Achieving the principles of sustainable development: implementation of smart solutions in the infrastructure of modern megacities

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Abstract. City residents get the opportunity to develop a comfortable and safe living environment with the effective use of smart infrastructure. First of all, this concerns the digitalization of the housing, energy, construction, and public transport sectors, the large-scale use of integrated digital platforms in city management, and control over environmental protection. Therefore, the governments of many countries are actively looking for ways for the balanced sustainable development of megacities, one of which is the policy of developing smart megacities using IT infrastructure. The purpose of the study is to identify promising areas for the development of smart infrastructure in the sustainable development of megacities. Using qualitative methods, the main opportunities for the development of digital infrastructure have been identified to achieve the principles of sustainable development, including opportunities for the development of smart infrastructure to improve an environmentally sustainable megacity, directions for solving transport and traffic problems, improving the efficiency of the waste disposal system and developing the smart energy consumption. However, the authors note that when implementing smart solutions, it is necessary to minimize the possibility of intentional human influence on the safety of the population or the creation of man-made threats, since the vital activity and safety of cities largely depends on the effective functioning of digital technologies.

1 Introduction

Megacities have become a place of choice for citizens seeking stability, adequate social security, and quality education, which has led to a gradual migration of the population from rural areas. The number of urban residents exceeded the number of rural residents for the first time in the history of mankind in 2008. According to [1], about 30% of the world's population lived in cities in the 1950s, this percentage increased to 55% in 2014 (3.5 billion people) and is expected to continue to grow, reaching 68% in 2050.

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Megacities are becoming centers of wealth creation, the combination of globalization and localization processes, i.e. international relations and national opportunities, create opportunities for global economic growth, forming 85% of the world GDP. There will be 43 megacities in the world with more than 10 million inhabitants each by 2030 [2].

In the long term, the well-being of megacities and their inhabitants is determined by the effectiveness of planning and development of urban areas [3], infrastructure in them, minimizing risks [4], and meeting the needs of a growing population [5]. Therefore, the high density of megacities inevitably leads to problems, including traffic congestion [6], increased energy consumption and greenhouse gas emissions [7], the need for waste disposal [8], as well as an increase in crime and the spread of antisocial behavior [9]. These trends are accompanied by an unprecedented increase in demand for water [10] and land resources [11], construction materials [12], and food [13]. From year to year, megacities need to improve the quality of services, improve the system of providing administrative services, and solve environmental problems [14].

Therefore, the Sustainable Development Goals include the need to "ensure openness, security, resilience and environmental sustainability of cities and towns" where residents have a decent standard of living [15].

In this connection, researchers consider the activation of the development processes of smart megacities as one of the main trends for achieving Sustainable Development Goals [16]. Megacities strive to achieve sustainable development thanks to smart networks, smart administration, a system of smart urban transport [17], water supply and waste management [18], as well as security [19].

2 Literature review

The problems of managing the growing areas of megacities and providing their residents with the necessary services are widely considered in the scientific discourse [20], modernization processes that make megacities more sustainable [21], as well as measures that strengthen the ecological, social and economic structure of megacities, without neglecting the renewal of historical and cultural heritage, by modernizing infrastructure and introducing digital technologies [22].

Researchers [23; 24] focus on the issues of smart urban planning of megacities, which is based on the development and implementation of smart infrastructure. According to [25], effective planning for the development of the megacities environment creates conditions for increasing competitiveness and also contributes to leveling negative development trends [26, 27].

The need to solve the problems of urbanization, combined with the obvious potential of a profitable market for technology and telecommunications companies developing digital solutions, gave rise to the popular concept of smart cities today [28], which was supported by the leaders of countries and individual cities, as well as international institutions and organizations [29].

Although the concept of a smart city is promising, there is a discourse about what characteristics or requirements define a smart city or what people should expect from it. Thus, according to D. Washburn et al. [30], the city makes reasonable the combined use of software systems, hardware, and network technologies to improve services in the field of local government, education, healthcare, public safety, construction, transport, and utilities. Similarly, R.P. Dameri [31] recognizes the importance of sensors, networks, algorithms, and other technological advances for the design, construction, and maintenance of urban infrastructure. Their goal is to create a safe, eco-friendly, green and efficient city. Harrison et al. [32] define a smart city as an urban area that uses operational data (data from traffic) to optimize work. In their definition, they emphasize the importance of (1) obtaining real-time data from physical and virtual sensors, (2) the relationship between various services and technologies within the city, and (3) data analysis, optimization, and visualization.

The development and implementation of the smart city concept remain one of the main directions of megacities development in the advanced country of the world [33; 34]. Different interpretations of a smart city reflect its various aspects, but they are based on a similar vision – territories with a high standard of living, a favorable ecological environment, and high rates of economic development [35]. Most definitions include the use of digital technologies to improve the efficiency of services, and the integration of ICT and IoT sensor solutions for managing city assets and processes [36, 37]. The most common in smart cities is the use of digital technologies, such as building information modeling [38, 39], the constant increase in Internet speed [40; 41], the Internet of Things [42; 43], big data [44; 45], cloud services [46; 47], AI – to solve demographic, economic, environmental and social problems of megacities [48-52]. In general, smart megacities can be interpreted as a megacity, where the management system is aimed at improving the quality of life of the population through the digitalization of various spheres of life.

It is important for a smart megacity to have a digital infrastructure, due to which large amounts of data are collected/processed to create an efficient and sustainable environment [53]. The combination of various sources of disparate data allows the megacity to develop a real understanding of social problems, such as sustainability, mobility, health, and safety, to provide a real-time understanding of what transport and energy flows, pollution levels and human behavior are [54-57]. However, on the other hand, high dependence on digital technologies affects the life and safety of the population when used in cases of intentional human actions or man-made accidents. For example, the use of special algorithms can contribute to the manipulation of populations, in cases where they initially contain data that do not reflect the full variety of realities, artificially increasing the weight for some factors affecting the development of megacities and underestimating the importance for others. An equally important problem is the high dependence on digital technologies, which can lead to serious disruptions in the life of cities. For example, "interference with GPS has a significant impact on the work of businesses, primarily car-sharing and taxi services, as well as the daily life of citizens" [58-61].

The purpose of the study is to identify promising areas for the development of smart infrastructure in the sustainable development of megacities.

3 Methods

A qualitative approach to research was chosen due to the novelty of the phenomenon under study and the research nature of the goal. We tried to answer the following research question in this article: What are the possibilities of digital technologies in the infrastructure of a megacity to achieve the principles of sustainable development?

We identified an indicative set of theoretical and empirical research methods to achieve the goal set in the study:

- theoretical generalization in substantiating the advantages of the digital infrastructure of a smart megacity to achieve the principles of sustainable development;
- an expert survey in establishing the possibilities of digital technologies in the infrastructure of the megacity to achieve the principles of sustainable development.

In the first stage of the research, we conducted a selection of scientific sources following the purpose of the study, which was carried out according to the Web of Science and Scopus international databases using the keywords "sustainable city", "sustainable megacity", "smart city", and "smart megacity" with a restriction on the publication date not older than 10 years.

An expert survey was conducted at the second stage of the study, with an offer to participate in which emails were sent to 45 experts from Russia. The criterion for the selection of experts was the presence of their publications on the research problem in peer-reviewed publications of at least three articles. Thus, 41 people agreed to take part in the survey, who were then sent emails with a research question and expressed a desire to provide answers in free form.

After receiving the answers, a second letter was sent to the experts, in which it was proposed, depending on the level of significance of certain capabilities of the digital infrastructure of the megacity to achieve the principles of sustainable development obtained as a result of the survey, to place them on a scale of order, after which the rank of each of them was determined.

The degree of consistency of expert opinions with mathematical processing of the results was measured using the Kendall concordance coefficient (W) for a more objective analysis of the data obtained during the expert survey. Further, the information obtained during the expert survey was processed to determine the weights.

4 Results and discussion

The results of the expert survey showed that digital technologies in the megacity infrastructure form a variety of opportunities to achieve the principles of sustainable development (Table 1).

Table 1. Opportunities of the digital infrastructure of the megacity to achieve the principles of sustainable development

No.	Digital infrastructure capabilities	Rank	Weight
1	Environmental impact	1	0.33
2	Smart mobility	2	0.27
3	Smart waste management	3	0.22
4	Smart energy consumption	4-5	0.09
5	Smart use of water resources	4-5	0.09

Note: compiled based on the expert survey; the value of the concordance coefficient $W = 0.73$ ($p < 0.01$), which indicates a strong consistency of expert opinions.

Let us take a closer look at the possibilities of the digital infrastructure of a megacity to achieve the principles of sustainable development (Table 1).

Environmental impact. As noted in studies [22; 46], urbanization negatively affects the overall state of the environment. In particular, environmental damage due to the inability to control emissions is serious and most common [6].

An efficiently designed and managed smart infrastructure can contribute to the environmental sustainability of a megacity [5]. Due to IoT and AI technologies, megacities in real-time can determine in detail the biggest problems of air pollution, the causes of their occurrence, as well as the impact on residents [6]. Air quality sensors can be placed on public vehicles, streetlights, benches, and garbage cans [41]. For example, Hangzhou (China) is known for the intelligent city system City Brain. All the city's data for analysis has been fed into the general monitoring system using smart sensors since 2016. Due to this system, the authorities will receive the necessary information about emergencies, which allows them to notify residents in advance of the onset of probable crisis phenomena [47].

Smart mobility. Urbanization and population growth in most megacities give rise to problems of movement around the city, since with an increase in the number of private and public transport, traffic jams on highways become longer [17]. Smart solutions for traffic management in megacities solve traffic problems and help eliminate congestion. The system tracks traffic and estimates the arrival time of the next group of cars before the green traffic light. The adaptation of traffic lights to real road situations allows for solving the problem of congestion.

Smart traffic management systems can also be extended to public transport [48]. All types of public vehicles can be connected to a single database, which allows users to be notified of the arrival time, and allows them to choose the optimal routes [36]. Smart solutions are used to apply a combination of timetables and IoT data of public transport to find the optimal way to travel. Programs, determine the location, and calculate the distance and time needed to get to the destination. It is possible to reduce travel time by an average of 20% in megacities where smart mobility applications are implemented [41].

It is also appropriate to note the smart systems on the roads that use technology to read traffic flows and regulate speed limits in real time, which allows for controlling traffic. The result is an increase in the capacity of the motorway without the need for its physical expansion, as well as a reduction in travel time, reduced pollution levels, and fuel use.

In addition, megacities can optimize parking spaces using real-time parking sensors (using IoT and AI), which can show drivers where the nearest parking lot is located [29].

The most striking example is 5G parking with AI. This development is used to improve the efficiency of parking in Shenzhen (China). There are more than 3.5 million vehicles registered in the city, and only about 1.7 million parking spaces. To solve this problem, local authorities are working with corporations to improve the efficiency of using existing parking spaces in hospitals, tourist spots, transport hubs, airports, commercial areas, etc. For example, drivers can easily reserve a parking space near a hospital at the same time as planning a visit to a doctor. That is, drivers do not need to worry about the availability of parking spaces and arrive in advance. If there is no parking space at the appointed time of the doctor's appointment, drivers can choose another convenient method of transportation for themselves. Such an intelligent system allows planning efficiently and saving time [34].

Smart waste management. Waste collection and recycling is one of the largest items of annual expenditures of megacities [3; 62-69]. One of the disadvantages of the waste management system is the inability to predict the frequency of their removal. This issue can be solved by using digital technologies.

The system of rational waste management allows for reducing waste volumes and ensuring their sorting by types, and sources of education, as well as developing methods of their proper processing. The smart solution is to equip garbage containers with sensors that determine the volume of waste. The data obtained allow us to optimize the number of garbage trucks and their routes. Smart solutions in the waste disposal sector, as an example, are provided by Rubicon and are available on the global Geotab market [21]. The goal is to help customers streamline their waste and recycling operations to achieve the SDGs. The set of technologies is aimed at helping the city authorities to carry out waste disposal and recycling operations more efficiently.

Smart energy consumption. Applications of sensors, smart meters, digital control systems, etc. provide automation, monitoring and optimize energy distribution and energy consumption [6, 49]. Such systems make it possible to optimize the functioning and operation of networks by balancing the needs of various subjects: consumers, manufacturers, and suppliers.

The energy smart infrastructure has several innovations, such as:

- distributed production from renewable energy sources. Traditionally, electricity is produced by large installations operating based on fossil fuels. Distributed generation based on renewable energy sources will lead to an increase in the number of small-capacity producers that can be used as a reserve;

- smart power grids. New generation power grids that can simultaneously produce and consume electricity. They allow not only to transport energy but also to generate and send data to end users. It is predicted that among the regions of the world, the Asia-Pacific region will experience the fastest growth in the introduction of smart grids, which will allow it to become the largest market for the development of smart network technologies [34];

- microgrid is a local area network with local energy sources and loads, which can work as part of the metropolitan network, but also separately. Microgrids help to reduce energy losses during transmission and distribution;

- intelligent measurement. An innovative example of this smart service is smart metering: a smart meter records electricity consumption at intervals of one hour or less and sends this data to a utility company. Thanks to such meters, consumers are involved in energy-saving measures, especially when demand is at a peak level;

- fast-reacting devices – a solution to reduce energy demand during peak hours. For example, household appliances such as washing machines and dryers may temporarily stop consuming energy when demand for it (and prices) increases.

Smart use of water resources. Smart solutions in the water sector are aimed at improving the level of water quality. The operation of a physical water supply system is combined with the use of information networks. This system usually analyzes the available flow and pressure data to detect leaks in real time. For example, smart water meters were installed in Mumbai (India), during the modernization of the water supply system that can be controlled remotely [35]. The following are among the main results of smart infrastructure in the water supply sector of megacities:

- leak detection: equipping the distribution network with sensors to provide real-time information on pressure, flows/leaks, and water quality;

- pollution detection: the use of sensors to measure the quality of surface water in real-time, which contributes to the sustainable development of megacity resources;

- water infrastructure maintenance planning: various data sources are combined (for example, flow and pressure sensors in pipes).

5 Conclusion

The introduction of smart solutions in the politics of modern megacities is a grandiose public socio-political project. Smart megacities can provide an answer to the challenges arising from the increase in population density and the constant impact on residential and transport infrastructure, waste management, water quality, and energy networks. It is necessary to actively develop ICT in combination with other factors in the development of the city's infrastructure to achieve all the sustainable development goals of a smart megacity.

The combination of digital technologies and the physical infrastructure of the megacity provides new opportunities for the development of smart infrastructure, which has the task of efficiently using the resources of the urban environment by all its participants to ensure a more comfortable, safe, and environmentally friendly life. The main argument in favor of smart infrastructure facilities is compliance with the needs of society while simultaneously implementing the concept of sustainable development.

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