Digital Twins of the Urban Ecosystem to Ensure the Quality of Life of the Population

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ABSTRACT

The development of digital twins of the urban ecosystem is gaining popularity and is the mainstream of the digital development of the territories of the world. Already today, there are domestic developments for the creation of digital twins, including the urban ecosystem. The aim of the article is to provide a theoretical description of the essence of the digital twin of a city and an overview of existing platforms for creating digital twins of an urban ecosystem to ensure the quality of life of the population. Research objectives: to identify the prerequisites for the creation of digital twins; to determine the essence of the definitional basis of the digital twin in the context of existing theoretical analogs; to characterize the conceptual foundations of creating digital twins of the urban ecosystem in Russia and the world, to identify the advantages of their development to maintain the quality of life of the population; to give an idea of the methodology for the development and functioning of digital twins of the urban ecosystem; to conduct a comparative analysis of the capabilities and functionality of digital platforms and technologies for the development of digital twins of the urban ecosystem; to conduct a comparative analysis of the existing digital twins of the urban ecosystem of the world. As a result of the study, data on existing domestic digital platforms and technologies for the development of digital twins of the urban ecosystem were obtained, their comparative analysis was carried out, advantages were identified, and the possibility of achieving technological leadership and competitiveness in this area in the world market was determined. Descriptive, analytical, and comparative methods were used as research methods. The results of the study showed that the use of digital twins of the urban ecosystem will allow municipal authorities to obtain effective levers of management, and the population - to ensure a high quality of their own life.

Keywords: digital twin, urban ecosystem, quality of life of the population, digitalization, digital economy, digital technologies

1. INTRODUCTION

Back in 1994, B. Lloyd and J. Naisbitt predicted that digitalization would become a megatrend in the modern economy based on the use of cybernetic management mechanisms and methods, digital technologies, and tools such as Big Data analysis and artificial intelligence [1]. The sagacity of scientists made it possible to predict the development agenda of the modern digital economy thirty years ago.

Other researchers are increasingly saying that modern society lives in the VUCA-world: the abbreviation is formed from the first letters of English words meaning variability, uncertainty, complexity, and ambiguity. In fact, this means the acceleration of all ongoing social processes not only in the economy, but also in other spheres of life [2, 3]. If the primitive society observed serious changes in its way of life every 10000 years, then further this range was increasingly reduced and reached the marks of 1000 years, 100 years, 1 year. Researchers

suggest that by 2038-2050 society will enter a point of technological singularity, in which changes will occur every minute.

Futurologists give contradictory assessments about how the accelerating world affects modern man. For the most part, they still emphasize the fact that a person, by the essence and psychological characteristics, is not able to change themselves so quickly under the influence of the external environment and is experiencing more and more stress [4]. In this regard, digital technologies (primarily Big Data and artificial intelligence) are designed to reduce the technogenic burden on the life of a modern person.

According to the definition of the World Bank, the digital economy is a system of economic, social, and cultural relations based on the use of information and communication technologies [5]. It can be stated that digitalization, to one degree or another, covers all sectors of the economy, which is confirmed by many studies, while this trend will continue to grow.

According to calculations by the Institute for Statistical Studies and Economics of Knowledge of the National Research University "Higher School of Economics" (Moscow, Russia), the contribution of digitalization to Russia's GDP will increase from 1% in 2017 to 18.4% by 2030, and the contribution of the information industry will increase from 0.1% to 2.3% for the same period [6].

According to the results of the RBC study in 2021, digitalization in Russia has mostly covered b2c companies. Among b2b companies, the highest level of digitalization is observed in the banking sector, trade, and the telecommunications industry. The automotive industry turned out to be at the middle level of digitalization (largely due to the existence of representative offices of international companies). Problems in adapting to digital reality are faced by the following: the fuel and energy complex (highly regulated industry and a lack of private initiative), metallurgy (due to the need for significant investments in conditions of regular crises), healthcare (conservative regulatory framework), mechanical engineering (low competition and customer requirements, most often represented by the state) [7, 8].

G.B. Kleiner, a corresponding member of the Russian Academy of Sciences, claims that humanity will enter the digital economy when every object of the world is accompanied by its digital model in the computer memory. Such a model will be created before the object itself appears and will continue to work after the object ceases to physically exist [9, 10].

Speaking about the digital economy and modern digital technologies, it is impossible not to mention the active development of the national technology initiative (NTI) markets in recent years. The criteria for identifying such markets are the following: significance on a global scale (expressed in the amount of more than 100 billion US dollars by 2035); lack of development at the moment (or the presence of an embryonic stage); orientation to the needs of people and the growth of the quality of life (b2c); replacement of intermediaries with control software; the presence of ambitious technology entrepreneurs in Russia who are ready to shape the supply for future demand. The number of NTI markets is constantly changing, most often they include Aeronet, Autonet, Marinet, Neuronet, Healthnet, Foodnet, Energinet, Technet, Safenet, Finnet, Edunet, Homnet, Gamenet, Medianet, Travelnet, etc. Development of concepts and hypotheses of NTI markets takes place within the framework of 20.35 accelerators organized by the University on the territory of Russia.

So, according to the results of the Foresight "Archipelago 2121", which took place in August 2021 in Veliky Novgorod (Russia), the hypothesis of the HomeNet market was developed, which includes the following components:

- modeling of life (systems for modeling socio-economic and technological space);

- inclusive city plan (Design Standards 3.0 "Living Urban Plan", which allows changing the city quickly to meet the needs of residents);

- adaptive spaces (a radical increase in the comfort of life through the design, construction, operation and disposal of modular, changeable and quickly modernized spaces);

- autonomous logistics;

- urban traffic ecosystem (optimization of transport operation);

- "first mile" of waste management (reuse);

- new mobility (new ways of moving people and goods);

- neoSOL (security through transparent mechanisms).

All these components fit into the concept of the

development of a smart city and a digital twin of the urban ecosystem, which ensures the quality of life of the population, especially regarding the formation of an inclusive "living" urban planning plan [11].

The digital twin of the urban ecosystem should integrate the capabilities of most modern digital technologies: Big Data, artificial intelligence, new production technologies, sensors and robotics components, wireless communication technologies, neurotechnologies, virtual and augmented reality (AR / VR) technologies, etc.

2. MATERIALS AND METHODS

The purpose of the article is to conduct a comparative analysis of these platforms and services to create digital twins of the urban ecosystem to ensure the quality of life of the population.

Research objectives:

- to identify the prerequisites for the creation of digital twins;

- to determine the essence of the definitional basis of the digital twin in the context of existing theoretical analogs;

- to characterize the conceptual foundations of creating digital twins of the urban ecosystem in Russia and the world, to identify the advantages of their development to maintain the quality of life of the population;

- to give an idea of the methodology for the development and functioning of digital twins of the urban ecosystem;

- to conduct a comparative analysis of the capabilities and functionality of digital platforms and technologies for the development of digital twins of the urban ecosystem;

- to conduct a comparative analysis of the existing digital twins of the urban ecosystem of the world.

To achieve the set goal of the study, data obtained from open sources were used, first – the official websites of manufacturers of platforms for digital twins of the city. Descriptive, analytical, and comparative methods were used in the work.

3. RESULTS

Several mathematicians consider the term "digital twin" to be a newfangled name for mathematical imitation models known in science for a long time [12]. Simulation mathematical modeling is a numerical method for studying complex systems, the elements of which are described by a heterogeneous mathematical apparatus and are united by a connecting information model. Meanwhile, the creation of such a model (corresponding to the concept of a "digital twin") is an expensive method of research due to its uniqueness (each model is a piece product), it allows the initial data to be formed in such a way that they cannot exist in real nature (system operation in an emergency or nonexistent mode, crash tests).

The term "digital twin" was popularized in 2003 by M. Grieves, Assistant Director of the Center for lifecycle and innovation management, who described it in the article "Digital twin and manufacturing excellence based on a virtual plant prototype". M. Grieves argued that the use of the digital twin occurs throughout the entire life cycle of a product to ensure a high level of quality for consumers. However, the term itself was coined by a little-known NASA engineer [13].

General Electric was the first to use digital twins to analyze and improve the efficiency of its wind turbines and aircraft engines. To date, the company has created over half a million digital twins for a wide range of products, processes, and systems. Then they were introduced into their work by Boeing, Airbus, Siemens, Dassault, and others. NASA tests each new equipment first in a virtual environment. Devices are not physically manufactured until their digital counterparts meet all required specifications.

M. Grieves wrote that a visual repetition of the original object's appearance is desirable, but its absence is not critical. Much more important is that the object should behave realistically during various tests, as well as the possibility of obtaining information generated using artificial intelligence, with an assessment of the current state of the object. Both points also describe the traditional application of the simulation model to solve real-world problems [14].

Thus, a digital twin is a digital representation of a product, process or service used to monitor, analyze, and improve its performance; "a bridge between the physical and digital world". The drivers of the development of the city's digital twins are technologies of "Big Data" and the "Internet of Things" (IoT) [15].

The architecture of the digital twin of the city contains three levels: the base level, where data is collected (on movement, carbon dioxide emissions, noise level, information from networks and sensors); the level of data processing in the integrated center; the level of receipt of processed comparable information into the digital twin of urban infrastructure, transport network, urban ecology, energy, etc. [16]

At the primary level, IoT devices and sensors provide the generation of a constant stream of data for analysis and can support the ability to control remotely. At the second level, "foggy calculations" are performed, which are performed by servers next to cameras, clusters for data preprocessing. At the third level, "cloud computing" is performed, the results of which are used for storing Big Data, analytical data processing and forecasting.

The digital twins of the urban ecosystem fit into the well-known concept of a "smart" city - ie. a city where the efficient use of resources helps to reduce costs and save energy, improve the quality of services and life, and reduce the harmful impact on the environment.

In 2019, the Ministry of Construction of Russia approved the "Smart City" standard, which included eight priority areas: city management; Housing and communal services; IoT for the urban environment; smart public transport; urban and environmental safety; accessible communication; service and tourism. The most illustrative example of the implementation of the "smart city" concept is adaptive traffic light control systems that promptly react to traffic situations and change the intensity of traffic flows (similar systems are available in Madrid, Mumbai, Quito).

Thus, the digital twin of the urban ecosystem is the sum of the "Smart City" and "Digital Twin" concepts. The digital twin of a city is a prototype of a real city, based on which it is possible to analyze the life cycles of an object and its reaction to possible changes and external influences. In addition, there is the possibility of making changes at the stage of modeling and design, which, in turn, leads to minimization of errors, since any number of tests becomes acceptable [17].

The following platforms for creating digital twins are known now: Dassault Systemes (the world's leading developer of digital solutions); 3DEXPERIENCITY platform (used to create digital twins for Singapore, Rennes, and Jaipur); Smart City (allows determining accurately the physical location,

nature and depth of existing underground assets and communications); DigiCity; LLC "Digital Twin"; platforms of the Urban Planning Institute "Giprogorproekt" and other scientific organizations [18].

Most digital twins differ in the number of city layers they offer and are capable of developing. Thus, the Moscow company DigiCity offers a digital twin of the urban environment with the following layers: lighting networks; water supply; forest belts; heating network; reservoirs; agricultural fields; addresses of residents. The module "Appeals from residents" allows reporting promptly on the problems of city life related to housing and communal services, amenities, urban infrastructure (parking, transport, parks, etc.) through a public link, QR-code or mobile application. This module provides the collection of Big Data for their subsequent processing using artificial intelligence.

One way or another, a dispatcher is involved, who, having received requests, distributes them between services and departments, allocates responsible persons. As a result, an integrated report on the execution of the request is generated. Filters can be used to mark the number and status of requests [19].

There are also open technologies for the formation of digital maps such as Cesium, which allows fixing infected with covid in the form of a heat map.

The Russian company Digital Twin LLC provides a wider range of services, which includes:

- providing scientific justification for the feasibility of urban projects;

- carrying out technical and economic expertise (allows analyzing the level of efficiency and effectiveness of financial and economic activities of the city, individual industries and municipal enterprises);

- risk assessment (formation of ratings of reliability and productivity of organizations carrying out projects at the expense of the city budget and city residents);

- feasibility study of projects;

- formation of plans and forecasts for the development of urban infrastructure;

- identification of "thin" places, crisis situations [20].

The list of object layers is expanded to include a geolocation data registry; functional areas; cadastral value of objects; resettlement and sex and age structure of the population at home; technical parameters of houses; objects of heat supply, water supply, sewerage, social, cultural, and domestic purposes, transport infrastructure, landscaping; layers of territorial division; class diagrams.

Initially, the company carries out the classification of municipal facilities, carrying out the classification of buildings, facilities of municipal services, territorial zones. Also, the company's resources allow creating a visualization of the flow of the city's fuel and energy resources.

There are many scientific projects that are currently creating digital twins of the urban ecosystem using grants. For example, Moscow State University of Geodesy and Cartography in 2021-2022 is creating a digital twin of the Novomoskovsky district of Moscow with funds from the "Umnik" grant from the "Fund for Assistance to the Development of Small Forms of Enterprises in the Scientific and Technical Sphere" [21].

Project goal: development of a digital model of the city using 3D geotechnology and augmented reality to solve the problems of business and city services on a preliminary assessment of the impact of the ongoing construction project on the existing infrastructure of the city.

The project involves the following tasks:

- development of a database (assumes automatic integration of data editing tools with a database for storing data; development of an administrator interface; data collection by means of GIS; development of a 3D environment);

- visualization of the collected data in a 3D environment (generation of landscapes, roads and buildings based on a database; creation of imitation of automobile and pedestrian traffic, sunlight and sound environment; development of 3D models of typical and unique buildings; imposition of 3D models on a map, texturing; manual processing terrain);

- development of analysis tools (setting up the output to virtual reality mode and 3D map mode; creating an algorithm for calculating traffic based on demographic data, digitized terrain data and information about the building; ensuring the output of traffic simulation based on the results of the traffic calculation algorithm);

- registration of a small innovative enterprise (SIE).

Based on the analysis of the existing digital twins of the urban ecosystem, it can be seen that they are rarely complex and completely universal. As a rule, their functioning is aimed at a targeted solution of problems specific to the city. So, the digital twin:

- Stockholm (Sweden) – allows predicting and visualizing various scenarios of the behavior of the public at large city events;

- Rennes (France) – provides interaction of residents with the municipality;

- Rotterdam (Netherlands) – solves the problems of water transport management, waste disposal, fire-fighting operations;

- Helsinki (Finland) – for example, creates an atlas for calculating and visualizing the solar energy potential of the city or makes a digital analysis of the effect of wind on high-rise buildings (the digital twin is open to any user);

- Newcastle (UK) – provides protection of infrastructure and residents of the city from natural disasters;

- Boston (USA) – allows determining the acceptable height of buildings near the historic center;

- New York City (USA) – uses a digital progress map for all projects and city initiatives;

- Dubai (UAE) – helps the authorities to monitor the state of the city in real time using IoT sensor networks (Dubai Pulse platform – "digital skeleton");

- Barcelona (Spain) – increases the efficiency of government in municipal administration;

- Lisbon (Portugal) – is created to simulate floods;

- Jaipur (India) – provides geolocation; it was made by residents after the city administration forbade Google to create a map of this area;

- Amaravati (India) – appeared even before the construction of the city itself.

Urban Development Institute "Giprogorproekt" has developed a digital twin of Kronstadt (St. Petersburg region), a development project for Vladivostok, Murmansk (Russia) [22].

But digital twin of the city-state of Singapore remains the largest and most complex digital twin in the world [23].

The "fashion" for digital twins of urban ecosystems could not bypass the capital of Russia. City strategy of Moscow "Smart City 2030" includes several directions:

- human and social capital (medicine, social support, education, culture);

- urban environment – "smart" planning of urban space and housing and communal services;

- digital mobility – creating a smart roadmap;

- city economy – introduction of innovations in finance, production and trade;

- safety and ecology – using digital twin to ensure various types of safety;

- digital government – city management based on Big Data analytics, digital workflow to ensure the openness of the work of authorities and government agencies.

4. DISCUSSION

The effectiveness of using various digital platforms to create digital twins of the urban ecosystem is still controversial in the scientific and practical environment, the activities of municipal authorities. Nevertheless, digital platforms created by domestic manufacturers are objectively more suitable for Russian cities, which is due to several advantages:

1) taking into account the Russian legal regulatory framework when creating infrastructure layers (especially in the urban planning part);

2) Russian-language interface and support service in Russia, convenient solution of controversial issues, including in court;

3) possibility of a more expeditious departure and research of the terrain in order to collect and verify information for the digital twin of the urban environment;

4) development of domestic information technologies, contribution to GDP, budgetary

effect, job creation, ensuring technological leadership and competitiveness in the world arena.

Thus, the use of domestic technologies to create digital twins of the urban ecosystem to ensure the quality of life will allow Russian technology companies to ensure sustainable development and innovative leadership.

5. CONCLUSION

The term "digital twin" is an analogy of the well-known imitation mathematical objects and is a digital copy of an object of the physical world. The popularization of digital twins in the industrial, and later in the socio-economic sphere is dictated by the needs of the development of the digital economy as a system of social, economic, and cultural relations based on the use of information and communication technologies; the entry of mankind into the era of the rapidly changing "VUCA-world", the development of markets for the national technological initiative (in particular, HomeNet).

The development of digital twins of the urban ecosystem to ensure the quality of life is not a "fashionable" trend, but an urgent need for the development of urban infrastructure and its transformation to meet the needs of the population in the digital economy. In this sense, the development of domestic technologies for the development of digital twins of the urban ecosystem, capable of providing:

- technological leadership and competitiveness to Russian companies;

- possibility to automate and optimize the work of services and departments to municipal authorities;

- possibility to get real tools of digital interaction with authorities, informing about their problems, which contributes to the achievement of a higher quality of life to the population.

AUTHORS' CONTRIBUTIONS

The authors made an equal contribution to the study: collection and analysis of material; definition of goals and objectives, research methods; formulation and scientific substantiation of conclusions, registration of key research results in the form of an article.

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