Towards A Novel Model for Smart Sustainable City Planning and Development: A Scholarly Backcasting Approach

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Abstract

In the early 1990s, the discourse on sustainable development produced the concept of sustainable urban forms that became, and continue to be, a hegemonic response to the challenges of sustainable development. However, such forms have been problematic, whether in theory or practice, and indeed are associated with a number of problems, issues, and challenges. This involves the question of how they should be monitored, understood, analyzed, planned, and even integrated so as to improve, advance, and maintain their contribution to sustainability. This brings us to the issue of sustainable cities and smart cities being extremely fragmented as landscapes and weakly connected as approaches, despite the proven role and untapped potential of advanced ICT, especially big data technology, for advancing sustainability under what is labeled “smart sustainable cities.” Essentially, there are multiple visions of such cities, and indeed multiple pathways to achieving them. With that in regard, this futures study aims to analyze, investigate, and develop a novel model for smart sustainable city planning and development using backcasting as a scholarly approach. It involves a series of papers of which this paper is the first, and which aims to report the outcomes of Step 1 and Step 2—an overview of a detailed trend analysis and a review of sustainable urban forms—by answering the guiding questions for each step. We argue that a deeper understanding between social, technological, and scientific solutions is required to achieve more sustainable urban forms. Visionary images of a long-term future can stimulate an accelerated movement towards achieving the long-term goals of sustainability. The proposed model is believed to be the first of its kind and thus has not been, to the best of one’s knowledge, produced, nor is it being currently investigated, elsewhere.

Keywords: Smart Sustainable Cities, Sustainable Urban Forms, Sustainable Cities, Smart Cities, Compact Cities, Eco-Cities, Big Data Technology, Sustainability, Sustainable Development, Backcasting, Futures Study.

Introduction

There is an increasing recognition that emerging and future ICT constitutes a promising response to the challenges of sustainable development due to its tremendous, yet untapped, potential to solve many socio-economic and environmental problems (see, e.g., Angelidou, Psaltoglou, Komninos, Kakderi, Tsarchopoulos & Panori, 2017; Batty, Axhausen, Giannotti, Pozdnoukhov, Bazzani, Wachowicz, Ouzounis & Portugali, 2012; Bibri & Krogstie, 2017a; Kramers, Höjer, Lövehagen, & Wangel, 2014). Many approaches to urban planning and development emphasize the significant role of advanced ICT, especially big data technologies, in advancing sustainability (e.g., Al Nuaimi, Al Neyadi, Nader, & Al-Jaroodi, 2015; Batty et al., 2012; Bettencourt, 2014; Bibri, 2018a, b; Bibri, 2019a, b, c; Twonsend, 2013). As pointed out by Bibri (2019b), the use of advanced ICT in both sustainable cities and smart cities constitutes an effective approach to decoupling the health of the city and the quality of life of citizens from the energy and material consumption and concomitant environmental risks associated with urban operations, functions, services, designs, strategies, and policies.

In light of the above, a recent research wave has started to focus on smartening up sustainable cities in ways that can improve, advance, and maintain their contribution to the goals of sustainable development, as well as on incorporating these goals in smart city approaches in a bid to enhance their sustainability performance (e.g., Al Nuaimi et al., 2015; Batty et al., 2012; Bibri, 2018a, 2019a; Bibri & Krogstie, 2017b; Kramers et al., 2014; Shahrokni, Årman, Lazarevic, Nilsson, & Brandt, 2015). This wave of research centers particularly around amalgamating the landscapes of, and the approaches to, sustainable cities and smart cities in a variety of ways in the hopes of reaching the required level of sustainability and improving the living standard of citizens through enhancing and optimizing urban operational functioning, management, planning, and governance in line with the vision of sustainability under what is labelled “smart sustainable cities” (Bibri, 2018a, b; Bibri, 2019b, c). It is generally concerned with addressing a large number and variety of issues related to sustainable cities and smart cities in terms of different practices in the context of sustainability. In light of this, numerous research opportunities are available and can be realized in the context of smart sustainable cities. In particular, there is a host of unexplored opportunities towards new approaches to smart sustainable urban planning and development to mitigate or overcome the extreme fragmentation of sustainable cities and smart cities as landscapes as well as the weak connection between them as approaches.

In terms of strategic planning and development, smart sustainable cities as a holistic approach to urbanism represent an instance of sustainable urban development, a strategic approach to achieving the long-term goals of urban sustainability—with support of big data technologies and their novel applications. Achieving the status of smart sustainable cities epitomizes an instance of urban sustainability. This notion refers to a desired (normative) state in which a city strives to retain a balance of the socio-ecological systems through adopting and executing sustainable development strategies as a desired (normative) trajectory (Bibri, 2018c). This balance entails enhancing the physical, environmental, social, and economic systems of the city in line with the long-term goals of sustainability over the long run. This requires, as noted by Bibri (2018a, p. 601), “fostering linkages between scientific research, technological innovations, institutional practices, and policy design and planning in relevance to sustainability. It also requires a long-term vision, a trans-disciplinary approach, and a system-oriented perspective on addressing environmental, economic, social, and physical issues.” All these requirements are at the core of backcasting as a scholarly and planning approach to futures studies, which offer promising approaches to building smart sustainable city foresight (Bibri, 2018a). Backcasting is well suited to any multifaceted kind of planning and development process (Bibri, 2019b; Holmberg, 1998; Holmberg & Robèrt, 2000), as well as to
dealing with urban sustainability problems and challenges (Bibri, 2019b; Dreborg, 1996; Miola, 2008; Phdungsilp, 2011).

This futures study aims to analyze, investigate, and develop a novel model for smart sustainable city planning and development using backcasting as a scholarly approach. It involves a series of papers of which this paper is the first, and which aims to report the outcomes of Step 1 and Step 2—an overview of a detailed trend analysis and a review of sustainable urban forms—by answering the guiding questions for each step. We argue that a deeper understanding between social, technological, and scientific solutions is required to achieve more sustainable urban forms.

The remainder of this paper consists of six sections. Section 2 introduces and outlines the backcasting methodology used in this futures study. Section 3 answers the guiding questions for Step 1. Section 4 answers the guiding question for Step 2 in a summarized version in terms of trend analysis, and with a focus on sustainable cities in terms of the current situation. Section 5 presents the results. This paper ends, in Section 6, with discussion and conclusion.

**Backcasting Approach to Strategic Smart Sustainable City Planning and Development**

As a special kind of scenario methodology, backcasting is applied here to build a future model for smart sustainable city as a planning tool for facilitating urban sustainability. Backcasting scenarios are used to explore future uncertainties, create opportunities, build capabilities, and improve decision-making processes. Their primary aim is to discover alternative pathways through which a desirable future can be reached. Scenarios can be classified into different categories, including projective and prospective scenarios, qualitative and quantitative scenarios, participatory and expert scenarios, and descriptive and normative scenarios. This futures study is concerned with a normative scenario, which takes values and interests (sustainability and big data technology) into account and involves reasoning from specific long-term goals that have to be achieved.

In terms of its practical application, backcasting is increasingly used in futures studies in the fields related to sustainable urban planning as a formal element of future strategic initiatives. It is the most applied approach in futures studies when it comes to sustainability problems and the identification and exploration of their solutions. This involves a wide variety of areas, including strategic city planning (e.g., Phdungsilp, 2011), transportation and mobility (Banister, Stead, Steen, Dreborg, Akerman, Nijkamp, & Schleicher-Tappeser, 2000), sustainable transportation systems (Akerman & Höjer, 2006), sustainable technologies and sustainable system innovation (Weaver, Jansen, van Grootveld, van Spiegel, & Vergragt, 2000), sustainable household (Green & Vergragt, 2002), and sustainable transformation of organisations (Holmberg, 1998). Backcasting studies must reflect solutions to a specified social problem in the broader sense (Dreborg, 1996).

Table 1. *The guiding questions for each step in the backcasting study*

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<th>Questions for backcasting steps</th>
<th>Methods</th>
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<td>Study design and problem formulation</td>
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<td>4. What are the sustainability goals these targets are translated to for scenario analysis?</td>
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<tr>
<td>1. What are the key trends and expected developments related to the socio-technical system to be studied?</td>
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<td>2. What are the major problems, issues, and challenges of sustainability and the underlying causes – the current situation?</td>
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<td>3. How is the problem defined and what are the possible problem perceptions?</td>
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<th>Step 3: Generate a sustainable future vision</th>
<th>Creativity method</th>
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<td>1. What are the demands (terms of reference) for the future vision?</td>
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<td>2. How does the future sustainable socio-technical system and need fulfillment look like?</td>
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<td>3. How is the future vision different from the existing socio-technical systems?</td>
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<td>4. What is the rationale for developing the future vision?</td>
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<td>6. Which advanced technologies and their novel applications have been used in the future vision?</td>
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<td>7. How can the future vision be made more sustainable and attractive?</td>
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<th>Step 4: Conduct empirical research</th>
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<td>1. What category of case studies is most relevant to the future vision?</td>
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<td>2. How many case studies are to be conducted and what kind of phenomena do they intend to illuminate?</td>
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<td>3. What is the rationale for the methodological approach adopted?</td>
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<td>4. To what extent can this empirical research generate new ideas and serve to illustrate the theories and their effects underlying the future vision so as to underpin its potential and practicality?</td>
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<tr>
<th>Step 5: Specify and merge the components of the socio-technical system to be developed</th>
<th>Creativity method</th>
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<tr>
<td>1. What specific design concepts, planning practices, and technology elements are necessary?</td>
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<td>2. What kind of urban centers and labs are necessary?</td>
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<td>3. What spatial dimensions and scale stabilizations should be considered?</td>
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<td>4. How can all of the ingredients be integrated into a model for strategic smart sustainable city planning and development?</td>
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<th>Step 6: Perform backcasting backward-looking analysis</th>
<th>Backcasting analysis</th>
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<tr>
<td>1. What urban and technological changes are necessary for achieving the future vision?</td>
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<td>2. What structural, institutional, and regulatory changes are necessary?</td>
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<td>3. How have the necessary changes been realized and what stakeholders are necessary?</td>
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<tr>
<td>4. What are the opportunities, potentials, benefits, and other effects of the future vision?</td>
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Bibri (2018d) concludes that backcasting approach is found to be well-suited for long-term urban sustainability problems and solutions due to its normative, goal-oriented, and problem-solving character. Generally, as argued by Dreborg (1996), backcasting is particularly useful when:

- The problem to be studied is complex and there is a need for major change
- The dominant trends are part of the problem
- The problem to a great extent is a matter of externalities
- The scope is wide enough and time horizon is long enough to leave considerable room for deliberate and different choices and directions of development.

Bibri (2018d) has recently conducted a comprehensive study on futures studies and related approaches. Its main focus is on backcasting as a scholarly approach to strategic smart sustainable city development. Its main objectives are to review the existing backcasting methodologies and to discuss the relevance of their use in terms of their steps and guiding questions for analyzing, investigating, and developing smart sustainable cities, as well as to synthesize a backcasting approach based on a number of notable future studies. Later, Bibri (2019b) adapted the approach, i.e., made minor changes so as to improve and clarify it in accordance with the overall aim of this futures study as well as the specificity of the proposed model. Indeed, a commonly held view is that the researchers’ worldview and purpose remain the most important criteria for determining how futures studies can be developed and conducted in terms of the details concerning the questions guiding the steps involved in a particular backcasting approach. This helps to identify and implement strategic decisions associated with urban sustainability. However, the outcome of the adapted synthesized approach is illustrated in Table 1.

**Step 1**

**Step 1-1: A Description of the aim of the backcasting study**

Aiming to analyze, investigate, and develop a novel model for smart sustainable city planning and development, this futures study endeavors to integrate the physical landscape of sustainable cities with the informational landscape of smart cities as well as the two approaches to urban planning and development at the technical and policy levels in the context of sustainability. This endeavor is supported by empirical investigation. In more detail, this futures study approaches this new integrated approach to urbanism from the perspective of combining the design principles and strategies of both the compact city (i.e., compactness, density, diversity, mixed-land use, sustainable transport, and green space) and the eco-city (i.e., renewable resources, passive solar design, ecological diversity, urban greening, and environmentally sound policies), and then amalgamating the resulting outcome with the data-driven city in terms of the associated innovative solutions and sophisticated approaches pertaining to big data technologies and their novel applications for sustainability. Worth noting is that such approach, which is one among others that have been proposed in the field of smart sustainable cities and are being investigated further and hence not implemented yet, focuses on the core elements of urban sustainability, namely planning, design, and technology. The proposed model of smart sustainable city is a result of the concept of urban sustainability as clarified, advocated, and advanced by many scholars, academics, and practitioners in the field, demonstrated in numerous real-world cities from across the globe, as well as evidenced by combining several cities from ecologically advanced nations.

**Step 1-2: A Description of the objectives of the backcasting study**

Examining the planning practices and development strategies of both the compact city and eco-city to identify their preferred measures, as well as to determine the extent to which these measures produce the expected environmental, economic, and social benefits of sustainability.
• Integrating the most theoretically informed, practically successful, and widely adopted design concepts and planning practices of the compact city and the eco-city, predicated on the assumption that the former has a form and the latter is amorphous (formless).
• Compiling multiple pathways to achieving sustainable cities, and distilling the most important aspects of those being currently pursued to further inform the integration of the compact city and the eco-city based on the most advocated strategies of sustainable urban forms.
• Examining the up-to-date big data technologies and their novel applications pertaining to sustainability as associated with the data-driven city as an instance of smart cities of the future.
• Amalgamating the integrative model of the compact city and the eco-city with the data-driven city by connecting the eco-compact city in terms of policies, strategies, designs, spatial organizations, and scale stabilizations to its operational functioning and planning through control, automation, management, and optimization in the form of urban intelligence functions. This process requires digital instrumentation, urban operating system, cloud computing infrastructure, and big data ecosystem, as well as control rooms, management systems, and urban intelligence labs and centers (see Bibri, 2019c for the anatomy of the data-driven smart sustainable city).

Step 1-3: Long-term targets
Here we identify the set of measures or indicators of the progress that is needed to get to the specified goals and thus realize the future vision or nearer to it in time. These measures include the following:

• High density and adequate diversity
• Mixed land-use and social mix
• Compactness
• Sustainable transportation
• Green and natural areas and biodiversity
• Energy systems based on renewable resources, energy efficiency technologies, and integrated renewable solutions
• Passive solar design and greening
• Environmentally sound policies
• Digital instrumentation, datafication, and computerization of the built environment based on cutting-edge big data technologies
• Urban operations centers, strategic planning and policy offices, research centers, and innovation and living labs dedicated to advancing different areas of sustainability knowledge and its practice.

Step 1-4: Specified goals
The model for smart sustainable city planning and development being predominantly based on the most prevailing, advocated, and successful models of sustainable urban form, supported with big data technologies and their novel applications as the most advanced solutions and approaches being offered by data-driven smart cities, will ultimately result in numerous sustainability benefits, the most prominent among them are (e.g., Bibri & Krogstie, 2017b; Jabareen, 2006; Rapoport & Vernay, 2011):

• Decreased energy and material use
• Reduced pollution
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- Minimized waste
- Preserved open spaces and ecosystems
- Reduced automobile use/car dependency
- Effective mobility and accessibility
- Enhanced quality of life and well-being
- Improved equity and social justice
- Community-oriented and livable human environments
- Economic development and viability

Step 2

In the second stage, the relevance of describing the broader context within which the analysis will take place lies in defining the different components that could act as direct inputs to the scenario analysis.

Step 2-1: Key prevailing and emerging trends and main expected developments

The trend analysis as to the way it is meant to be conducted in this paper entails identifying the key forms of trends at play in the world today, and then performing an analysis to understand their nature, meaning, as well as their implications in relevance to the development of the novel model for smart sustainable city planning and development. In this case, the way forward is to look at a number of studies previously done on the diverse topics related to smart cities and sustainable cities to identify a set of pertinent, interrelated patterns of change of various kinds pertaining to these phenomena and their integration, and then to envision certain developments. One form of this envisioning in the context of this paper could be approached from the perspective on the synergy and complementarity of the respective forms of trends—of which the outcome is the development of multiple visions of smart sustainable cities as new approaches to urbanism, as well as how this phenomenon will evolve and the extent to which it will spread in the years ahead. The envisioning also involves other expected developments than smart sustainable cities and the continuation of this paradigm of urban planning and development in the future.

In addition, the trend analysis in this context requires probing what is causing the identified forms of trends to emerge, whether the causes will continue in that direction, what other external forces may affect the trends, whether they are part of rather larger societal shifts with far-reaching and long-term implications, and if there are some limitations and challenges associated with the trends. The identified forms of trends and related issues, as well as the expected developments, are described and analyzed in more details in Bibri (2019b). The specific topics addressed in this regard include the following:

- Sustainable cities
- Smart cities
- Smart sustainable cities
- Sustainable smart cities
- Big data computing
  — Characteristics, concepts, and prospects
  — Research status of big data analytics as an enticing investigation area
  — Data growth projection and related core enabling and driving technologies
  — Urban data deluge and its sources and enabling capabilities
- Key external forces affecting the integration of the trends: the role of political action in smart sustainable cities
Step 2-2: The current situation
Models of sustainable urban form: deficiencies, limitations, fallacies, difficulties, uncertainties, and prospects

Scholars and practitioners from different disciplines and professional fields have, over the past three decades or so, sought a variety of sustainable urban forms that could contribute to sustainability over the long run in response to the rising concerns about the environment and the socio-economic needs (Bibri & Krogstie, 2017a, b). The compact city (e.g., Jenks, Burton, & Williams, 1996a, b; Hofstad, 2012; Neuman, 2005) and the eco-city (e.g., Joss, 2010, 2011; Joss, Cowley, & Tomozeiu, 2013) are the most prevalent models of sustainable urban form and often advocated as more sustainable (e.g., Bibri, 2018a, 2019b; Jabareen, 2006; Kärrholm, 2011; Rapoport & Vernay, 2011; van Bueren, van Bohemen, Itard, & Visscher, 2011). These models are compatible and not mutually exclusive, but there are some distinctive concepts and key differences for each one of them (Jabareen, 2006). However, the challenge of meeting the goals of sustainable development has induced scholars, planners, policymakers, international organizations, civil societies, and governments to propose these two models as a way of redesigning and restructuring urban areas to achieve sustainability, which have been addressed on different spatial levels, including the regional level, the metropolitan level, the city level, the community level, the neighborhood level, and the building level. However, the underlying challenge continues to induce researchers, practitioners, and decision-makers to work collaboratively to enhance existing models of sustainable urban form across several spatial scales to achieve the requirements of sustainability and, ideally, to integrate its physical, environmental, economic, social, and cultural dimensions (Bibri & Krogstie, 2017a, b). The ultimate goal of the endeavor is to develop more robust models of sustainable urban form. This has indeed been one of the most significant intellectual and practical challenges for more than three decades (e.g., Bibri, 2018a, 2019b; Bibri & Krogstie, 2017a, b; Jabareen, 2006; Kärrholm, 2011; Neuman, 2005; Williams, 2009). As concluded by Jabareen (2006, p. 48) after analyzing a distinctive set of the design concepts and typologies as planning practices characterizing compact cities and eco-cities, among others, and how these can be compared and classified in terms of their contribution to sustainability, “neither academics nor real-world cities have yet developed convincing models of sustainable urban form and have not yet gotten specific enough in terms of the components of such form.” This implies that it has been a challenging task to translate sustainability into the built form and, thus, evaluate the extent to which existing models of sustainable urban form contribute to the goals of sustainable development. Indeed, it is not evident which of these models are more sustainable and environmentally sound, although there seems to be in research on sustainable urban forms and anthologies a consensus on topics of relevance to sustainability (e.g., Bibri & Krogstie, 2017b). In line with this argument, a critical review of such forms demonstrates a lack of agreement about the most desirable form in the context of sustainability (e.g., Jabareen, 2006; Williams, Burton, & Jenks, 2000). Besides, it is not an easy task to “judge whether or not a certain urban form is sustainable” (Kärrholm, 2011, p. 98). Even in practice, many governments, planning experts, landscape architects, and so on are grappling with the dimensions of models of sustainable urban forms by means of a variety of design, planning, and policy approaches (Jabareen, 2006; Kärrholm, 2011). In addition, there is a lack of theory that can serve to compare different forms according to their contribution to the goals of sustainable development, as well as to evaluate whether a given urban form contributes to sustainability (Jabareen, 2006). In a nutshell, not only in practice, but also in theory and discourse, has the issue of sustainable urban form been problematic and difficult to deal with as manifested in the kind of the non-conclusive, limited, conflicting, contradictory, uncertain, and weak results of research (Jabareen, 2006; Kärrholm, 2011; Neuman, 2005; Williams, 2009), particularly when it comes to the actual effects of the benefits of sustainability as assumed or claimed to be achieved by design concepts and typologies. Conclusively, “yet knowing if we are actually making any progress towards sustainable...
cities is problematic. In one sense, so much has been achieved in raising the profile of sustainability and sustainable cities over the last 30 years that the rate of change is inspiring... We seem to be going backwards to the extent that it is hard to see where there is any room for optimism. Urban problems...are becoming more acute as populations rise and resources become scarcer.” (Williams, 2009, p.2)

In addition, the conventional sustainable urban planning approach alone is no longer of pertinence as to ensuring or maintaining the effectiveness of sustainable urban forms with regard to the operation, function, and management of urban systems, as well as the integration and coordination of urban domains, in the context of sustainability due to the issues being engendered by the rapid urbanization. In relation to this argument, Neuman (2005) contends, in reference to the fallacy of compact cities, that conceiving cities in terms of forms remains inadequate to achieve the goals of sustainable development; or rather, accounting only for urban form strategies to make cities more sustainable is counterproductive. Instead, conceiving cities in terms of “processual outcomes of urbanization” holds great potential for attaining these goals, as this involves asking the right question of “whether the processes of building cities and the processes of living, consuming, and producing in cities are sustainable,” which raises the level of, and may even change, the game (Neuman, 2005). The underlying argument is that while the layout or urban form can influence the environmental impact, it is rather the people and their behavior that ultimately determine the negative or positive environmental impact of urban areas. Monitoring, understanding, and analyzing the latter set of processes, in particular, can well be enabled by big data technology as an advanced form of ICT to further improve sustainability. Townsend (2013) portrays urban growth and ICT development as a form of symbiosis. However, the process–driven perspective as to be enabled by big data technology paves the way for a more dynamic conception of urban planning and design that reverses the focus on urban forms governed by static design and planning tools (Bibri, 2019b; Bibri & Krogstie, 2017a, b). This holds more promise in attaining the elusive goals of sustainable development (Neuman, 2005). Existing models of sustainable urban form as to the underlying design concepts and typologies seem to have failed to account for changes over time (Bibri & Krogstie, 2017a, b).

In light of the above, it is timely and necessary to apply the innovative solutions and sophisticated approaches being offered by big data technology to deal with the challenges of sustainability as well as urbanization. Besides, a well–established fact is that cities evolve and change dynamically as urban environments, so too is the underlying design and planning knowledge that perennially changes in response to new emergent factors and changes. To put it differently, cities need to be dynamic in their conception, scalable in their design, efficient in their operational functioning, and flexible in their planning in order to be able to deal with population growth, environmental pressures, changes in socio–economic needs, global shifts/trends, discontinuities, and societal transitions (Bibri, 2018a; Bibri, 2019b). For example, Durack (2001) argues for open, indeterminate planning due to its advantages, namely the tolerance and value of topographic, social, and economic discontinuities; continuous adaptation; and citizen participation, which is common to human settlements. This can be accomplished through incorporating big data technologies into urban planning and design due to their innovative, disruptive, substantive, and synergistic effects.

Furthermore, in urban planning and policy making, “the concept of sustainable city has tended to focus mainly on infrastructures for urban metabolism—sewage, water, energy, and waste management within the city” (Höjer & Wangel, 2015, p.3), and thereby fall short in considering smart solutions and sophisticated methods in relation to operational functioning, planning, and design (Bibri, 2019b; Bibri & Krogstie, 2017b). The concept of urban sustainability has long been promoted by systems scientists using the pragmatic framework for urban metabolism; smart urban metabolism as an ICT–enabled evolution of such framework is being implemented to overcome some of its limitations in the context of eco–city (Shahrokni et al., 2015).
All in all, there are several critical issues that remain unsettled as well as under-explored for applied purposes with regard to the extent to which the challenges of urban sustainability can be addressed, despite the promotion of sustainable cities as a desirable goal within the context of policy and planning. In relation to this, Williams (2009) identifies two fundamental, critical, and interesting challenges pertaining to policies and monitoring strategies. The first is, the challenge of “the vision”: do we know what “the sustainable city” is? And the second is, the challenge of change: do we know how to bring about “sustainable urban development”? The latter entails developing a deeper understanding of the multi-faceted processes of change required to achieve more sustainable cities. This relates to the view that there are multiple processes of sustainable urbanism, and hence multiple visions of, and pathways to achieving, the sustainable city. On this note, Williams (2009, p. 3) adds that if we understand and respect this view, “then we need to accept that making our cities more sustainable will be dependent on a similarly wide-ranging selection of actions. Some actions will be top-down and require strong leadership and, perhaps, large-scale investment programs, other changes may be bottom-up, and rely on…shifts in behavior. These changes…will happen at different paces…, and at difference spatial scales.”

In the above line of thinking, it seems that the eco-city and the compact city as instances of sustainable cities are relatively well understood as a way of practically applying existing knowledge about what makes a city sustainable. Notwithstanding this dominant view in the prescriptive literature, what seems to prevail in research about the relationship between urban design and planning interventions and sustainability objectives is a subject of much debate (Bulkeley & Betsill, 2005; Williams, 2009). This means that realising an eco-city requires making countless decisions about sustainable (green) technologies, urban layouts, building design, and governance (Rapoport & Vernay, 2011), just like the case for compact city (Kärholm, 2011). Furthermore, several studies (e.g., Guy & Marvin, 1999; Jabareen, 2006; Rapoport & Vernay, 2011; van Bueren et al., 2011; Williams, 2009) point to the issue of diversity underneath the various uses of the terms eco-city and compact city and shed light on the extent of divergence on the way projects and initiatives conceive of what eco-city and compact city models should be or look like. Indeed, in relation to the compact city, there are great differences between cities in terms of their urban form whose key elements can be distinguished: density, surface, land use, public transport infrastructure, and the economic relationship with the surrounding environment (van Bueren et al., 2011). Similarly, Rapoport and Vernay (2011) determine the differences in the way projects and initiatives conceive of what an eco-city should be. Guy and Marvin (1999) address the issue of the different models and pathways in terms of the diversity of sustainable urban futures. Williams (2009) offers a conceptualization of multiple pathways and processes of sustainable urbanism, and argues that a move to a deeper understanding of the interplay between social and technical solutions for sustainable cities is required. On the whole, there is a great deal of heterogeneity among city initiatives and projects that are considered to be sustainable cities. However, there is a need for recognizing that these multiple pathways and processes of sustainable urbanism need some coherence of purpose. Or else, there will be no conceptual anchor in the event of the continuing conflicts and contradictions within sustainable urbanism thinking and practice, and to this anchor, sustainability principles, the sustainable use and wise management of natural resources, and equity and justice are of high relevance and usefulness. Regardless, understanding the multiplicity and diversity of socially constructed visions of sustainable urbanism is at the heart of stimulating and advancing research and practice, as long as it is driven by some coherence of purpose. In this respect, it has been interesting to witness how many socio-culturally specific ideas have been replicated in different locations across the globe, with little consideration or investigation of their appropriateness (e.g., Williams, 2004, 2009). As asserted by Guy and Marvin (1999, p. 273), “the role of research is to keep alive a multiplicity of pathways by opening a wider discourse and dialogue about the types of future we might be able to create.”
Towards A Novel Model for Smart Sustainable City Planning and Development

In relation to the ongoing efforts for smartening up sustainable urban forms using big data technology and its application, Bibri (2018a) points out that one of the key scientific and intellectual challenges pertaining to smart sustainable urban forms is to relate the underlying design concepts and typologies and thus urban infrastructures to their operational functioning and planning through control, automation, management, and optimization. This relates to new urban intelligence functions as new conceptions of the way such forms can function and utilize the complexity sciences in fashioning powerful new forms of simulation models and optimization and prediction methods (on the basis of big data analytics) that generate urban forms and structures (design concepts and typologies) that improve sustainability, efficiency, equity, and the quality of life (e.g., Bibri, 2018a; Bibri & Krogstie, 2017b).

Bibri (2019b) identifies many gaps and issues within the flourishing field of smart sustainable urban forms, the most relevant of which to this futures study and this paper are the following:

- There is a need for solidifying existing applied theoretical foundations in ways that provide an explanation for how the contribution of sustainable urban forms to sustainability can be improved and maintained on the basis of big data technology and its application.
- There is no strategic framework for merging the informational and physical landscapes of existing models of sustainable urban form.
- Sustainable urban forms remain static in conception, unscalable in design, inefficient in operational functioning, ineffective in planning without advanced ICT in response to urban growth, environmental pressures, changes in socio-economic needs, global shifts/trends, and societal transitions.
- Sustainable urban forms fall short in considering smart solutions within many urban systems and domains where such solutions could have substantial contributions to sustainability.

The main argument in the ongoing debate over sustainable urban forms as instances of sustainable cities is that urban systems are in themselves very complex in terms of functioning, operation, management, and planning, so too are urban domains in terms of coordination and integration as well as urban networks in terms of coupling and interconnection. Therefore, it is of high relevance to develop and employ innovative solutions for solving, and sophisticated approaches into dealing with, the challenges of sustainability and urbanization. This requires a blend of sciences for creating powerful design and engineering solutions, which ICT is extremely well placed to initiate for its application to urban systems, domains, networks, as well as related processes is founded on computer science, data science, urban science, and complexity science (e.g., Batty et al., 2012; Bibri, 2018a, 2019b; Bettencourt, 2014). Indeed, the role of ICT–enabled solutions in improving sustainability is becoming evident in light of the ongoing endeavors to advance both sustainable cities and smart cities (see, e.g., Al Nuaimi et al., 2015; Batty et al., 2012; Bibri & Krogstie, 2017b; Bettencourt, 2014; Kramers et al., 2014; Shahrokni et al., 2015).

All in all, despite the huge advances in different areas of knowledge and a number of impressive practical initiatives and programs in the realm of sustainable urbanism, there is still much more that needs to be done according to what arises of change on the ground. Hence and again, it has become of high significance and importance to theoretically and practically amalgamate the design principles and strategies of urban sustainability with the sophisticated approaches and innovative solutions being offered by big data technology. The ultimate aim is to find more effective ways and more robust methods to improve, advance, and maintain the contribution of sustainable cities to the goals of sustainable development by assessing, optimizing, and enhancing the underlying strategies and approaches using cutting–edge technologies under what is labelled “smart sustainable cities of the future.” This is important to embrace and pursue in an increasingly computerized and urbanized world. Especially, big data computing is offering great opportunities for, and unsurpassed ways of,
effectively monitoring, understanding, analyzing, and planning such cities to achieve the optimal level of sustainability (Bibri, 2018a, 2019b).

Other related topical subjects
This part of Step 2 is a rather comprehensive review of the current situation (see Bibri, 2019b), involving other topical subjects that inform this futures study, including the following:

- Sustainable cities—Models of sustainable urban form
  — Key benefits
- Smart cities
  — The inadequate contribution of the smart cities of today to the goals of sustainable development
- Smart sustainable cities
  — Key underlying and driving forces for smart sustainable city development
  — Research gaps
  — Key scientific and intellectual challenges
- Big data analytics and its application for sustainability
  — Big data applications for multiple urban systems and domains
  — Research issues and challenges

Results: The Outcome of Step 2

Long–lasting trends
The main emerging and prevailing trends identified include:
- Global shifts: sustainability, ICT, and urbanization.
- Intellectual discourses: sustainable urbanism, smart urbanism, data–driven urbanism, scientific urbanism, and sustainable development.
- Computing paradigms: pervasive computing, ubiquitous computing, the IoT, and big data computing.
- Scientific paradigms: data–intensive science.
- Technological innovations: big data technologies, analytics, applications, and ecosystems.

Expected developments
The main expected developments identified are believed to be already happening or to arrive soon, including the following:
- Instrumentation, computerization, and computation are routinely pervading the very fabric of sustainable cities and smart cities.
- Sustainable cities and smart cities are becoming increasingly datafied and thus dependent upon their data to operate properly—and even to function at all with regard to many domains of urban life—datafication.
- Sustainable urban and smart urban processes and practices (operational functioning, management, planning, design, development, and governance) are becoming highly responsive to a form of data–driven urbanism.
- Sustainable cities and smart cities are increasingly embracing big data technologies and their novel applications to improve, advance, and maintain their contribution to the goals of sustainable development towards achieving the requirements of sustainability.
Sustainable cities and smart cities are becoming more and more connected as approaches and merged as landscapes.

Smart sustainable cities are gaining foothold and traction worldwide as a promising response to the challenges of sustainability and urbanization.

Data–driven urbanism is increasingly becoming the mode of production for smart sustainable cities, i.e., a new era is presently unfolding wherein smart sustainable urbanism is increasingly becoming data–driven.

Data–intensive science as a fourth scientific paradigm is drastically changing how urban analytics and urban studies are done in relation to urban sustainability knowledge production.

**Problems, issues, and challenges of the current situation**

Sustainable urban forms have always been problematic and daunting to deal with. Indeed, they are still associated with a number of problems, issues, and challenges when it comes to their compact and ecological planning, design, and development. These are compiled in Table 2.

<table>
<thead>
<tr>
<th>Problems</th>
<th>Deficiencies, limitations, difficulties, fallacies, and uncertainties</th>
</tr>
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<tbody>
<tr>
<td>Not only in practice but also in theory have sustainable urban forms been problematic and daunting to deal with as manifested in the kind of the non-conclusive, limited, conflicting, contradictory, uncertain, and weak results of research obtained. This is partly due to the use of traditional collection and analysis methods and data scarcity. These results pertain particularly to the actual effects and benefits of sustainability as assumed or claimed to be delivered by the design principles and strategies adopted in planning and development practices.</td>
<td></td>
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<tr>
<td>Sustainable urban forms fall short in considering smart solutions within many urban domains where such solutions could have substantial contributions to the different aspects of sustainability.</td>
<td></td>
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<tr>
<td>Deficiencies in embedding various forms of advanced ICT into urban design and planning practices associated with sustainable urban forms.</td>
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<tr>
<td>Sustainable urban forms remain static in planning conception, unscalable in design, inefficient in operational functioning, and ineffective in management without advanced ICT in response to urban growth, environmental pressures, changes in socio–economic needs, global shifts, discontinuities, and societal transitions.</td>
<td></td>
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<tr>
<td>Realizing compact cities and eco–cities require making countless and complex decisions about green and energy efficient technologies, urban layouts, building design, and governance.</td>
<td></td>
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<tr>
<td>What to solve, address, and overcome</td>
<td>Deficiencies, limitations, difficulties, fallacies, and uncertainties</td>
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<tr>
<td>Divergences in and uncertainties about what to consider and implement from the typologies and design concepts of models of sustainable urban form.</td>
<td>Sustainable urban forms are in themselves very complex in terms of management, planning, design, and development, so too are their domains in terms of coordination and integration as well as their networks in terms of coupling and interconnection.</td>
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<td>Sustainable cities and smart cities are weakly connected as ideas, visions, and strategies as well as extremely fragmented as landscapes at the technical and policy levels.</td>
<td>Sustainability goals and smartness targets are misunderstood as to their—rather clear—synergies</td>
</tr>
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<td>There is a need for solidifying the existing applied theoretical foundations in ways that provide an explanation for how the contribution of sustainable urban forms to sustainability can be improved and maintained on the basis of big data technology and its applications.</td>
<td>There is no strategic model for merging the informational and physical landscapes of the existing models of sustainable urban form.</td>
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<tr>
<td>In relation to spatial scales, the existing models of sustainable urban forms tend to focus more on the neighbourhood level than on the city level in terms of design and planning due to the uncertainties surrounding the design principles and planning practices as to their actual sustainability effects and benefits.</td>
<td>Conceiving cities only in terms of forms remains inadequate to achieve the goals of sustainable development. It should be informed by the processual outcomes of urbanization to attain these goals, as this involves asking the right questions related to the behavior of inhabitants; the processes of living, consuming, and producing; and the processes of building urban environments—in terms of whether these are sustainable.</td>
</tr>
<tr>
<td>Cities evolve and change dynamically as complex systems and urban environments, so too is the underlying knowledge of design and planning that is historically determined to change perennially in response to new factors.</td>
<td>In urban planning and policy making, sustainable cities have tended to focus mainly on infrastructures for urban metabolism—sewage, water, energy, and waste management while falling short in considering innovative solutions and sophisticated methods for urban operational functioning, planning, design, and development.</td>
</tr>
</tbody>
</table>
What to solve, address, and overcome | Deficiencies, limitations, difficulties, fallacies, and uncertainties
---|---
Challenges | One of the most significant challenges is to integrate and augment sustainable urban forms with advanced technologies and their novel applications—in ways that enable them to improve, advance, and maintain its contribution to the goals of sustainable development.

There are difficulties in translating sustainability into the built, infrastructural, and functional forms of cities.

There are difficulties in evaluating the extent to which the existing models of sustainable urban form contribute to the goals of sustainable development. It is not an easy task to even judge whether or not a certain urban form is sustainable.

One of the key scientific and intellectual challenges pertaining to sustainable urban forms is to relate the underlying typologies and infrastructures to their operational functioning and planning through control, automation, management, optimization, and enhancement.

There will always be challenges to address and overcome and hence improvements to realize in the field of sustainable cities, and this has much to do with the perception underlying the conceptualization of progress concerning cities. This centers around what we think we are aspiring to, what we assess ‘progress’ to be, and what changes we want to make.

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**Discussion and Conclusion**

This paper reported the outcomes of Step 1 and Step 2—an overview of a detailed trend analysis and a review of sustainable urban forms—by answering the guiding questions for each step. Concerning Step 1, we determined the aim and stated the objectives of the backcasting study. Then, we specified the long–term targets and goals of sustainability in relation to the proposed model for smart sustainable city planning and development. As regards Step 2, a number of different, yet related, forms of trends associated with the phenomenon of smart sustainable cities were identified, described, and elaborated. In addition, the interrelationships between these trends were discussed in relevance to the core aim of this futures study. The forms of trends identified include global shifts, intellectual discourses, academic discourses, computing paradigms, scientific paradigms, and technological innovations. Also, envisioning how smart sustainable cities will evolve was supported by the status of the recent and ongoing research endeavors in the field as involving most of the trends identified in this context. Moreover, the causes triggering the various forms of trends to emerge were examined, so was how and why they will continue in that direction. In addition, the key external forces affecting these forms of trends were elucidated and discussed while highlighting that these trends and their amalgamation constitute part of larger societal shifts with far-reaching and long–term implications, namely sustainability transitions.

Remaining on Step 2, the outcome of the current situation this paper was concerned with shows that sustainable cities are currently associated with a number of problems, issues, and challenges, and therefore need to embrace what smart cities of the future have to offer in terms of big data technologies and their novel applications in order to improve, advance, and maintain
their contribution to the goals of sustainable development. Especially, one of the most significant challenges at the moment is to produce a theoretically and practically convincing and robust model of sustainable urban form with clear components—and seamlessly integrated with advanced technologies and their novel applications (Bibri & Krogstie, 2017b). Besides, a large part of research in the area of smart sustainable cities focuses on exploiting the potentials and opportunities of advanced technologies as an effective way to mitigate or overcome the issue of sustainable cities and smart cities being extremely fragmented as landscapes and weakly connected as approaches (see Bibri, 2019b for an overview).

The debate over the ideal or desirable urban form dates back to the end of the 19th century, and obviously, the concept of sustainable development revives it and develops existing models of sustainable urban form further by enhancing them with the planning principles and ecological design of sustainability (Jabareen, 2006). Again, smart development as being predominately driven by big data technology has recently revived this debate, and is attempting to enhance the existing models of sustainable urban form by smartening up the performance of the underlying design principles and strategies, thereby increasing their contribution to sustainability. It has become of high relevance and importance to augment sustainable urban forms with big data technologies and their novel applications (Bibri & Krogstie, 2017b).

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References

Towards A Novel Model for Smart Sustainable City Planning and Development


