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Cybernetics and the 4D Smart City: Smartness as Awareness

Emilia Rönkkö *, Aulikki Herneoja and Essi Oikarinen

School of Architecture, University of Oulu, FI-90014 Oulu, Finland; aulikki.herneoja@oulu.fi (A.H.); essioikarinen@gmail.com (E.O.)
* Correspondence: emilia.ronkko@oulu.fi

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Abstract: The complexity of urban challenges obliges us to seek smarter paths for urban development and increase our awareness of urban dynamics in a more holistic manner. Stemming from the discipline of architecture and urban planning, this concept paper outlines an idea of a cybernetic urban management for anticipatory governance of smart cities. A cybernetic system absorbs information from different sources, such as buildings that are aware of their energy efficiency, a city aware of its traffic flows, and citizens who are aware of the affordances of urban life. Defined as context-aware cyber-physical social systems, smart cities of the future are planned and managed with increasing awareness of the manifoldness of physical, experiential, and virtual life. The benefits of a cybernetic urban management could, for instance, be related to dynamic service network planning with a real-time view to service network efficiency. This in turn could lead to better services for citizens, resource efficiency, and better allocation of financial resources. Cybernetic management and smart city production necessitates a shared view of urban processes that is not dedicated only for the eyes of a few experts but is widely accessible and supports information exchange and dialogue among city authorities, decision-makers, and citizens.

Keywords: smart cities; urban planning and design; cybernetics; urban experiences; north

1. Introduction

Urbanization, climate change, demographics, and globalization are forces that create increasingly complex challenges for cities all around the world. A force that is pervasive to all the above and is generally regarded as part of the solution of these challenges is digital technology. Cities play a key role in the systemic transition towards a more sustainable future, and the current speed of climate change is pushing this interest forward. As the age of Anthropocene has altered the Earth's systems and feedback loops on a scale that threatens even planetary existence; incremental steps are no longer sufficient [1]. As Naomi Klein and other contemporary thinkers have stated, we need systemic change in order to stop climate change.

Consequently, the 'Smart City' has established itself as a central concept for urban management and planning in the 21st century. So far, a variety of definitions has been suggested for framing 'smartness' in urban context. The concept is loosely defined to cover innovative urban development utilizing information and communication technology [2]. Furthermore, urban smartness is based on the idea that cities are able to increase their sustainability and eco-efficiency [3], and at the same time promote the well-being of citizens [2]. Sometimes, the concept of a smart city is used broadly to indicate the development of a knowledge-intensive economy within a certain region. In terms of urban management and service coordination, smartness also refers to applying information technologies to different stages of planning, designing, building, and operating cities [4].

Along with smartness, urban experiences have taken a significant place as a conceptual urban idea. Interest for centering experiences has risen because of global market competition and a quest for future experiences that is necessary for a thriving downtown. This conceptual position emphasizes everyday life and the environment where it happens [5]. The life of the city with its temporal, sensory dimensions supersedes, for example, distanced, aerial ways of looking at the city within urban planning practices. While stemming from a different conceptual origin than experiential cities, digital, smart cities provide possibilities for understanding and developing urban experiences further.

New modes of smart city production give rise to considerations of urban agency and dwelling in "Smart City Lifeworlds" as stated by [6]. Today, human agency is increasingly enmeshed in the digital landscapes of cyberspace, sometimes defined as the New Human Condition (NHC) in reflection to the political philosopher Hannah Arendt's seminal work in the late 1950s [7]. Contemporary "digital humanism" can be regarded as alienation from both the common, artefactual, and natural world, as human agency is branched into both 'environmental' and 'digital' milieus [6]. Today, the question of diminishing human agency is also greatly intertwined and further constrained by climate change. Along with these considerations, discussions have emerged around posthumanism and nonanthropocentric design in the context of smart city production [8,9]. These recent orientations are challenging the prevailing idea of such human centeredness also in terms of urban planning and digital technology. According to [9], the primary purpose of design is negotiation of the boundaries between humans, nonhumans, and the environment, and finding a sustainable ground for appreciative coexistence. Ethical discussion of planetary boundaries and systemic balance are timelier than ever.

In the Finnish Smart City field, the larger southern cities have been in the forefront in smart city development. Smart city concepts are implemented through "empty land tactics", i.e., planning smartness from scratch, as well as urban infill projects such as 'smartification' of existing (sub)urban areas. Recently, in many Finnish cities railway station areas have been developed as nodes of smart living, commuting, services, and work. The authors of this paper have mainly been involved with smart city development outside the southern metropolitan region. Our empirical studies have been associated with the city of Oulu in northern Finland and the city of Kuopio in eastern Finland. Oulu has served as an interesting urban laboratory for studying smartness and the preferences and experiences of citizens and the design of urban ICT from the viewpoint of urban seasonality and a northern climate [10]. This research work has specific relevance, as in the boldest visions, the northern hemisphere would be urbanized rapidly within the next fifty years [11]. Kuopio, in turn, has been at the forefront of developing a digital dashboard for public service network planning in order to improve its capacity for interorganizational cooperation and effective resource allocation.

General criticisms of smart city production lean towards its technology-optimistic ethos and exposure to "bug-prone" urbanism, urban hacktivism, and, in general, the enthusiasm of bringing new digital technologies and services to market in a supply-driven, instead of demand-driven, manner. Furthermore, the development of smart city models and smart city approaches has been based on a set of principles or ideals (conceptual cities) rather than on integrated urban theory. Concerning some of the shortcomings on the smart city research agenda and in smart urban planning theory, we ask: How would smart city production establish its theoretical, epistemological, and ontological orientation if it de-centers the technological push from its pedestal and takes a more balanced and (eco)systemic approach, applying recent advances in digital technology for the benefit of urban, environmental systemic balance and equilibrium?

2. Smart Cities as Cognizant Urban Systems

Recognizing the complexity and systemic interdependency of designed urban landscapes, natural systems, and cyber world, we are advocating an approach for systems-based and contextual (co)governance of urban challenges. Echoing the viewpoint presented by [12], smart cities can be understood as cyber-physical systems (CPSs). The essential features defining such systems are sensing and cooperative data collection, real-time data-driven optimization, and dynamic resource allocation [12]. What we are underling here is the notion of context-awareness, featured by feedback mechanisms, self-organization, and cyclical learning. Self-organization is in natural systems based on interactions between a system's parts and feedback mechanisms, which regulate its internal environment much as a living organism regulates, for instance, its body temperature [1,13]. In urban systems, self-organization is used to describe emerging structures or "patterns" of interaction, referring also to citizens' active and autonomous engagement in the production of their city, also known as 4th sector activity [14]. A citizen, who has the role of passive user or even an observed target, is an outdated utopia. Rather, smart citizens evaluate, recommend, interpret, and share experiences; give feedback; participate actively in the creation of smart urbanism; and engage in the cybernetic governance of urban space through generating data of location and activity, preferences, or even mood. Citizens are, in turn, informed by the urban dynamics and possibly optimize their individual behavior (for instance, by leaving their own car at home in case of traffic jams). This new urban awareness is transforming humans into living, breathing, remote sensor-generating cybernetic data points and flows of information, allowing the visualization, analysis, and experience of 'digital' spaces and 'active' places in the environment of a city simultaneously, as stated by [6]. Through a meshwork of material and virtual reality that significantly expands the agency gradient, cities of the future have the ability to sense and act, and even learn skills and develop [9]. Thus, in order to capture the multidimensional nature of what a smart city represents, the role of human lifeworld in cyber-physical systems must be recognized. Therefore, it is more accurate to speak of Cyber-Physical Social Systems [12].

A feasible ground for this kind of approach can be found within cybernetics, an interdisciplinary science for exploring digital, mechanical, or biological regulatory systems [15]. Classical cybernetics has, since its establishment in the 1940s, evolved into second or third order cybernetics, i.e., the cybernetics of observing (rather than observed) systems, which also concerns the principles of learning and communication [16,17]. Today, cybernetics has been considered useful over a wide range of fields related to complex systems, such as in game theory, bioengineering, or computer science. In line with the original meaning of the word, "to steer, navigate, or govern", cybernetics can be applied to examining the design and function of any complex system, including cities. However, cities are in a particular manner defined by individual urban experiences in space and time. Failing to recognize this aspect has been the weakness of cybernetics, as it was originally mostly focused on structure and form, leaving temporality and meanings to the observer's interpretation and insertion [17]. Since, cybernetics has evolved from simple function-form determinism into a more holistic direction. In Glanville's words, "Cybernetics is a way of thinking that bridges perception, cognition and living-in-the-stream-of-experience (the involvement of the observer), which gives important value to interaction and what we hold between ourselves and others—whether animate or inanimate" [17].

Defined as context-aware cyber-physical social systems, smart cities of the future are planned and managed with predictive insights with regard to urban risks and uncertainties, but with awareness of the positive urban affordances as well [18]. Such system may work towards goals and adapt to changing circumstances, navigate in uncertainty, and learn to adapt to inhabitants' individual needs, e.g., related to navigation, biological well-being, or sense of security. As an example, algorithm aided methods and design tools are currently being developed in University of Oulu School of Architecture, especially for designing adaptive lighting in urban contexts [19,20]. It could be everyday reality in our cities that intelligently controlled lighting is designed on the basis of multidimensional environmental experience of urban space inhabitants, especially pedestrians. The lighting would have the ability to respond to specific natural lighting conditions and climate. Intelligent systems can eventually learn where people mostly spent their leisure time based on movement, and attract citizens to social interaction increasing safety, pleasantness, and experiential quality in urban surroundings.

3. Towards Cybernetic Management of Smart Cities

Smart cities of the 21st century are putting their faith in data and its utilization possibilities with ubiquitous technologies [21]. Digital technology is transforming conventional three-dimensional space into cyber-physical-social meshworks. As stated by [22], augmented, virtual reality has constituted new temporality of cities, in which the future and the past can be present in a digitized "now". Further, this has denoted human existential change, as our embodied existence blends with virtual existence. Two scales of digital urban praxis thus become central: "the urbanite body and the city itself" [22].

As illustrated in Figure 1, the proposed new type of cybernetic awareness for smart city planning integrates the viewpoints of spatial structures to social and experiential structures. Consequently, the holistic cybernetic management model illustrates the ontological differences between the conceptual cities (1D-cities); bi-dimensional cities (2D-cities); three-dimensional cities (3D-Cities); and dynamic, spatio-temporal cities (4D-Cities). As development concepts, smart cities mostly focus on non-spatial features, such as smart services, smart management, or policies. Architecture and urban planning, however, primarily work with space, creating spatial solutions represented as square meters in two-dimensional x-y planes. Digitalization of the planner's drawing board has revolutionalized this with 3D-volumes and surfaces. Today, 3D-city models are visually high-quality mesh models offering even greater possibilities of virtual reality. As digital planning tools have been developed simultaneously with urban big data practices, 4D-modeling is one of the novel tools that enhance our understanding of the diverse time horizons of urban development and urban change in history, allowing speculations of the future as well. Unlike static representations, these type of dynamic models include the temporal dimension, and seasonality, which planners often forget while working with city plans.

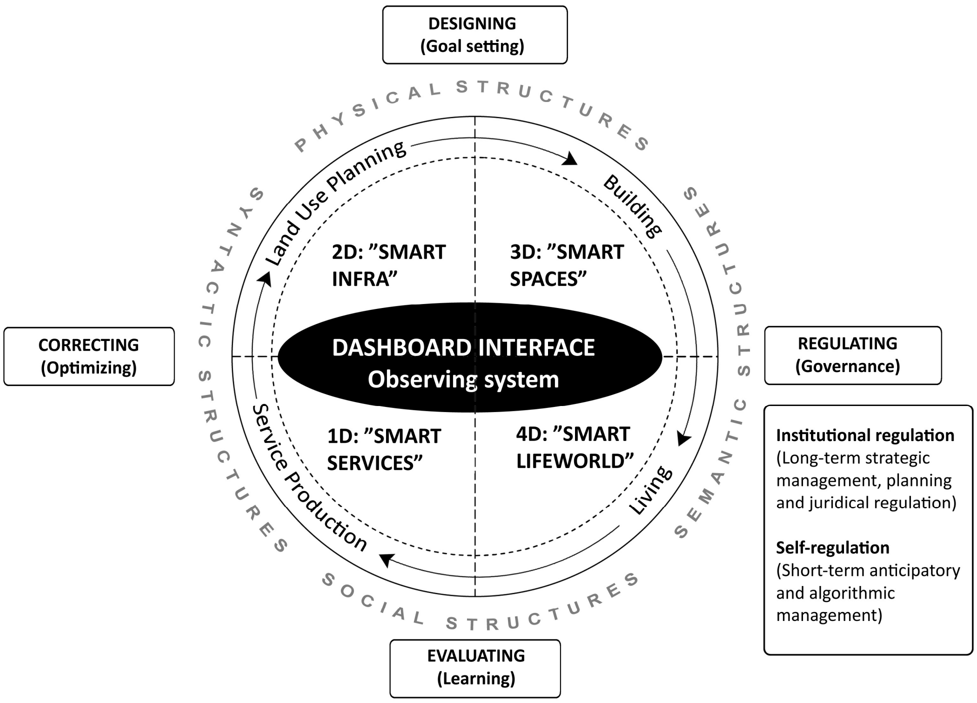

Figure 1. The dimensions of smart city services, infrastructures, spaces, and lifeworld, intertwined. 4D Smart City and cybernetic management system is both iterative and cyclical, and thus illustrated with a circular loop. The main components of the system are urban governance (the regulator) and city-scale practices (the regulator's program, plans), which aim to optimize spatial interventions based on urban information (feedback).

Inclusion of semantic content in urban data generation is enabled by the latest development in urban analysis practices based on the utilization of social media platforms. Integrating data of individualized urban experiences from flows of real-time geocoded social media content to sensor data from the physical environment adds temporal dimension to urban management and planning. Public streaming APIs capture semantic content as it is being generated by individuals in real-time, and facilitate an understanding of human behavior [22,23]. In the context of urban planning practices, semantic analysis helps us to gain knowledge about what kind of affordances and possibilities urban spaces offer, and what kind of rhythms and temporal layers urban spaces reflect and what kind of rhythms they force urban life to take. Gaining such a comprehensive insight into city operations is like putting 'one's finger on the pulse of a city' [24]. This multidimensionality considered, it is clear that different metrics should not be entirely based on technological performance or efficiency of smart systems but also on signification and meanings that help us to understand what happens where and when (and perhaps, why) things happen in cities [25].

A Dynamic Tool for Service Network Planning for the City of Kuopio

As urbanization continues, many cities in Finland are finding it difficult to keep providing the range of services that are required. So far, public organizations have viewed the state of their service networks in a project-like manner every 3–5 years, with the end product being static reports, which are often outdated as soon as they are printed on paper. Another concern is that cities are managed under multiple separate domains, and city officials have no single place to interact in real time or the ability to coordinate resources in anticipatory, rather than reactive, manner [4]. In general, network coordination has been complicated, as each department is operating in a disconnected silo [4]. Furthermore, city administration handles in its different departments vast amount of data, which is divided into silos, varies in quality, requires manual work with data entries, and is not up to date. Effective coordination of data would also necessitate a common platform that breaks technological and institutional silos [12].

Addressing these challenges, the city of Kuopio, with little under 120,000 inhabitants, recently launched a pilot project, called "Development and innovation of dynamic service network design model for public organizations (DigiPAVe)". According to the new city strategy, Kuopio seeks to have 200,000 residents by the year 2040. This would denote major yearly population growth and, consequently, significant pressures to the public service production. Kuopio's strategic, top-priority project, smart Savilahti urban infill project, is an integral part of realizing the strategic growth aims. It is the largest investment project in the history of the city, including approximately 1.5-2 billion euros of private and public investments. The area is expected to grow into a smart city district of about 35,000 residents, workers, and students by the year 2030. The challenge with Savilahti smart development and in many other cases is that smart services are conducted on a market-driven basis through digital platforms, and simultaneously the role of local governance and institutional planning in such an ecosystem is left ambiguous. The city itself will never have enough resources to keep up with tech/software development, nor it should; instead of top-down coordination, cities ought to seek new type of alliances with the market of technological innovations and hybrid governance models in common platforms. Importantly, cities should have a key role in clearing the way for the adoption of new disruptive technologies in service production. Major fundamental questions are still unanswered; What implications will, for instance, sharing economy or 4th sector activities have for the size and format of public service production in the future?

Even though service network planning is just one part of the large puzzle of public sector management and governance, it is a critical component to the aspired growth and vitality of the city. In the spirit of Kuopio's slogan "Permission to do otherwise", which entails bold new ways of doing things and ability to critically assess routine actions, the city has been motivated to improve the allocation of resources in service provision, and testing how to use a dynamic digital platform that integrates "business intelligence" on public services to building information andspatial data. The idea is to leverage information across all city agencies and present the information on a dynamic platform to facilitate insightful decision-making. In this vision, all the necessary data related to public service network planning is transactional, dynamic, and simultaneously widely used as "plug and play" in the same visual dashboard view. In addition, the city wants to increase its organizational cooperation capability, ensuring that everyone is on the same page in terms of far-reaching investment decisions. This means that the dynamic view on service network performance is dedicated not only for few experts but is also widely accessible to city authorities, decision-makers, and, eventually, it will be accessible even to the public. Ideally, planners and decision-makers can anticipate strategic implications with predictive analysis and thus improve the city's level of preparedness.

Even though the project in Kuopio is at a very early stage, and we are just starting to valorize the possibilities of dynamic dashboards and cybernetic management in public sector service planning, we are able to make preliminary conclusions about the required shift in thinking in service network coordination and management processes. First, as the operational environment is getting more and more complex, there is an urgent need to shift from single projects to continuous processes approach in service network planning. Secondly, global and national competition between cities necessitates resource efficiency and agility of the service network, enhanced usability of facilities, and better allocation of financial resources. In the private sector, especially in retail, companies have for a long time taken advantage of network-based spatial analysis tools in order to obtain a complete operational picture. Ultimately, optimal location is the "deal breaker" for successful operations. Why should not the same principal apply in public sector service production also, as we are handling millions of euros worth of public investments?

What Oulu and Kuopio have in common is that smart city approaches are seen critical for their ability to compete against the metropolitan development in southern Finland. Our criticism points towards the one-sided comprehension of smartness in urban environment, often assimilated with smart infrastructure and tech/software development. Smartness is not just about the convergence of different technologies, it is about convergence of syntactic structures (services and infrastructures) and semantic structures (perceived environment and life world). In other words, smart city development integrally needs to touch upon the life within the city, recognizing also the benefits of self-organized smart living concepts and "social smartness".

4. Discussion

Urban information flows first began to attract interest within urban design and planning during the 1960s and 1970s. The future of cities was captured in utopian concepts like the 'Plug-in-City', and in the ideal of comprehensive rationality design argumentation. This development continued from the late 1980s, followed by consequent futuristic concepts such as 'cyber cities', 'digital cities', and, lately, 'sentient cities' [24,26]. In terms of urban planning paradigms, "communicative turn", [27], "evidence-based turn" [28], and "complexity turn" [29] have resulted in new urban science and epistemology which is permeated by digitalization. It already plays an important role in urban management by helping to improve services, engage citizens, foster sustainability and resilience, solve urban issues, stimulate innovation, and grow the local economy [30,31]. It also enables and empowers self-organizing civic action [13]. In the era of data-driven urbanism, information is produced through sensing devises and various forms of ubiquitous technology embedded into the city fabric, and analyzed with algorithms and artificial intelligence. In the future, the highly dynamic nature of the urban environment calls for novel resource allocation mechanisms beyond conventional algorithms [12]. There is urgent demand to further develop dynamic, interactive, and interlinked visual analytics to show in real-time the state of play of cities [26,29]. Dynamic service network planning tool currently developed in the city of Kuopio can be regarded as an example of implementing this type of analytics in the public sector.

In terms of cybernetic management of urban development through monitoring, evaluation, learning, and open-ended strategies, it is relevant to ask: What is the role of institutional planning in the algorithmic age [13]? It seems that the use of big data is shifting the focus of institutionalized planning from longer term perspective to short-term management of cities [25]. Plans are turning more into snapshots of the desired development instead of static blueprints, and their focus is much more on temporality and movement than on the long-term configuration of the urban structure. This new turn requires new thinking in public sector governance, praxis, and legislation. Recent developments with Digital Urban Planning and related data infrastructure in Europe (EU INSPIRE–Directive) will shift planning into interactive platforms. Information-system-based planning is concerned with dynamic spatial information, works region-specifically, and includes policy-oriented strategic planning and design-oriented areal guidelines and building codes.

Techno-optimistic or not, urban planning is always goal-oriented, purposive, and intentional; planners are constantly trimming and adjusting their strategies to achieve better future. To use terminology borrowed from cybernetics, urban planner is a 'helmsman' who navigates a ship. A cybernetic system can work towards long-term strategic goals even though it constantly trims and adjusts actions at the operational level. However, as the scope of urban planning has (hopefully) expanded from a modernistic functional-structural space to temporal and even culturally produced semantic place, the paradox of planning is still embedded in its attempt to manage the unmanageable and to model and control the performance of a (living) system [17]. Demanding northern conditions are a good example, as they mostly deal with purely spatial and physical solutions (i.e., roofings and interior passages) that offer structural protection. These solutions follow a modernistic logic of attempting to manage the unmanageable (living) weather system, which does not necessarily support understanding climate as a part of a culturally and socially produced place. For instance, in the case of Oulu smart city, local climate and weather ought to be a productive point of view for design [32], not just a natural phenomenon to which people adapt (or protect themselves from) deterministically. Instead of thinking of cities as buildings in which everything is controlled, an alternative would be to see them more as landscapes [33], in which immaterial, partly unpredictable features are regarded as a part of the material design [34]. This kind of approach to urban smartness holds potential for providing more flexible, resilient solutions than the strictly spatial, atemporal, top-down measures.

To conclude, urban smartness is not about efficiency and control. Thus, the challenge with implementation lies within steering smartness towards tolerating and even supporting inefficiency. Otherwise, the city becomes an operating system, in which modernist ideals are only personalized to function ideally for everyone [35], and urban citizens are merely given the role of active sensing nodes or citizen-sensors [36,37] without power of their own. At the other end of the spectrum lies "city as commons", meaning city as a set of resources that belongs to the collective of citizens, perhaps even peer-to-peer technologies and systems without institutional parties [35]. Bottom-up and self-organizing urban groups and movements, whose core activities are supported by a novel variety of everyday digital tools, are already contributing to new types of citizen engagement in cities [38]. The observed impact of digital technologies to urban behavior further questions vision's strong emphasis on functional-structural measures and refill-building and mixed-use development. Networked social media and digital services change the importance of centrally located places and traditional urban logic based on location [39].

Yet, this development is by far the most unproblematic and there are also several unresolved questions concerning, e.g., the value-neutrality or instrumental rationality of information-system-based planning and cybernetic management. Another is concerning the illusion of over-simplification and partiality of dashboards, as noted by [30]: "Dashboards suggest that a city is simply the sum of its measures and be can be known, planned and controlled through data processes and algorithms alone; that a city is simply a system that acts in a 'rational, mechanical, linear and hierarchical' way and 'can be steered and controlled' much like a car is through its dashboard. Dashboards only visualize a sample of the data, which it is not by any means neutral, value-free or absolute representation of a city." Following the pragmatic line of thought, cybernetic management must search for acceptable paths rather than a simple optimum [17]. Designerly thinking is essential in dealing with complex challenges, as design almost always faces situations in which it has so many interrelated variables that the problems are essentially transcomputable. According to [17], the central task of the creative process is in (re)defining and simplifying variety so that it becomes manageable. He has even argued that cybernetics and design can be considered complementary arms of each [17].

It is quite obvious that most of the concerns of cybernetic urban management are related to questions of pervasive monitoring, privacy, and confidentiality [25]. Skeptics think we might end up with an urban dystopia of 24/7 surveillance and securitization, in which active citizens are subjected as urban sensors. Continuous monitoring, tracking, and identification of individual bodies coupled to automated facial recognition technology are seamlessly embedded across numerous cityscapes of the world today. However, we must recognize the danger of creating inequalities [22]. One rather evident example is the exclusion of elderly citizens in algorithmic aggregations, who 'do not [necessarily] register as digital signals', as [22] puts it.

To conclude, as the human interaction component has become increasingly important for planning processes, the notion of systemic imbalance caused by human actions necessitates increasing attention in smart city making. Cities definitely need strategies through which to govern and plan urban ecosystems in a more holistic manner, being aware of the balance between natural, designed, and digital systems. Smart city making in the era of ubiquitous technology, but also of complex problems and uncertainty, has been favorable soil to data-driven urbanism. Even though the comprehensive systemic benefits of cognizant, smart cities and data-driven urbanism still await their full realization, data utilization for increased urban smartness can certainly offer a potential medium through which to govern and plan a city. Advantages of cybernetic urban management and operating systems are clearly in real-time situational information for monitoring, analyzing, understanding, planning, and operating smart cities. The future of digital urban planning certainly denotes a significant change to our current process-oriented, hierarchical, and rigid planning practices. As stated by [13], what are indeed challenged are the top-down corporative smart city models.

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