INVESTING IN INTELLIGENT SMART CITY TECHNOLOGIES

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Abstract. Modern information and communication technologies are becoming the basis for a new quality of cities, the organisation of a comfortable living space in cities, improving the quality of life of the population, ensuring sustainable development and improving technology as a tool for implementing these tasks. The implementation of all these measures requires significant investments, which makes it necessary to find various ways of diversifying financial sources and mechanisms. *The purpose* of the article is to identify modern investment processes in the development of smart technologies of the world's smart cities in the conditions of large-scale digitalisation. *Methodology.* Graphic visualization methods are used to characterize trends in the penetration of the latest ICT technologies into the life of cities, the growth of the ICT market in smart cities, including 5G technologies. *The methods* of system analysis and generalisation allowed to determine the main directions of investment in smart city technologies and to identify the processes of formation of the newest forms of investment. *Practical implications.* The generalisation of the smart city practice made it possible to identify the following basic technologies necessary for the formation of a smart city ecosystem: Internet of Things (IoT), artificial intelligence (AI), Big Data, cloud computing, etc. These technologies are used to improve the quality of life, increase the efficiency of the economy and infrastructure, ensure community safety and promote the sustainable development of the smart city. These key areas require significant investment: communications infrastructure (5G network); traffic management systems; energy efficiency; security and surveillance systems; electronic service management. Global investment in smart city technology is predicted to increase many times over in the coming years. *Value/originality.* The need to attract significant investment in the development of the city's digital infrastructure has led to the emergence of the latest financial technologies that have widened the range of opportunities: direct investment, venture capital, corporate investment, corporate partnerships, state and local funds, crowdfunding, bonds, fintech, blockchain, etc.

Key words: smart control systems, smart infrastructure, digital technologies, Internet of Things (IoT), artificial intelligence (AI), 5G technologies.

JEL Classification: G24, G28, O33, R51, R53

1. Introduction

The spread of the practice of creating smart cities in the countries of the world is due to the actualisation of the issues of organising a comfortable living space in cities, improving the quality of life of the population, ensuring sustainable development and improving technology as a tool for implementing these tasks. Modern technologies are becoming the basis for creating a new quality of cities. Solving all the problems of urban development (transport, water and air quality control and purification, waste collection, disposal and processing, resource use, energy efficiency improvement, security, etc.) will be possible with the large-scale use of the latest information and communication technologies. Smart Cities will implement intelligent waste management systems (to reduce the amount of waste and optimise the process of its collection and recycling), smart lighting systems (which ensure automatic switching on of lights depending on the light and reduce electricity costs), sensors of the quality of air, water and other environmental resources (allowing for the reduction of carbon dioxide emissions), and many others.

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The implementation of all these actions requires significant investment. Firstly, the development of the latest technologies and products based on them, which allow performing various functions (listed above and many others), requires investment. Secondly, the implementation of these means in the daily life of the city is also quite expensive, it requires significant funds, which are not always within the power of individual municipalities. Therefore, the search for various ways of diversifying financial sources and mechanisms is an urgent problem of modern economic science and practice.

2. Review of Researches

The topic of smart cities is very relevant in the modern world scientific literature. The research of the nature of smart cities, their characteristics, features, factors of development and success is devoted to the works of numerous scientists: M. Angelidou (Angelidou, 2016; Angelidou, 2017), A. Andrijenko (Andrijenko, 2018), R. Giffinger (Giffinger, 2019; Benchmarking, 2021), A. Greenfield (Greenfield, 2013), I. Kalenyuk, I. Uninets, L. Tsymbal (Kalenyuk, 2022), A. Caragliu (Caragliu, 2011), P. Lombardi (Lombardi, 2012), A. Pleshkanovskaya (Pleshkanovska, 2021), etc. The problems of the role of ICT in the development of the smart city ecosystem are studied by: Z. Chen, I.C.C. Chan (Chen, 2023), J.A. Dias (Dias, 2022), T. Nam & T.A. Pardo (Nam, 2011), A. Pozdniakova (Pozdniakova, 2017; Pozdniakova, 2019). At the same time, the problems of the development of smart cities, the role of ICT, investment and others still have a lot of room for further research, which makes them very relevant.

The purpose of the article is to identify modern investment processes in the development of smart technologies of the world's smart cities in the conditions of large-scale digitalisation.

3. Results

The development of the latest technologies is at the heart of the creation of a new digital space that makes up the ecosystem of a smart city. Smart cities use data and digital technologies to improve the quality of life, increase economic and infrastructure efficiency, ensure community safety and promote sustainable development. Key advanced technologies include the Internet of Things (IoT), artificial intelligence (AI) and data analytics. Investing in the development of smart cities is an important step towards improving the quality of life of citizens and optimising the functioning of cities. They are typically implemented in the following key areas:

1. Communications infrastructure. Building a powerful and reliable communications network, such as broadband internet access, is the foundation for deploying smart technologies in cities. Investing in the development of 5G networks and expanding the coverage of communication networks can ensure fast data transfer and facilitate the connection of various smart devices.

2. Transport management systems. Smart management of transport infrastructure can improve mobility, reduce congestion and ensure road safety. Investments in intelligent signalling systems, vehicle tracking, electronic payment systems and intelligent parking can contribute to the development of intelligent transport.

3. Energy efficiency and sustainability. Smart cities can be designed to optimise energy use and reduce negative environmental impacts. Investments in renewable energy sources, smart grids, energy efficient lighting systems and energy monitoring can help reduce energy costs and environmental impact.

4. Security and surveillance systems. Smart cities can use intelligent cameras, sensors and data analytics to keep the community safe. Investment in video surveillance, facial recognition, early hazard detection and air quality monitoring systems can help improve the safety and well-being of residents.

5. Electronic management of services. The development of platforms for the electronic management of city services, such as e-government, online payment systems, mobile applications with access to city information and services, can facilitate the interaction of residents with the city administration and improve the efficiency of service delivery.

These areas are just some of the many opportunities for investment in the development of smart cities. A key aspect is public-private partnership and public involvement in the decision-making process. Investing in smart cities can improve the quality of life for citizens, make cities more sustainable and efficient, and contribute to further sustainable development.

Investing in the development of smart city technologies cannot rely on the municipal budget alone, as it requires quite significant investments to attract various technologies implemented at different levels. According to Deloitte estimates, public-private partnerships are the most popular of all possible funding sources (Figure 1).

However, in practice, investment in the development of smart cities (in advanced technologies and innovations to improve the lives of residents, optimise resources and increase the efficiency of the urban economy) takes the following forms:

1. Direct investment. This includes own financial investments in smart city projects. An investor may invest in specific projects or companies developing smart city technologies.

2. Venture capital. Financing of start-ups and young companies developing intelligent technologies.
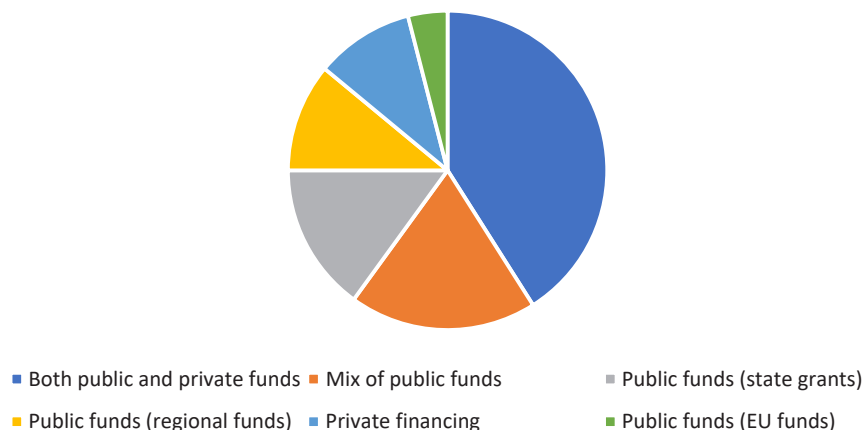
Figure 1. Financing/financing options commonly chosen by smart city projects

Source: (The challenge of paying for smart cities projects)

The investor takes a stake in the company and hopes for its continued success and market entry.

3. Corporate investment. Many large companies invest in smart technologies that can improve their operations or meet strategic goals. This may involve setting up their own innovation departments or funding external projects.

4. Corporate partnerships. Major companies can enter into partnership agreements with other organisations developing smart technologies. This can include joint funding and cooperation in the development and implementation of smart city projects.

5. State and local funds. Governments can create funds and funding programmes for the development of smart cities. These can be grants, subsidies or competitive funding for start-ups and companies working in the field of smart technologies.

6. Crowdfunding. Investors can fund smart city projects through crowdfunding platforms. This involves raising money from many individuals who contribute small amounts in exchange for a stake in the project or other types of rewards.

7. Stocks and municipal bonds. Governments can issue shares or municipal bonds to finance smart infrastructure. This provides an opportunity to invest in smart city projects and receive income in the form of interest from bonds (He, 2020).

8. Fintech. Smart technologies are extending to financial services, with the latest technologies (fintech, blockchain, etc.) creating more opportunities and investment options thanks to new tools and platforms.

These are just some of the forms of investment in smart technologies for the development of smart cities. The choice of a particular form will depend on the investor, its objectives, the scale of the investment and the regulatory conditions in a particular region.

The development of technology is key to the functioning of smart cities. In general, research shows that spending on technology in the development of smart cities around the world will increase from 2018, and this growth is expected to more than double by the end of 2023. So, in 2018, the cost of smart city technologies amounted to about 81 billion USD, by the end of 2023 this indicator will amount to 189.5 billion USD. This expenditure is aimed at forming a system of sensors to automate a range of services to achieve better performance, reduce costs and environmental impact, forming the vertical of the Internet of Things, which is used to define a network that connects not only people, but also objects around them (He, 2020).

The main characteristic of smart cities is the use of digital technologies to improve the quality of life. In practice, the composition of the main components of "smart cities" can vary significantly, as it is based on the needs of the residents of a particular city. One of the most important programmes of a smart city is mobility. The use of smart technologies that provide mobility, municipal services, health care, security, and community involvement in management are becoming important priorities in the future of smart cities (Index score of leading smart cities worldwide in 2019).

Smart city technologies are one of the trends in the formation of global markets, and the projected global revenue from smart city technologies, products and services will reach 89 billion USD. US in 2023, which includes revenues from companies that use information and data technologies to create greater value for society in the urban environment, such as providing the necessary infrastructure (such as cloud computing and connectivity) to enable cities to use these technologies (Projected revenue generated by companies in the global smart city from 2020 to 2028). In general, experts estimate that the size of the smart city market will grow from 511.6 billion USD in 2022 to 1,024.4 billion USD. in 2027, with a growth rate of 14.9% over the period (Smart City...).
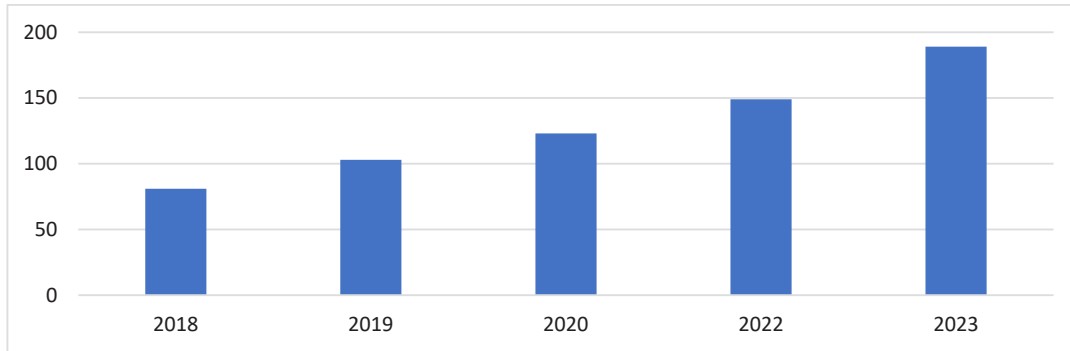
Figure 2. Technology spending in smart city initiatives worldwide, 2018–2023, billion USD

Source: (Technology spending on smart city initiatives worldwide from 2018 to 2023)

One of the key prerequisites for ensuring techno-logical development is 5G technology, a new technology of information dissemination based on fundamentally new technological solutions, and such coverage is only beginning to spread in the system of smart city development (Figure 3).

5G technology has gained momentum, and according to forecasts from 2019 to 2027, the number of 5G subscriptions worldwide will increase dramatically from over 12 million to over 4 billion. Northeast Asia, Southeast Asia, India, Nepal and Bhutan are expected to have the highest number of subscriptions by region. Increasing the number of technology deployments will be a prerequisite for the development of the Internet of Things.

5G (fifth generation) communications is expected to drive growth in the Internet of Things (IoT) market in the coming years, as the new mobile technology will connect machines and devices with higher data rates, ultra-low latency, and increased availability. By 2023, connected cars are expected to form the largest installed base of 5G IoT endpoints worldwide, with more than 19 million installed endpoints. Outdoor surveillance cameras and fleet telematics devices are also key drivers of the 5G IoT endpoint install base [forecast number]. In general,

estimates suggest that by 2030, China will have the largest number of IoT-connected devices (more than 8.6 billion in total), followed by European and North American countries (Figure 4).

The IoT market is growing rapidly and experts predict that by the end of 2027, the global Internet of Things (IoT) enterprise market will grow to 483 billion USD. In 2022, market revenue from this technology reached 201 billion USD for the first time, and forecasts show that this figure will grow to around 238 billion USD by 2023 (Forecast Enterprise...).

In general, the Internet of Things is defined as a promising niche for investment funds, which covers a large number of aspects of the functioning of cities and can form its own ecosystem. The rapid development of IoT technologies is increasing the need for intelligent security solutions, including perimeter intrusion detection systems (PIDS), efficient energy management solutions, development of transport infrastructure in smart cities, minimising carbon emissions and optimising routes. Investment in upgrading aging infrastructure is widespread, with India planning to invest 7.51 billion USD to transform 100 existing cities across the country into smart cities. In 2016, the United States allocated
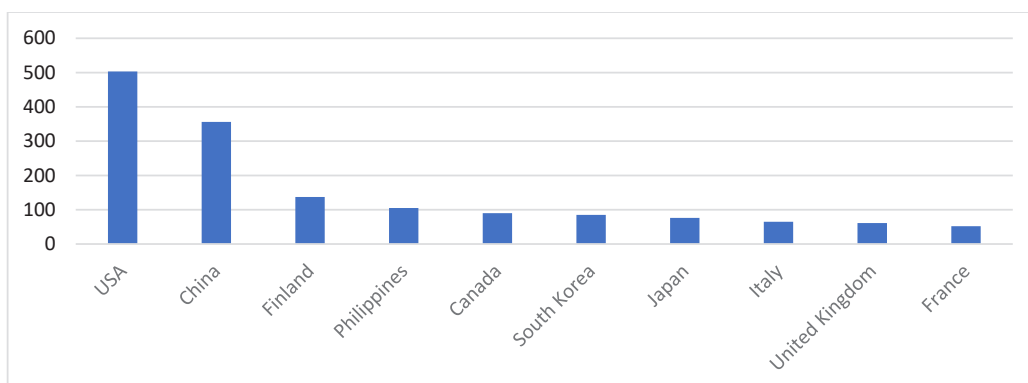
Figure 3. Number of cities where 5G will be available in 2023 by country

Source: (Number of cities in which 5G is available 2023 by country)
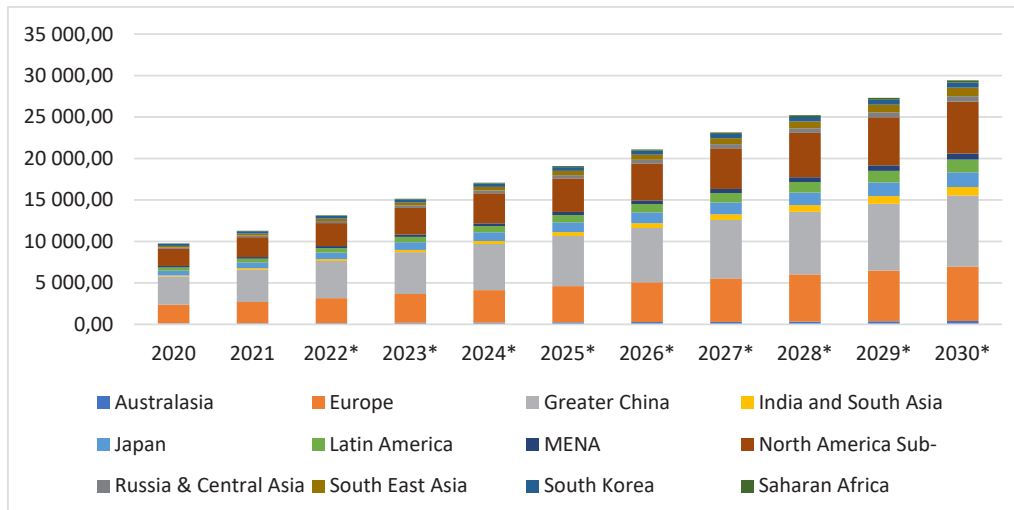
Figure 4. Number of devices connected to the Internet of Things (IoT), 2020–2030 (in millions), by region

Source: (Number of Internet of Things (IoT) connected devices from 2020 to 2030 (in millions), by region)

165 million USD for the development of smart city technologies. This funding will contribute to the development of the Smart Cities initiative and the Internet of Things market (IoT…).

One of the key issues is the need for significant capital investment in the initial infrastructure, as well as the need for major investment in technology development. One example is 5G technology, which will be used not only for mobile communications but also for the creation of an intelligent digital infrastructure. In this context, one of the key roles of local authorities is to invest in the transformation of urban infrastructure. Monetisation of these systems is one of the tasks of central government, which can ensure the profitability of such investments, as smart solutions reduce operating costs and increase the efficiency of the infrastructure.

Examples of large-scale government support for investment in digital and smart infrastructure can be seen in cities such as Amsterdam, Chengdu and Masdar City. In general, however, the North American market is the most dynamic in the development of IoT in the smart city market. The US and Canada have a stable and developed economy, which is a key prerequisite for the formation of a portfolio of investments in scientific research activities, the development of new technologies, the expansion of telecommunications networks, the transition to 5G infrastructure, the development of peripheral computing technologies, the introduction of IoT in smart cities to reduce the costs of strategic city management. Overall, experts expect the global IoT market in smart cities to grow from 130.6 billion USD in 2021 to 312.2 billion USD by 2026, representing a compound annual growth rate (CAGR) of 19% (IoT...).

Smart Cities IoT technologies are supported by city authorities in the United States, according to the Smart Cities Development Programme, city authorities are investing about 41 trillion USD over 20 years to upgrade infrastructure, increase its intelligence and improve efficiency. For example, Intel and the city of San Jose, California, are working together in a public-private partnership to implement the Intel IoT Smart City Demonstration Platform to support the city's Green Vision initiative (SMART CITIES USA). This will help stimulate economic growth, create 25,000 clean tech jobs, ensure environmental sustainability and improve the quality of life for citizens. By installing a network of air quality, sound and microclimate sensors, Intel and San Jose are creating a "sustainability lens" for the city, using IoT technology to measure characteristics such as airborne particulate matter, noise pollution and traffic flow. City leaders will use this information to improve air quality, noise levels, transportation efficiency, environmental sustainability, health and energy efficiency.

The rollout of the 5G network will provide 20 times the data transfer of the 4G network and 10 times the network connection density, opening up significant opportunities for innovation and economic development. This creates significant prospects and economic opportunities in many industries, particularly retail, agriculture, manufacturing, healthcare, housing and utilities. By supporting networks that can reliably perform complex tasks at high speeds, 5G will reduce the limitations imposed by 4G on edge computing, artificial intelligence and the Internet of Things (IoT), enabling deeper and more efficient use of these technologies. In the US alone, the introduction of new

technologies is forecast to add up to 1.5 trillion USD to GDP by 2025. USD to the national gross domestic product (GDP). In California alone, 5G deployment is expected to generate 253 billion USD and up to 2.39 million jobs, with New York and Texas also projected to add more than 130 billion USD to GDP (5G in the United States …).

In general terms, modern technologies are already enabling the creation of an infrastructure that can be used to ensure the operation of a digital ecosystem of a new quality and level, from mobile phones to sensors. An increased level of functionality is becoming a key factor in the choice of devices that can perform tasks in the modern technological space. For example, 79% of respondents consider the availability of 5G to be a valid argument when choosing a mobile device, leading to an increase in the share of mobile phones with 5G from 3.3% to 13.5% in just half of 2020 (5G in the United States …). At the same time, the expansion of the 5G coverage network is taking place, which is seen as a competitive advantage for the creation of significant economic benefits. It is estimated that by 2030, the increase in GDP due to 5G technology alone will amount to 484 billion USD in the US (in 2019 indicators), and 220 billion USD in China (5G contribution …). Accordingly, the number of users of such a network and the number of subscriptions will increase from 14.42 million in 2020 to 411 million in 2027 (5G in the United States...). Looking at the regional breakdown, the average impact of 5G will be between 0.35% and 0.51% of total GDP, depending on the region (Mid-band …).

The increased download speed makes it easier and faster to transfer high-definition media files in densely populated areas, out of range of Wi-Fi access points and in other situations. This enables integrated management of a large number of connected devices and points in a smart society, providing lower technology costs, lower energy consumption, improved communication support and ensuring its stability. This, in turn, provides opportunities for the development of IoT functionality, such as self-driving cars, smart factories, management of urban systems, and more (5G – statistics...). For example, the network of connected cars in the 5G network alone will amount to more than 19 million installed endpoints, but also important elements in this network are external surveillance cameras, telematics devices, city traffic management sensors, and so forth (Forecast number …).

Investing in smart cities takes the form of an environmentally responsible attitude, which is in the paradigm of creating a smart economy as a whole. Such investment solutions have significant development potential and are forecast to grow to almost 600 billion USD by 2030 in cities around the world. In 2021, investment in green solutions will amount to only 28 billion USD, a figure that has the potential to grow to 113 billion USD by 2030 (Infrastructure investment outlook for cities worldwide by 2030, by infrastructure type).

4. Conclusions

Smart cities use the Internet of Things (IoT), artificial intelligence (AI), etc. to improve the quality of life, increase the efficiency of the economy and infrastructure, ensure community safety and promote sustainable development. Investments will be made in the following key areas: communication infrastructure (5G network); traffic management systems; energy efficiency; security and surveillance systems; electronic management of services.

According to experts, the size of the smart city market will double between 2022 and 2027. One of the key prerequisites for ensuring technological development is 5G technology, a new information dissemination technology based on fundamentally new technological solutions, and such coverage is only beginning to spread in the Smart Bridge development system. 5G technology has gained dynamic penetration and will contribute to the growth of the Internet of Things (IoT) market. The Internet of Things is a very promising niche for investing funds in smart cities, covering a large number of aspects of their functioning and allowing the formation of a separate ecosystem.

The development of urban infrastructure, including digital infrastructure, requires significant investment. Accordingly, there is a growing need for investment in the modernisation of outdated infrastructure, investment in initial infrastructure, and greater investment in technological development. Investing in the development of smart city technologies cannot rely on the municipal budget alone, as it requires significant investments to attract different technologies implemented at different levels. In practice, however, investment in the development of smart cities (in advanced technologies and innovations to improve the lives of residents, optimise resources and increase the efficiency of the urban economy) takes the following forms: direct investment, venture capital, corporate investment, corporate partnerships, state and local funds, crowdfunding, bonds and municipal bonds, fintech, blockchain, etc.

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