in Utrecht in 2015 with a diversity of participants, some of whom were very happy with the analytical and visualization utilities offered by the available PSS, while others felt hugely restricted in their possibilities to express their creativity by that same PSS, owing – in their view – to its very restricted design utilities. It is therefore not coincidental that several of these contextual factors are also expressed in the distinctive parts into which the chapters in this *Handbook* have been grouped. For instance, the factors described in Figure 1.2 as 'policy model', 'dominant planning style', 'characteristics of planning and policy process', 'political context' and 'user characteristics' are all associated with Part IV on participation and engagement. Likewise, the factor termed 'specific characteristics of information, knowledge and instruments' is linked to the Parts I–III on data, methods and smart cities respectively, while the factor referred to in Figure 1.2 as 'content of planning issue' is associated with the Parts V and VI on land-use, transportation and sectoral planning.

Similarly, distinctive chapters in this *Handbook* illustrate the value of each of these

factors. For instance, in several of the chapters there are expressions of factors influencing the supportive role of PSS in planning practice, such as the political context (for example, Chapter 15), the content of planning issue (for example, Chapter 33), characteristics of the planning and policy context (for example, Chapter 12), the policy model (for example, Chapter 16), user characteristics (for example, Chapter 18), the dominant planning style (for example, Chapter 17) or specific characteristics of information, knowledge and instruments (for example, Chapter 20). More explicit attention to these factors is considered a first step to overcome the PSS implementation gap and to make sure that PSS application in planning practice will become more in accordance with our expectations.

In addition to explicit attention to methodological and application-orientated contextual factors, we can identify that PSS are increasingly embedded in digital data infrastructures which form an integrated whole, such as in the case of the Australian Urban Research Infrastructure Network (AURIN), an online workbench which provides access to a large number of data sets, a range of spatial statistical tools and a constellation of PSS (Pettit et al. 2015b, 2017; Chapter 4 in this volume). In addition, we can acknowledge that the emerging concept of the smart city has tended to blur the distinctions between systems, tools, instruments, apps, social media, big data, and so on, that by itself can fulfil an ICT-based supporting role in planning practice. It is for these reasons too, that we prefer to use the term planning support science. We have also seen the rise of a new science of cities (Batty 2013) and big data and data science as applied in the context of shaping cities (Thakuriah et al. 2017). The intersection of planning support science, city or urban science and data science is offering exciting new possibilities in data driven approaches to city planning. However, within planning support science, we still consider that Dick Klosterman's (1997) argument – made more than 20 years ago – that technology is not the problem but that the appropriate role for planning technology must begin with a conception of planning, still holds true. Planning support should start from the peculiarities of the planning activity, and not from characteristics of the technology. This will help to overcome what was expressed by the godfather of PSS more than 20 years ago as '[p]lanners and designers, in 1970 and to an extent today [1998], have generally been antagonistic toward highly systematic and computer-based methods, or at least distrustful of them' (Harris 1998, p. 24).

In this *Handbook*, our intention has been to take the reader on a journey through the world of planning support science as it applies at the beginning of the third decade of the twenty-first century, a journey which seamlessly flows into the world of smart urban futures where big data, city analytics and visualization approaches to real-time information provided through open data feeds and social media are becoming increasingly common. The chapters in this volume discuss a combination of innovative PSS methods, techniques and case studies which can arm the next generation of planners with the ability to tackle both global and local challenges head on and endeavour to make our cities and regions more sustainable, productive and resilient.

In the remainder of this chapter we introduce the reader to the structure of the *Handbook* and to the content of the contributions. The chapters have been grouped into six parts, beginning in Part I with a series of three chapters on one of the key themes in contemporary data science, the integration of data from different sources, in many cases to create new information. While data linkage frequently involves some form of modelling, Part II of the *Handbook* contains six chapters that have a clear methodological

focus. Part III contains six chapters that examine the relationship between PSS and smart cities, while Part IV is devoted to participation and engagement. There are eight chapters on this theme, demonstrating the importance of the attempts being made to bridge the implementation gap through collaboration between the stakeholders, planners and PSS experts involved. The focus shifts to a series of case studies of the more traditional land-use and transportation PSS in Part V and of a range of applications in different private and public sectors (including retail, education, housing and rural areas) in Part VI. The six parts of the *Handbook* are introduced in turn, after which each of the associated chapters is briefly summarized.

2. DATA INTEGRATION AND LINKAGE

In Part I, 'Data integration and linkage', the chapters elaborate on one of the trends mentioned in the introduction to this chapter, that is, the rise of big data and data science as applied in the context of planning cities (Thakuriah et al. 2017). In the literature and in several chapters in this *Handbook*, authors have identified the three Vs that characterize big data – velocity, variety and volume – although some have added two others, veracity and value, which refer, respectively, to the quality of data being uncertain and that data can be valorized. It is clear that the current big-data environment enables detailed analysis of complex real-life processes owing to the availability of enormous amounts of up-to-date data and the associated analytical tools to cope with these data. Thus, data linkage plays an increasingly important role in relation to digital data infrastructures. As described in the first chapter in Part I, linking together data from social media, web-browsing behaviour and loyalty card transaction patterns helps to identify insightful patterns of consumption and sales opportunities for retailers. Many more examples of these data linkages can be given and are provided in the forthcoming chapters, not only in Part I. It is in the large-scale availability of big data and the increasing possibilities of linking these data in digital data infrastructures in which data analytics, spatial informatics and PSS are integrated, that planning and decision support is entering a new and exciting era of application possibilities.

In the first chapter of Part I (Chapter 2) entitled 'Data linkage and its applications for planning support systems', Mark Birkin, William James, Nik Lomax and Andrew Smith explore the ways in which multiple data sources may be linked using spatial microsimulation modelling for dealing with complex future-orientated questions. They demonstrate how such an integrated framework can provide a platform for next-generation PSS, as exemplified through two case studies in the UK, one on population projections for infrastructure modelling and the other on consumer demand forecasts. They conclude that there are many potential avenues for future directions of data linkage, which range from the improvement of implementation and calibration of models to extending to new and exciting application domains. Furthermore, the authors address some associated important issues, notably around privacy and public trust, in making new data available for planning purposes.

In Chapter 3, Elisabete A. Silva, Lun Liu, Heeseo Rain Kwon, Haifeng Niu and Yiqiao Chen identify the emergence of a new data science which investigates how new data collections and analysis methods contribute to solving real-world problems. This

is characterized by a mixed-methods approach of integrated hard-physical, quantitative analysis and soft-aspatial, qualitative approaches. Emphasis is put on a range of associated topics, such as data availability, collection methods, linked soft- and hard-data applications, data harvesting, mining and calibration, and the role of behavioural theories in supporting new learning algorithms. The authors conclude that the new data science provides immense opportunities for urban computation and modelling, although for urban planning support, several challenges lie ahead, such as including the wider geographic, socio-economic and political contexts for planning.

In the final chapter of Part I (Chapter 4), Christopher Pettit, Bob Stimson, Jack Barton, Xavier Goldie, Phillip Greenwood, Robin Lovelace and Serryn Eagleson discuss three parallel and mutually reinforcing drivers of change in the field of GIS: open access data, open source software and cloud computing. They explore these drivers with the help of the Australian Urban Research Infrastructure Network (AURIN), an online, cloud-based data portal and GIS, containing data of various types assembled from a wide variety of different sources. They conclude that the drivers offer users great advantages, such as increased accessibility, transparency and consistency, but may also involve some risks associated with the potential benefits to society. The authors raise the provocative question relating to PSS implementation: should international organizations such as the United Nations invest in a global AURIN?

3. METHODS FOR SPATIAL PLANNING

Following the theme of data integration in the previous section, Part II focuses more specifically on the methods that planners can use for support in performing their complex tasks and, here again, integration is a major focus. There have been distinctive times when planning has been dominated primarily by methods from either end of a spectrum ranging from purely qualitative methods, such as social discourse analysis, through to purely quantitative methods, such as mathematical modelling. For years, believers and nonbelievers in one or other approach have sought supremacy. Currently it seems that, with the increase in the diversity of data sources (for example, social media and sensor technologies) and the availability of large quantities of diverse data (for example, real time and online registers), mixed methods approaches are gaining substantial ground in planning. The era of big data is offering us new data together with new methods of querying, filtering and analysing the data in almost real time. Also, social media are transforming the ways in which we communicate and obtain information and this phenomenon, without doubt, will become more important within planning too. An important example of such a mixed-method approach in planning is the upcoming field of geodesign. Therein, both modelling exercises (quantitative), such as that adopted for forecasting future trends, and deliberative design approaches (qualitative), such as that used for developing future spatial scenarios, are combined to contribute to worthwhile outcomes. The integration of methods is, relatively speaking, still in its infancy, and experimentation seems to be the most logical approach to find out the most exciting and fruitful ways to proceed.

In the first chapter of Part II, Michele Campagna introduces geodesign as a fairly new, although quickly establishing, approach to address complex urban developments. After an introduction to its history and background, Chapter 5 contains a review of the

main technologies for geodesign support and their coupling in PSS. In the final section, the author asks what it is that geodesign and its enabling technologies can contribute to planning practice, and concludes that they provide opportunities to bring innovation into current spatial planning practice and to address some of the most critical parts of the design process, the effective link between knowledge-building, design creation and decision-making. In so doing, geodesign will pave the way towards a new generation of technology integration for planning support.

Chapter 6 by Tianyu Su, Shihui Li, Jing Li, Hungyu Chou and Ying Long also fits with the ideas of a stronger design orientation within planning. The authors introduce a new quantitative methodology for urban planning and design called data-augmented design (DAD) and explain two key toolkits used in DAD research: existing condition analysis and spatial parameter extraction. By applying these to a planning problem in the Panyu-Xinhua Area in Shanghai, the effectiveness of the approach is assessed. In their conclusion, the authors foresee that urban planners, officers and citizens can all benefit from the application of DAD, in particular in the fields of planning and design support, future estimation and public participation.

A different way of looking at the linkage between PSS and geodesign is presented by Yexuan Gu and Brian Deal in Chapter 7 entitled 'Geodesign, resilience and planning support systems: the integration of process and technology'. Therein, to overcome the PSS implementation gap, they propose a generic procedural framework for integrating PSS technologies into the geodesign process. The framework is designed to stimulate a variety of organizations, stakeholders and community residents to collaborate and arrive at more resilient outcomes. This is tested in a case-study application in Sangamon County, Illinois. Based on their experiences, the authors conclude that the proposed framework enhances the usefulness of the PSS and improves the overall credibility of the design process. Finally, they acknowledge that the transferability of the framework across different contexts is the most challenging issue for future research.

Subhrajit Guhathakurta, Ge Zhang and Bon Woo Koo take a different methodological stance in Chapter 8, 'Spatial modelling and forecasting'. They start from the finding that despite the overflow of spatial data availability owing to growing numbers of sensors, the application of methods of modelling and forecasting in spatial planning lags far behind sectors such as agriculture, retail and transportation. The authors discuss the evolving approaches to spatial modelling and forecasting, for example, machine-learning based techniques that can be applied to support spatial planning. The new data sources and specialized methods will offer us many opportunities in planning. In the meantime, the authors conclude by warning us about the dangers of blind belief in automated systems in that only systems with human-in-the-loop oversight mechanisms, together with increased engagement from stakeholders, can both offer the benefits of new technologies and avoid their pitfalls.

Related to the previous chapter, Michael Wegener asks the question in Chapter 9: 'Are urban land-use transport interaction models planning support systems?' These land-use interaction (LUTI) models integrate many (spatial) developments to anticipate spatial scenarios under certain policy assumptions. Despite their potential role for better understanding and communicating the long-term future of cities, these models are typically highly complex and require large data sets and long computing times which reduces their role as planning support tools. The author concludes that for LUTI models to be able

to be called a PSS – calculating the impacts of planning policies, for example – certain conditions will have to be fulfilled, in particular the possibility of generating real-time outcomes within extremely short computing times so that the results can be generated in planning meetings.

In Chapter 10, the last in Part II, Claire Daniel focuses specifically on methods and associated technologies for monitoring planning policies. She starts by acknowledging that, in practice, ongoing monitoring and post-implementation evaluation of planning policies have been largely neglected, despite their value for improving planning decisions. Nevertheless, recent improvements in GIS, artificial intelligence and image recognition offer many possibilities for monitoring spatial developments in a relatively automated way. Based on practices in Australia, the USA and the UK, she concludes that there is still a lot of work to be done, including the development of data standards and mechanisms to encourage open source and collaborative development of software tools.

4. PSS AND THE SMART CITY CONCEPT

In following on from Parts I and II on data and methods, respectively, Part III of the *Handbook* involves a set of chapters that expound on how these new data and methods contribute to arrive at smarter cities and the role envisioned for PSS in that transition. A smart city is, by definition, an urban area where different types of electronic data sensors are used to generate information that can thereafter be used to manage resources more efficiently. Big data play a substantial role in the development of smart cities. For instance, mobile phone data or transit smart-card data can capture the spatial–temporal movements of people in a city and thereby enable improved public transport provision. Moreover, data analytics and data-driven approaches are needed to model, analyse and visualize these big data to ensure accurate interpretation of the spatial–temporal behaviour of citizens. It is in this complementarity that we foresee PSS being able to make a significant contribution. We do not comply with the meaning of smart city as a neoliberal technology-driven city, fully captured by large corporations. For us, a smart city is a socio-technological entity, in which human capital in its broadest sense is collaborating with the help of technologies to achieve more sustainable and resilient urban futures for everyone.

In Chapter 11, the first of Part III, Anthony G.O. Yeh, Yang Yue, Xingang Zhou and Qi-Li Gao address the question of how to plan a smart city effectively. In deriving an answer, they review how different types of big data are captured and, using data analytics, how they are pre-processed, analysed and applied to advance our knowledge. By presenting some case studies, including the job–housing balance and segregation, they show the importance of evaluating the space–time behaviours of people and conclude that with a better understanding of the space–time dynamics of social groups, planners and decision-makers will become able to estimate how certain decisions might positively or negatively affect people. Thus, big data and data analytics will make it easier for planners and decision-makers to explain their decisions. However, some unresolved issues must be tackled, such as privacy concerns, validation and representativeness.

In Chapter 12, 'Planning support systems and science beyond the smart city', Zhibin Zheng and Renée Sieber continue the discussion of the contribution of big data and data analytics for planning, but take a different stance by comparing these with PSS

developments. The authors detect both potential commonalities as well as divergences between PSS and smart cities. The issue they explore is whether the common elements are sufficient, or the divergences are too big, to integrate PSS and the smart city. The authors detect some potential challenges in the adaptation of PSS related to concepts of technocracy and opacity, digital divides, wicked problems and the role of civic participation. They conclude that the integration of PSS and the smart city is bidirectional; technocratic and data-driven approaches should not supplant communicative and democratic methods in urban planning.

Chapter 13 is one of several chapters in this section that have a particular country focus. The authors, Shifu Wang, Zhaohua Deng, Zheng Liu, Nannan Zhao, Xiaoyang Zhang and Jie Liu, extend the debate concerning the relationship between smart-city developments and PSS by focusing specifically on three stages of Chinese planning: urban plan preparation, the adoption of urban plans and plan implementation. By analysing distinctive case studies of urban development projects in Guangzhou, the authors tease out the impact of PSS. It appears that PSS is applied more successfully in the phase of plan preparation than in the implementation stage. In particular, the lack of community-based support systems is envisioned to hinder the engagement of the general public in plan implementation. The authors conclude that PSS in China is in need of more attention in the plan implementation stage, preferably with more collaborative efforts.

In Chapter 14, 'Smart governance in the making: integrating "smart" in local spatial planning', Patrick Witte, Eline Punt and Stan Geertman take a similar perspective to that of the previous contribution. They ask themselves how technologies associated with the notion of smart governance – as a sub-domain of a smart city – are working out in practice in the Netherlands. More precisely, they investigate the willingness and ability of Dutch municipalities to implement smart-governance applications in their local context. Based on their empirical research, the authors discover that municipalities in the Netherlands are using a large variety of smart-governance applications, notably to enhance their smart policy-making and improve internal organization. However, what are still missing are examples of smart governance for smarter administration and, in particular, for smarter urban collaboration (triple/quadruple helix).

Chapter 15, by Zsuzsanna Tomor and Stan Geertman, concentrates on one of the central issues identified in the two previous contributions, that is, the influence of political context in shaping the roles of technologies in planning practice. The authors' starting point, based on an extensive literature review, is that in the planning support science discourse, minimal attention is paid to the influence of contextual factors on the role of technology. Consequently, the authors start investigating the influence of the political context on smart-city initiatives in three distinctive geopolitical contexts: Glasgow in Scotland, Utrecht in the Netherlands and Curitiba in Brazil. Based on this comparative analysis, they conclude that political contextual factors play a prominent role in influencing smart-governance initiatives, although for a more precise answer a longer research timespan is needed.

The final chapter in Part III is also country specific. Chapter 16 has been written by Ciro Biderman and Daniela Coimbra Swiatek, and is titled 'Challenging the conventional wisdom: the case of MobiLab, São Paulo, Brazil'. Here, the notion of political context and its influence on the role of technology in planning practice is taken to a very detailed level for one specific metropolitan area, São Paulo in Brazil. The authors describe the

processes that underpinned the creation and operation of MobiLab – the São Paulo City Laboratory for Mobility Innovation. The laboratory was launched in an environment of old management forms, lack of ICT systems and social-political turmoil to find new ways for improving urban mobility in a congested city. After its first successes, MobiLab struggled with declining results, when a new mayor started his mandate. The authors conclude that the achievements were dependent strongly on political support, denoting that technological innovation is impossible without robust political backing by appropriate smart-governance structures.

5. PARTICIPATION AND ENGAGEMENT IN PLANNING

In Part IV, each of the contributions has participation and engagement at its core. From a planning theory perspective, public participation in urban planning is associated with communicative rationality, which was gradually developed by Jürgen Habermas (1984, 1987) to reformulate modernity's concept of reason, named instrumental rationality. Planning guided by instrumental rationality refers to the harnessing of social scientific knowledge and the techniques to manage the collective affairs of urban planning. In doing this, technical experts are considered to be the best qualified decision-makers. However, from the premise that planning involves a trade-off between multiple value dimensions, communicative rationality is at the core of planning activity. Planning guided by communicative rationality stresses the involvement of various stakeholders directly affected by the plan, whose positions are almost mutually interdependent in the negotiation process to build a consensus on planning issues (Healey 1996). Early timing of participation has been emphasized generally, since it enables the effective use of knowledge but also supports the acceptability of the plans by fostering trust among participants (Innes and Booher 2004). Nevertheless, the scientific literature – including the chapters that follow – show an enduring discourse on the possibilities and restrictions, likewise on the pros and cons, of participatory/collaborative planning (for example, see Roy 2015) and, in the slipstream, the potentials of ICT in general and of PSS in particular.

In the first chapter of Part IV, Chapter 17, Scott N. Lieske tackles the PSS implementation gap by investigating a range of distinctive, mostly participatory and/or collaborative, PSS use cases. Based on his review, he concludes that there is nothing wrong with the utility of most publicly available commercial and open source PSS, which are shown to be consistently useful for data integration, values integration, collaborative planning, scenario development, impact analysis, suitability analysis and, to a lesser extent, three-dimensional visualization. The associated PSS benefits include increasing public and stakeholder involvement, facilitating group communication, information and process transparency, as well as learning and knowledge development. In contrast, the author indicates a number of societal trends that are antithetical to effective and impactful PSS implementation in planning practice; in particular, the change in planning from managerialism to entrepreneurialism that prevents effective implementation of PSS in planning practice is highlighted.

In Chapter 18, 'Limitations and potential of planning support systems application in planning in southern Spain: bridging academia and practice' the authors, Irene Luque-Martín and Karin Pfeffer continue with the theme of the PSS implementation gap but

take a different stance. They acknowledge a range of challenges in contemporary planning practice – transdisciplinary approach, temporal factor, situated context and process phasing – and elaborate on how these could be addressed by means of PSS. Furthermore, they explore the usability of PSS in a planning culture in southern Spain that lacks a collaborative approach. Based on their investigation, they conclude that PSS can play an important role, not so much as products to be developed but as facilitators of current processes of planning practice. A key message is that academics and practitioners should join together in testing and researching the development and application of different PSS components to realize the desired outcomes of planning practices.

The Dutch energy sector provides the context for Chapter 19, in which Johannes Flacke, Cheryl de Boer, Frans van den Bosch and Karin Pfeffer demonstrate how the PSS implementation gap can be overcome by improving the usefulness of PSS. Various case studies reveal an increasing usefulness of PSS, when designed as an interactive system implemented on a map table. They suggest that most studies using these interactive PSS and evaluating their usefulness have merely involved planning practitioners, that is, professional stakeholders possessing domain or expert knowledge of the case at hand. In contrast, the authors have involved lay persons, ordinary citizens, in their workshops on the energy transition in the Netherlands, and conclude that, in addition to other aspects such as user-friendliness and contextual factors, one of the most necessary aspects for proper citizen participation is to build trust among participants from the very beginning of the process.

'Participatory urban planning in the digital era' is the title of Chapter 20, in which Aija Staffans, Maarit Kahila-Tani and Marketta Kyttä begin with the general statement that participation processes are often ineffective for planners, residents and other actor groups. In contrast to other chapters in this part, the authors approach the planning process as a flow of communicative actions where the knowledge needs and modes of working go hand in hand, sometimes opening up the process to large-scale participation and at other times closing down the process to an intensive collaboration among smaller groups. By applying this model approach to public participation geographic information system (PPGIS) tools and collaboration arenas for the Helsinki City Plan process, they show a variety of advantages and disadvantages in the use made of the digital participation tools, and conclude that more attention should be placed on the link between produced knowledge in the public participation process and the content and solutions of the resulting plans.

While Chapter 20 involves participation in the planning of Finland's capital city, Chapter 21, by Richard Kingston and Vasileios Vlastaras entails the development of an online PSS to support participation in planning at the neighbourhood scale in the UK. The online PSS that the authors have developed aims to support communities to overcome the difficulties they face in mobilizing technical and planning expertise, in particular to meet the legal requirements to produce the evidence base for the neighbourhood plan. Thus, the system contains utilities to support baseline analysis, participatory mapping and functions for monitoring and evaluation. The PSS has been developed for a small village community in Bootle, Cumbria, and the authors outline the pros and cons of the system as well as the lessons learnt and the future improvements envisaged. Their experience suggests that many of the challenges around user engagement still persist today, just as they did 20 years ago when they first started this type of participatory planning supportive research.

The next two chapters focus on the structure and role of PSS workshops. First, in Chapter 22, Robert Goodspeed and Peter Pelzer explain the importance of the workshop setting in the application of PSS in collaborative planning practice. They conceive of workshops as socio-technical settings in which the characteristics of PSS instruments are mediated by different factors, such as group dynamics, facilitation and tool involvement by participants. Two reasons underline the importance associated with the topic of PSS workshops. Together with the communicative turn in planning, workshops as collaborative settings where dialogue occurs are central to planning practice. Moreover, empirical studies show that the way a workshop is organized has a critical effect on stakeholders' experience and the process of coming to a decision. This is illustrated by two PSS workshops, one with Envision Tomorrow in the USA and one with Urban Strategy in the Netherlands. The authors conclude with a critical reflection on the role of academic research in initiating and evaluating PSS workshops.

Second, in Chapter 23, Ron Janssen describes some collaborative workshops in Mozambique that were supported by a geodesign tool that was used to draw value maps on a touch screen. A value map combines value judgements from stakeholders with spatial attributes of the planning area. In the workshop that Janssen describes, the process of defining and entering attribute scores resulted in active participation and a feeling of joint ownership of the results. Feedback from the participants showed that the graphic interface was appealing and the absence of a quantitative model was not experienced as a problem. The author's experience in this context leads him to believe that the Mozambique workshops were remarkably similar to workshops held previously in the Netherlands and the UK; in all the workshops there was a strong sense of cooperation and there was little difference in the way participants used the geodesign tool.

The final chapter in Part IV provides evidence from two other countries about the adoption of PSS and e-planning. Walter Musakwa and Thembani Moyo reflect on the changes in planning and planning support that have taken place in South Africa and Zimbabwe. The authors explore the application of technologies such as PSS, e-planning tools, social media, smartphones and big data in four southern African cities, suggesting that there is a great deal of potential to involve citizens in the planning process by using e-planning mechanisms. However, there is limited usage of PSS in three of the metropolitan municipalities which are the case studies in their analysis. Challenges such as the lack of training and resources, organizational culture and quality of education for planners have inhibited the widespread uptake of PSS technologies. Nevertheless, the authors are optimistic about the future, given the increased penetration of smartphones as well as the fast-growing Internet access and the eagerness of young population in both countries to adopt these new technologies.

6. SUPPORT SYSTEMS FOR LAND-USE AND TRANSPORTATION PLANNING

Part V contains chapters on one of the most prominent and long-standing application fields of planning support systems, that of land-use and transportation planning. Although this field of application will be familiar to most readers, as a means of introduction, we offer a citation which accurately expresses the core of the field:

> Land-use planning is a hopelessly complex human endeavour. It involves actions taken by some to affect the use of land controlled by others, following decisions taken by third parties based on values not shared by all concerned, regarding issues no one fully comprehends, in an attempt to guide events and processes that very likely will not unfold in the time, place, and manner anticipated. (Couclelis 2005, p. 1355)

Based on this complexity, we can easily understand that land-use and transportation planning can use all the help it can get from the broadest possible spectrum of academic fields, both in the natural and the social sciences and in humanities, including supporting fields such as urban modelling and PSS. In the chapters of Part V, this complexity and the integrating nature of its supporting needs are exemplified.

In Chapter 25, Jip Claassens, Eric Koomen and Bart Rijken outline their recent modelling efforts undertaken to support spatial planning at a time of climate change. This requires a thorough understanding of both the socio-economic and the physical dynamics that shape the land-use system and requires an integrated modelling approach using the Land Use Scanner PSS. The authors use their experience to identify several lessons learnt that are related to credibility, transparency, spatial resolution, flexibility and simplicity. They believe that by taking these lessons seriously into account, the gaps between the art of modelling and the practice of land-use planning can be overcome.

A different modelling approach for support of land-use planning is proposed by Xia Li and Anthony G.O. Yeh in Chapter 26, 'Cellular automata modelling for urban planning in fast-growth regions', in which they summarize the main advantages and applications of modelling based on the principle of cellular automata (CA). The authors have developed a unified framework of various CA models, agent-based models (ABM) and swarm intelligence models (SIM), named geographical simulation and optimization systems (GeoSOS). They apply this framework to address a wide spectrum of environmental and resource management issues, such as the zoning of basic farmland protection areas, the coupling of land-use dynamics with facility siting, and the delineation of urban growth boundaries. Based on these applications, the authors conclude that CA modelling is a useful tool for urban researchers and planners to solve a series of simulation and planning problems in fast-growing regions, not least because of their flexibility and simplicity.

In Chapter 27, Paul Waddell, Edward Janowicz, Samuel Blanchard and Samuel Maurer present UrbanCanvas, a cloud-based PSS platform in which planning organizations, cities, counties and citizens can participate more effectively in informed, evidence-based planning. The platform consists of regionally shared data and cloud-based analytics for the planning of infrastructures and urban developments at diverse scales. The main purpose of such a platform is to provide participants in scenario planning processes with tools that will inform them about how plans and markets interact in the real world. The platform has already been tested in a diversity of contexts in northern America, Europe and Africa, providing insights into contextual diversities and ways to generalize the approach. The authors express the hopes for what is considered to be a robust community engagement platform, enabling citizens to become more actively and meaningfully engaged in the planning of their neighbourhoods, and to be more capable of impacting the future of their communities in positive ways.

Chapter 28 by Oliver Lock, Simon Pinnegar, Simone Z. Leao and Christopher Pettit completes the set of chapters in Part V and describes the construction of a PSS for scenario planning for accessibility modelling, based on open data and analytical tools.

Their transport accessibility PSS (TAPSS) offers the possibility to perform rapid route-option testing, which is illustrated with a case study in New South Wales, Australia. The authors conclude that such a PSS with interactive web-based models allows for rapid assessment of route-options although with less detail well before the use of more detailed mode-specific strategic traffic and transport models are brought into the process. They consider its usability an important added value and foresee future studies to observe and evaluate the use and form of TAPSS in specific contexts, where citizens and end-users as well as planners and policy-makers will play an important role.

7. SECTORAL PLANNING SUPPORT

In 2003, as editors of one of the first PSS overview books, *Planning Support Systems in Practice* (Geertman and Stillwell 2003), we concluded that applications of PSS in practice were primarily experimental and tended to be restricted to land-use and/or transportation planning. In our follow-up PSS overview book, *Planning Support Systems: Best Practice and New Methods* (Geertman and Stillwell 2009), in addition to the more traditional PSS application fields, we also identified alternative PSS application fields, such as environmental planning, tourism planning and public health service planning. The extent of PSS applications had widened during the 2000s, although slowly and step by step. The final part of this *Handbook*, Part VI, 'Sectoral planning support', contains a number of contributions suggesting a continuation of the widening of the range of PSS applications. Furthermore, the chapters indicate that dedicated systems have grown at the expense of the general-purpose systems. It is encouraging to see the roles that PSS are playing in supporting planners in these alternative fields of application.

In the first chapter of Part VI of the *Handbook*, Andy Newing, Nick Hood and Iain Sterland take a look at the role of PSS in the highly competitive and rapidly evolving commercial retail sector where PSS are applied to enhance evidence-based, location decision-making and to facilitate the management of store portfolios. Drawing on examples from the UK grocery sector, the authors demonstrate the range of PSS applied to new-store site selection, impact assessment and revenue prediction. Based on these empirical studies, they demonstrate the need for continuous innovation in PSS to drive growth in store portfolios, assess the impacts of the expansion of online channels and evaluate network optimization opportunities. Furthermore, they draw attention to the ongoing investments in new PSS which can capitalize on the increasingly large volumes of near real-time consumer data that are available to retailers and which contain a wealth of customer information.

An example of public sector planning support not reported previously is provided by Peter Boden, Rebecca Hughes and John Stillwell in Chapter 30, illustrating how a combination of data sources and forecasting methodology provides the necessary components for a school-place PSS that meets the requirements for regulatory reporting and provides evidence to support the education departments of councils in their decision-making processes. In the UK, every child between 5 and 18 years of age is entitled to a school place, and local authorities have a statutory responsibility to provide sufficient school places to meet local needs. This presents a complex challenge to school-place planners charged with providing the evidence to support investment (or divestment) in school

infrastructure and services. The authors describe the complexities of this school planning system and conclude by identifying the key criteria for effective school-place planning and for a supportive PSS.

Another sector in which PSS have been applied recently is the housing sector. Chapter 31 by Paul Waddell, Christiana Whitcomb, Francisco Figari, Federico Fernandez and Justin Martinez describes an online platform, Penciler, to evaluate the feasibility of the development of affordable housing on specific sites in San Francisco. The core of Penciler is a proprietary algorithm developed by UrbanSim that uses constrained optimization to lay out residential floorplans given the zoning constraints of the site and building programme requirements of the user. Three-dimensional visualization allows for visualizing building results in context. Penciler is intended to help users analyse building programmes for development sites, keep track of funding needed and better understand the impact of policy decisions on building feasibility. The authors foresee the application of Penciler in other areas, which will involve generalization of capabilities and adaptation of its tools to the specific regulatory and financial landscapes of other housing markets.

Chapter 32 is a further example of the use of PSS in the housing sector or, more specifically, 'A GIS-based planning support system for inclusionary housing profitability optimization in Cape Town, South Africa'. Philip Krause, Mark Zuidgeest and Roger Behrens describe a PSS which has been developed to aid decision-making in housing policy and implementation in South Africa. As a legacy of apartheid, South African urban centres are characterized by deeply entrenched and increasingly racial-operating spatial inequality (for example, gentrification). To halt and ideally reverse this trend, planning authorities have introduced inclusionary housing policies and the authors endeavour to support these policies by using a PSS. The chapter discusses the factors considered by the PSS, the operating principles and the data sources before presenting some case studies in Cape Town. This leads the authors to the conclusion that an inclusionary housing PSS does have the potential to address the needs of private and public sector stakeholders in the context of post-apartheid South Africa; however, the present PSS does not adequately meet the identified needs of all stakeholders.

In the final chapter of Part VI and of the *Handbook*, Jeffrey D. Hamerlinck investigates the prospects for application of urban planning support science to rural planning research and practice. He explores two enabling drivers: big data and planning support contexts, and acknowledges that while many big-data concepts in rural settings lag behind successful implementation in urban settings, nevertheless the usefulness of ICT for rural planning may be expanding by developing PSS technologies adapted to the constraints of rural planning practice. The chapter identifies a need for better understanding the unique cultural, economic and institutional characteristics of rural places and rural planning, and foresees that rural planning support science can be advanced by identifying these rural-specific aspects of planning and mapping them onto PSS methods and functions.

8. CONCLUDING DISCUSSION

On reflection, at least four important general conclusions can be drawn that are based on the extensive collection of contributions relating to planning support science that have been assembled in this *Handbook*. First, besides the more traditional PSS application

fields such as land-use and transportation planning, the field of PSS application has continued to expand, as exemplified with case studies in retail, school places and housing. With these and other examples in mind, it is apparent that PSS has established a firm position in these alternative PSS application fields, particularly when the ongoing PSS implementation gap discussions in the more traditional PSS application fields are taken into account.

Second, in our previous overview studies (Geertman and Stillwell 2003, 2009), we concluded that the application of PSS still was primarily experimental, which in many cases meant case-specific, one-off and abstract from some important factual details of the PSS application in practice. The contents of this *Handbook* show that increasingly more PSS are becoming essential instruments in various planning and decision-making processes. It is therefore becoming increasingly plausible to claim that PSS will soon achieve a status of indispensability for the planning practitioner, akin to that of the stethoscope for the medical doctor.

Third, the contributions in this *Handbook* provide evidence of how the sub-fields of planning support science, on the one hand, and the smart city and big data, on the other, are getting closer together, that is, are becoming more integrated. Increasingly more open and/or big data are used by PSS to fulfil their respective tasks. However, does PSS also become part of ongoing smart city/smart governance developments? It is exciting to consider where this convergent trend will lead over the coming years, particularly given the rapid development of the technologies involved. Referring to our discussion in the introduction of this chapter, questions still remain about the extent to which innovations in planning support science will support breakthroughs in practice of the range of smart city/smart governance developments. Similarly, there is still uncertainty as to how ongoing developments in smart city/smart governance/big data/data analytics might contribute to overcoming the long-standing PSS implementation gap.

Fourth, in resuming the discussion in the introduction on *what* and *how* contextual factors influence the take-up and support role of information, knowledge and PSS in planning practice, we conclude that these contextual factors are playing a more important role in these scientific and/or practice-orientated discussions than ever before. Many of the contributions to this book, which we have summarized in this chapter, pay explicit attention to one or more of these contextual factors, in contrast to the situation ten to 15 years ago. This provides further proof for our earlier contention that the field of PSS is maturing into a planning support science.

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