Smart urban planning: modern technologies for ensuring sustainable territorial development

V Yu Spiridonov¹, S G Shabiev²

¹Ural Territorial Branch, Russian Academy of Architecture and Construction Sciences, 50a, Lenina ave., Yekaterinburg 620075, Russia
²Faculty of Architecture, South Ural State University, 76, Lenina ave., Chelyabinsk 454080, Russia

E-mail: shabievsg@susu.ac.ru

Abstract. The issues of improving the methodological foundations on urban planning based on the requirements of "smart" planning and managing sustainable development of territories are considered. The concepts of “smart urban planning”, “urban planning information platform”, “digital twin” of a territory and “cyber physical urban development system” are defined. A brief review of the world experience in adopting "smart" technologies for urban development is given. The paper sets the long-term problems associated with theoretical and practical development in the field. Finally, the authors propose the concept of "smart urban planning", aimed at providing comfortable and safe living conditions. It provides fundamental principles of goal-setting, planning and adopting the sustainable territorial development using information and communication technologies; a theoretical model of the urban planning information platform based on automation methods, adaptation conditions, as well as describing the “digital twin” layers of an urban development object.

1. Introduction

The technological growth, innovations, modernizing and digitalizing urban and regional resources and their systems is the basis for successful social and economic development, competitiveness and cooperation among the large cities and regions. Urban planning, as a key area in urban space management, focuses on “smart” technologies, which is enshrined in the law systems in the developed and developing countries. It is one of the goals of the United Nations Economic Commission for Europe (UNECE), Organization for International Economic Relations (OiER), International Organization for Standardization (ISO) etc. Urban planning development is based on implementing the international programs and projects for sustainable developing “smart” cities and communities, “smart” regions, including the “United Smart Cities” project [1]. It should be focused on the “smart” planning and management fundamentals in territorial development, based on the global priorities [2], as well as the current standards for developing a comfortable, safe and landscaped environment in large cities and regions [3].

For the last past decades, the urban planning development has been related with the systems theory [4-5]. It is currently based on the laws and principles of goal-setting, planning and sustainable development of territorial and spatial systems [6]. These complex systems are characterized by stochasticity, thus increasing the importance of research and concepts in forecasting their probabilistic
development [7-8]. In the context, informatization and digitalization directly affect the practice, as well as improving the methodological foundations of modern urban development.

Over the past decade, the world experience in the sphere of introducing and using technologies of “smart” planning and territorial development management provides the basis to analyze the results of its approbation [9], as well as to determine the prospects to develop the urban planning theory. The improved terminological apparatus, the structure of new principles and methods, innovative concepts, techniques and models should be the basis for the theory.

Methodologically, our study used urban planning and system theory laws and principles for “smart urban planning” in territorial development management; the principles of a systemic, civilized and strategic approaches, as well as the comparative analysis methods.

2. The main part

Today, we can witness many successful practices accumulated in digitalizing urban and regional spaces, using progressive technologies in urban planning and other related fields. These practices are based on safety, comfort, environmental friendliness and health standards, identity and diversity, current living environment, its efficient management with active participation of residents, business and the scientific community [10].

The study shows that the practices aim at meeting the international standards of “smart” cities and regions that serve as criteria for goal setting and assessing their success. The indicators system has been developed by the United Nations Economic Commission for Europe and the International Telecommunication Union (UNEC - ITU, 2015) [11]. The indicator scale for “smart” technologies and practices, as well as IQ of cities and regions is based on their certification based on the international standards ISO 37120: 2014 and 37151: 2015 (international registry of WCCD), awarding the status of “Smart City” by getting into the list of the International Club of Sustainable and Smart cities (ISSCC), Forbes ratings, PwC, Juniper Research, EasyPark, IESE etc. [12]. “Smart” technologies in urban planning are often the evaluation criterion, e.g. IESE Cities in Motion Index, 2019 [13]. According to the world ratings, the leaders of “smart” development are Singapore (1st position in the Juniper Research rating), London (Great Britain, 1st position in IESE rating), New York (USA, 1st position in PwC rating), Barcelona (Catalonia, Spain, 1st position in Forbes rating), Copenhagen (Denmark, 1st position in EasyPark rating). The list of “smart” cities includes: Oslo (Norway), Boston (USA), Zurich (Switzerland), Stockholm (Sweden), Shanghai (China), Amsterdam (Netherlands), Nice (France), Paris (France), Reykjavik (Iceland), Melbourne (Australia), Geneva (Switzerland), San Francisco (USA), Tokyo (Japan), Vienna (Austria), Berlin (Germany) and others.

The analysis of the global “smart practices” shows that successful digitalization models in territorial and spatial urban development focus on the introducing “digital twin” technologies, a geo-information platform and “cyber physical system”. At the same time, the most advanced digital models of urban development management today are the models of Singapore (Virtual Singapore), Amaravati (India), Boston (USA), Newcastle (Great Britain), Helsinki (Finland, Helsinki 3D +), Rotterdam (Netherlands), Renna (France, 3D Experience City), Antwerp (Belgium), Stockholm (Sweden, Open Cities Planner), Jaipur (India) and several other.

Using digital models to plan and manage territorial and spatial resources and systems has been studied in many research works. However, the issue of using the models in practice hasn’t been studied thoroughly yet. The problem is the unicity of each territory as a city-planning system [14].

The concept of a digital city model is directly related to the probabilistic development modeling of a territorial structure and its elements and testing the impact on the urban planning system in the shortest possible time without adding risks while experimenting with a real project. In this case, the digital model can aim at analyzing and systematizing the Big Data obtained, situational modeling a system’s behavior when changing the data of its subsystems or elements and digital “smart” modeling the long-term development of an urban planning system, its subsystems and elements [15].
Due to the unicity of each urban system and managing its development, there is no a unified interpretation of the terms “digital twin” of a city or region [16-18], «geographic information (city information) platform» [19-21], and “cyber physical system” of an urban space [22-24].

Based on the literature review and generalizing the specific knowledge in the urban development field, our study proposes the following aggregated definitions of the terms:

- “digital twin” is an interactive digital model of a city-planning object, implemented in the planning and management system based on a complex analytical urban information computer platform;
- “urban planning information platform” is an AI platform to manage big spatial data with automated information and analytical support to control the urban property and urban development as well as social and environmental fields;
- “Cyber physical urban planning system” is a complex distribution system of interrelated computing and physical elements (resources) of an urbanized object, which constantly receives data from the environment (through the Internet of Things, IoT) to optimize urban planning processes and urban development management.

The urban development theory is considered as a doctrine to design scientific fundamentals for creative planning, construction and architectural city development [25]. The theoretical and practical basis in the urban planning field that deals with developing the methodological provisions of the “cyber physical urban planning system”, “urban planning information platform”, urban “digital twin” and their interrelations are considered as “smart urban planning”.

The study proposes the concept of “smart urban development”. It includes primary targets, the principles of “smart” planning and management for sustainable territorial development and a theoretical model for the urban planning information platform.

“Smart urban planning” focuses on technological progress in the urban planning field based on increased efficiency of urban planning and territorial development management; transparency of managerial decisions; using innovative technologies to develop a comfortable, safe and improved living environment; increasing the residents satisfaction with architectural and artistic quality of urban and rural environments; developing new mechanisms to create unique and recognizable architectural look of a city or a region and their attractiveness; optimizing construction and maintenance costs; quick defects investigation in the urban planning sphere.

Thus, the main issues of “smart urban development” are as follows: increasing efficient and transparent managerial decisions to ensure an urban object life and development, its infrastructures using spatial resources; obtaining reliable and comprehensive information on urban system development; effective urban facilities registration and optimizing urban development changes; systematizing source information for urban planning and architectural modeling; designing territorial development based on the intellectual analysis of Big Spatial Data; improving the quality of urban zoning documentation and urban planning regulations; reducing construction time and simplifying construction procedures; 3D and 2D modeling and visualization based on the existing architectural and planning environment [26]; virtualizing planned ideas for the revitalization, reorganizing and renovating the developed planning elements; identifying and forecasting technogenic and natural emergency situations in the urban development field; forecasting the influence of other factors on the social and ecological environment and residents satisfaction with it; developing and using BIM technologies in construction; reducing construction costs based on digitalizing the processes of structures life cycles; using information systems to monitor the construction processes with video and photo controlling technologies, as well as effective mechanisms for construction quality checking; organizing the controlled access to registry data and ensuring data security; providing publicly available information within the legislation limits.

The study considers the principles of “smart” urban development planning and management, such as “Smart” urban planning; using “Smart” urban planning technologies to solve urban and rural problems; residents’ participation; business and scientific community participation; using digital
technologies to create comfortable living conditions; optimizing and harmonizing living environment; urban planning policies transparency; providing government regulation and control.

The proposed theoretical model of the urban planning information platform includes the structures of automation methods, its implementation conditions, as well as the detailed purpose characteristics of the “digital twin” layers for an urban developing object.

Based on the purpose, the following processes can be considered as objects of automated urban planning information platform: automated collecting and systematizing city property, urban planning and other spatial data (keeping registers); automated intellectual analysis and mapping the living environment based on the property, urban planning and other spatial data; automated modeling the urban and rural environment; interdepartmental spatial data exchange; providing open access to spatial data (metadata) and materials, as well as information used to provide services to the public.

Urban planning information platform can be provided by common subsystems and layers of the territorial “digital twin”. The layers structure includes a city or region property fund; urban planning cadaster and investment map; social, transport and engineering infrastructure; landscaping and gardening infrastructure; historical, cultural and natural heritage; tourism and recreation; non-permanent construction, small architectural forms, advertising and sign boards; reconstruction objects; layers of living environment; models of figurative identity; strategic urban development; urban project master plan; urban planning models to identify and predict emergencies; BIM-technologies in construction.

These layers characteristics are based on the analysis of implementing and using “smart” technologies in the field of urban development, presented in the Internet resources.

1. The “Property fund” layer includes the address and property register, technical information about real estate objects; financial indexation of the property complex; a platform to model the structural development of the territorial property fund.

2. The “Urban planning cadastre and investment map” layer uses the register of the planned land property including the information on its engineering and transport infrastructure), urban planning regulations, ideas for urban development; a platform to model the territorial investment structure.

3. The “Social infrastructure” layer covers the register of social infrastructure facilities, including their workload and availability maps; a platform to model the social infrastructure framework.

4. The “Transport infrastructure” layer uses the register of transport infrastructure, including traffic flows maps, technical and calculated indicators; a platform to model the transport framework.

5. The “Engineering infrastructure” layer includes the register of engineering facilities, including their workload and availability maps; investment programs data; plans of energy supplying organizations; a platform to model the engineering infrastructure framework.

6. The “Landscaping infrastructure” layer uses the register of landscaping objects; a platform to model green framework of the urban planning system.

7. The “Historical, cultural and natural heritage infrastructure” layer is based on the register of the cultural heritage security zones, construction and economic activities zones, protected natural landscape zones (e.g. historical objects, sightseeings); a platform to model historical environment revitalization.

8. The “Tourism and recreation infrastructure” layer uses the register of territorial image objects, business, cultural, entertainment and industrial tourism; recreation objects; a platform to model the tourist and recreational complex.

9. The “Infrastructure of non-permanent construction, small architectural forms, advertising and sign boards” layer includes the register of the objects; a platform to model their placement schemes.

10. The “Accessible environment” layer is a register of zones and objects accessible for people with limited mobility; a platform to model the structure of such zones and objects.
11. The “Construction and reconstruction objects” layer uses a register of constructed and reconstructed objects based on their technical specifications, architectural and artistic features; 3D-visualization (based on a 3D map); information systems platform to monitor the construction processes using video and photo control.

12. The “Figurative identity model” layer uses a register of unique architectural, artistic and spatial elements including the objects of historical and cultural heritage, a system of outdoor and public spaces, zones and territories with increased architectural and artistic requirements; 3D visualization of panoramas and perspectives; a platform to form a unique and recognizable image of a city or a region.

13. The “Model of strategic urban development” layer includes a register of strategic facilities and life support facilities, social and economic spatial clusters; a platform to model their development.

14. The “Development Masterplan” layer uses a platform for 3D and 2D modeling the territorial development based on the above layers, oriented to the population (non-professional persons); analytical platform of unrealized urban development projects.

15. The “Emergencies identifying and forecasting” uses a platform of technical indicators and maps analyzing the ecological state of urbanized and natural environment; a platform to predict anthropogenic and natural emergencies in the urban development field; a register and maps of the preceding emergencies.

16. The “BIM-technologies in construction” layer is based on a platform to introduce and promote BIM-technologies in construction process.

3. Conclusion

The study shows that the practical experience in introducing and using “smart” technologies for spatial planning and territorial development management requires reviewing the theoretical and practical issues of urban planning as well as developing a new field – “Smart urban planning”. It should include a system of the innovative terminological basis and concepts, theoretical models, principles, techniques and methods. It should use the latest innovative principles of goal setting, forecasting and implementing the sustainable territories development using information and communication technologies.

“Smart urban planning” aims at studying the methodological and methodological issues of a “cyber physical urban planning system”, an urban planning information platform, a city and region “digital twin”, as well as their relations. These innovative areas are the most promising in the urban development theory, practice and the related fields.

The concept of “Smart urban planning” presented, including priority targets, the principles of “smart” planning and sustainable development management, the theoretical model of the urban planning information platform can be used in the current urban planning and management activities.

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