Gentrification. 2025; 3:85
doi: 10.62486/gen202585
ISSN: 3046-4137

ORIGINAL

Smart city concept: Integrating technology into municipal governance

Concepto de ciudad inteligente: Integración de la tecnología en la gobernanza municipal

Olha Yatsun[1]

[1]Department of Law, State University "Kyiv Aviation Institute". 03058, 1 Liubomyra Huzara Ave., Kyiv, Ukraine.

Cite as: Yatsun O. Smart city concept: Integrating technology into municipal governance. Gentrification. 2025; 3:85. https://doi.org/10.62486/gen202585

Submitted: 22-02-2024 **Revised:** 12-07-2024 **Accepted:** 22-12-2024 **Published:** 02-01-2025

Editor: Estela Hernández-Runque

Corresponding Author: Olha Yatsun

ABSTRACT

The article highlights the basics of the Smart City concept. The author considers general theoretical approaches to its understanding and analyzes the constituent elements of this phenomenon. The author systematizes statistical data on Smart Cities and theoretical foundations. The analysis of these factors made it possible to identify the advantages and disadvantages of Smart Cities. In addition to identifying them, the author of the article proposed specific steps to overcome or minimize their impact on the safety and life of citizens. The article also focuses on specific examples of European cities and analytical data on the advantages of certain smart projects. The work emphasizes that Ukrainian initiatives within the framework of the Smart Cities concept are promising, but fragmentized. The novelty lies in citing specific initiatives taken as an example of implementation in European cities with statistically proven effectiveness and their application in Ukraine. The author also takes into account those elements that are already functioning and those that need to be expanded. In addition, attention is focused on those initiatives that are not yet fully functioning in Ukraine. The author paid special attention to the importance of implementing the Smart Cities Concept in the post-war reconstruction of the country.

Keywords: Economic Growth; Public Administration; Smart Technologies; Sustainable Development; Urbanization.

RESUMEN

El artículo destaca los fundamentos del concepto de ciudad inteligente. El autor considera los enfoques teóricos generales para su comprensión y analiza los elementos constitutivos de este fenómeno. El autor sistematiza datos estadísticos sobre las Smart Cities y fundamentos teóricos. El análisis de estos factores permite identificar las ventajas y desventajas de las Smart Cities. Además de identificarlas, el autor del artículo propone medidas concretas para superar o minimizar su impacto en la seguridad y la vida de los ciudadanos. El artículo también se centra en ejemplos concretos de ciudades europeas y en datos analíticos sobre las ventajas de determinados proyectos inteligentes. El trabajo subraya que las iniciativas ucranianas en el marco del concepto de ciudades inteligentes son prometedoras, pero fragmentarias. La novedad radica en citar iniciativas concretas tomadas como ejemplo de implantación en ciudades europeas con eficacia estadísticamente demostrada y su aplicación en Ucrania. El autor también tiene en cuenta los elementos que ya están funcionando y los que deben ampliarse. Además, la atención se centra en aquellas iniciativas que aún no funcionan plenamente en Ucrania. El autor presta especial atención a la importancia de aplicar el concepto de ciudades inteligentes en la reconstrucción posbélica del país.

Palabras clave: Crecimiento Económico; Administración Pública; Tecnologías Inteligentes; Desarrollo Sostenible; Urbanización.

INTRODUCTION

Urbanization began a long time ago and is taking place rapidly worldwide. According to the UN, as of 2021, half of the world's population lives in cities. In addition, the UN predicts that by 2050, 7 out of 10 people will live in an urban area. At the same time, cities are the drivers of economic growth. They generate more than 80 percent of global GDP. At the same time, they account for more than 70 percent of greenhouse gas emissions. Therefore, the UN notes that proper planning and management are key to creating sustainable, inclusive cities. The basis for the functioning of smart cities should be clear and transparent urban planning (Hajduk, 2016). In addition, the high population concentration in cities raises important issues for municipal authorities regarding the rational use of resources and comfortable living conditions. All of this has led to the fact that, in recent years, urban organization has become a relevant area of research (Pereli, 2023).

Given its high relevance, information and communication technologies are an effective tool for improving urban infrastructure. Modern solutions allow collecting, analyzing, and promptly using data to make informed management decisions (Krasyliuk, 2024). This helps to reduce costs and improve the environmental performance of cities significantly. In addition, the integration of innovative technologies contributes to social transformation. It involves the community in the decision-making process through electronic platforms and services. The opportunity to actively participate in city development strengthens the democratic dimension of urban governance. It also builds trust between the authorities and citizens.

The study's relevance is also manifested in the current situation in Ukraine, namely in the context of Russian armed aggression. Military operations have led to extensive destruction of Ukrainian cities. In addition, local government reform processes have not been completed. For the effective recovery of Ukrainian cities, the Smart City concept should be applied in reconstruction and development plans. In addition, it should also be applied to cities that are less damaged but require a qualitatively new development. Thus, the effective development of Ukraine requires a thorough review of the basis and concepts of public administration of urban development. In addition, the analysis of international experience is also intended to show the advantages and disadvantages of applying this concept. So, the study of introducing innovative technologies in municipal governance is hugely relevant for both large and smaller metropolitan areas.

METHOD

Over the past decade, the issue of smart cities has gained popularity. This is mainly due to the development of new technologies. Accordingly, this concept has not gone unnoticed by scientists. Scientists around the world are actively studying the concept of smart city. Its popularity is due to the rapid development of technologies that have become key tools for solving urban problems. Scientists such as Mohanty et al. (2016) and Anthopoulos (2017) emphasize integrating the Internet of Things, Big Data, and artificial intelligence to optimize urban processes. The European Commission (2023) emphasizes that smart cities aim to improve the efficiency of traditional networks and services through digital solutions. Such solutions benefit residents and businesses.

At the same time, studies such as by Silva et al. (2021) emphasized the importance of the environmental component. It is this component that ensures sustainable development and rational use of resources. Analysis of recent statistical data, such as reports from the European Commission (2023), indicates the rapid growth of the innovative technology market and the significant economic and social impact of their implementation. However, studies also reveal several challenges. Thus, recent studies confirm both the advantages and disadvantages of the Smart City concept. It requires careful analysis and adaptation to specific conditions.

This concept is particularly relevant in the Ukrainian context, given the need to restore destroyed cities and modernize infrastructure. Ukrainian scientific works continue to study the Smart City Concept. However, there are almost no works that would trace the impact of martial law. In addition, no scientific works have considered implementing the Smart City Concept in the post-war reconstruction plan of Ukraine. Therefore, the article highlights these issues.

RESULTS

The Smart City concept is being studied quite actively today, but many open issues remain. In addition, the active development of technology creates new opportunities for developing this concept. There is no exact date for the formulation of the Smart City concept. It is generally accepted that its beginnings in the national environment date back to the 1990s (Anthopoulos, 2017). At that time, the first ideas about the possibility of using the latest technologies in urban development began to emerge. This concept became widely used in urban planning in the 2000s (Pereli, 2023). However, it began to be widely discussed in academic and political

circles in the first decade of the 21st century. A significant impetus for the popularization of this approach was the Smart Planet initiative of IBM in 2008 (Paroutis et al., 2014). Back then, the company presented several real-life examples of innovative technologies.

Even among scholars, there is no single approach to defining the Smart City Concept (Mohanty et al., 2016). Nevertheless, various aspects of Smart Cities can be considered. For this purpose, it is important to understand the essence of this concept and its constituent elements. The European Commission notes that a smart city is a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and businesses.

Researchers from India note that Smart Cities are a center for innovation and economic development (Manoharan et al., 2023). US researchers have noted that a smart city is where traditional networks and services become more flexible and efficient by using the latest technologies. They are used to improve functioning for the benefit of citizens. In other words, in a smart city, digital technologies are transformed into better public services for residents (Mohanty et al., 2016). The Smart City concept can be understood as a combination of competitiveness and sustainable development goals. In particular, it is manifested in the areas of administration, management, governance, and communication. The dominant idea is a high level of urbanization and environmental and technological development, achieved through infrastructure modernization.

The Smart City concept is fundamentally about using data and technology to optimize various aspects of urban life (Adenekan et al., 2024). Smart cities integrate a multitude of digital solutions to collect and process data in real time. This leads to sustainable development and the creation of safe living conditions in such cities (Lea, 2017). The concept's essence is to create an urban environment that leverages information technology to ensure comfortable living for its residents. These innovations also aim to ensure security and efficient resource use. The key idea is that data collected from various sources is quickly analyzed and transformed into useful information for decision-making, ultimately optimizing urban infrastructure operations, reducing costs, and ensuring sustainable development.

Smart cities worldwide have diverse characteristics and components (Mohanty et al., 2016). As the Smart City Concept envisages the comprehensive use of modern technologies, one of the key elements is the Internet of Things. This component is emphasized by most researchers (Mohanty et al., 2016; Dziundziuk, 2023; Gramchuk & Nikitenko, 2023). This can be explained by the fact that accurate environmental data is collected in the urban environment. This information forms the basis of decisions that allow for a quick response to problems and anticipate possible problems in advance.

This technology implies that the collected data is extensive, so Big Data processing technologies come to the rescue. These technologies provide fast processing and analysis of the data received. They can also identify patterns and make informed management decisions. Artificial intelligence also functions alongside them. It can analyze recurring situations and identify possible risks. Based on the data obtained, it provides the most convenient solution to the problem.

E-governance, a crucial aspect of Smart City development, empowers citizens by enhancing communication with authorities through digital services and mobile applications. Digitalization facilitates access to information about city services and processes, allowing users to not only avail of services but also participate in city improvement surveys or propose initiatives. Another key element of the Smart City concept is environmental and energy conservation, which is realized through the introduction of modern technologies and monitoring systems. However, the linchpin that ensures the functioning of all these elements is cybersecurity, given the vulnerability of Smart Cities to cyberattacks.

Therefore, it is advisable to take care of data encryption, build reliable communication channels, and have a strict policy of protecting citizens' privacy. Considering all the components, a Smart City is a complex system combining technological innovations. Thus, the following elements of the Smart City can be distinguished: the Internet of Things, Big Data, artificial intelligence, digitalization, energy-saving technologies, and cybersecurity. Thus, the Smart City concept's primary goal is to make citizens' lives safer, more comfortable, and more environmentally friendly. The concept combines many elements, mainly related to technological advances. However, the multidimensionality and novelty of this approach make it complex and, at the same time, indicate an insufficient level of its study.

Any innovation has its dual nature and has both positive qualities and certain disadvantages. Studying these qualities is significant for our research because a qualitative analysis will help determine whether Smart Cities need to be implemented everywhere. The implementation of the Smart City concept in recent years has demonstrated a significant increase in investment from municipalities worldwide. The SNS Insider report notes that the smart cities market was valued at USD 606,3 billion in 2023 and is expected to grow to USD 3052.7 billion by 2032, achieving a compound annual growth rate (hereinafter referred to as CAGR) of 19,69 % during the forecast period from 2024 to 2032.

The example of smart street lighting shows energy savings ranging from 20 % to 40 %. For example, in Singapore, introducing an adaptive lighting system in recent years has helped reduce energy consumption by

about a quarter (Bachanek et al., 2021). In addition, environmental performance is improving through the implementation of IoT solutions. For example, Barcelona has launched a system for monitoring and controlling water consumption (Garcia et al., 2020). According to the data, in 2023, the total water consumption at the University of Barcelona was 122 813,44 m^3, while in 1995, it was 471 642 m^3 (University of Barcelona, 2024). This data is well aligned with one of the key areas of smart cities - resource efficiency.

Another significant advantage that can be identified based on another component of the Smart City is digitalization. In particular, digitalizing services contributes to increased accessibility to city services. According to Deloitte's 2022 Global Tax survey, about 60 % of citizens living in cities with developed digital municipal services reported a significant reduction in bureaucratic obstacles and a shorter time to obtain the necessary certificates or permits (Deloitte, 2022). This dynamic is due to the effective combination of e-governance, online platforms, and mobile applications that bring authorities and communities closer together. In addition, cities that implement intelligent security systems reduce the response time of emergency services.

In this context, it is also important to mention the expansion of electronic communication channels. This includes, for example, platforms for petitions and public discussions. They contribute to a higher level of citizen engagement in decision-making processes. According to Eurobarometer surveys in 2021, more than 70 % of respondents who have access to such services report increased trust in the actions of local authorities and the ability to influence their decisions (European Union, 2021). Some researchers also note the benefits of municipal digitalization in electronic taxation (Yin et al., 2015; Amine, 2023). The totality of these data shows that implementing the Smart City concept reduces the cost of municipal administration and makes it more efficient. In addition, it enhances interactive interaction between the authorities and the community, which is key to developing democratic values.

Another advantage is the ability to implement business effectively. Smart cities promote diversified and demand-driven entrepreneurship. This can manifest itself in all sectors, starting with agriculture and introducing innovations in entrepreneurship, marketing, and management (Amine, 2023). Convenient digital tools contribute to this. In addition, another component of a smart city, Bis Data, plays an important role here. Large amounts of information about market trends allow for informed management decisions.

Innovative technologies can be easily adapted in traditional areas such as agriculture and more technologically advanced industries. According to a 2018 McKinsey Global Institute study, in cities that are actively implementing smart city technology solutions, the growth rate of small and medium-sized businesses can exceed the national average by about 10-15 % (Woetzel et al., 2018). Another advantage identified is attracting foreign investment. When local authorities invest in developing a progressive and technologically advanced Smart City, it attracts large technology companies and various startups.

A large block of advantages is the development of the so-called Smart Mobility. Its development can be divided into public mobility, private and commercial mobility, and related infrastructure (Benevolo et al., 2016). In public mobility, digital solutions allow for more efficient management of public transport routes and quicker response to increased passenger traffic. Several European capitals already have integrated e-ticketing systems in place. According to the International Association of Public Transport, 2022, using such technologies has reduced the average waiting time at bus stops by 25 %.

At the same time, passengers can plan their trip, taking into account changes in traffic in real time (Macedo et al., 2021). Private and commercial mobility is an equally important component. According to a 2023 McKinsey Global Institute report, in several US and Western European cities, the active use of ridesharing services helped reduce the number of private trips by 10-20 % (Heineke et al., 2023). The commercial sector, including courier services, is benefiting from introducing telematics systems and route algorithms. They reduce logistics costs and increase delivery speed.

The accompanying infrastructure is crucial for the functioning of these processes. This includes charging stations for electric vehicles, dedicated lanes for public transport and cyclists, digital information boards, and mobile navigation applications. In its Global Competitiveness Report 2022, the World Economic Forum noted that cities that have invested in expanding the relevant related infrastructure have higher citizen satisfaction (World Economic Forum, 2022). In addition, they are becoming more interesting for tourists, which contributes to the development of the relevant business sector. In the EU, the number of public charging points for electric vehicles has increased by more than 60 % over the past few years (Macedo et al., 2021).

Therefore, the benefits of implementing the Smart City concept are significant. The following have been identified: economic use of resources, environmental friendliness, public access to public services, strengthening of civic principles, development of entrepreneurship, growth of foreign investment, and development of smart mobility. All the identified advantages are closely linked to their key components and form a single synergistic structure that drives the city's development forward. Implementing such solutions leads to forming a basis for interaction between municipal authorities, businesses, and citizens. Ultimately, this integration of technologies makes it possible to respond adequately to modern challenges and ensure a comfortable life in a rapidly urbanizing environment.

Nevertheless, despite the obvious advantages, a complete understanding of the Smart City concept requires considering aspects that may slow down or complicate its implementation. Therefore, a closer look at several factors that reveal the other side of urban environment smartness is proposed. The first significant drawback is the significant financial burden on municipalities, as the creation and maintenance of smart infrastructure requires significant investment. The World Bank's 2022 reports show that in some urban digitalization projects, especially in transition economies, the estimated costs exceeded the original estimates by 15-25 %. In some cases, this leads to revisions of city budgets and the postponement of other important programs. Moreover, sometimes, it even leads to a complete cessation of innovative solutions.

However, our task is to highlight the shortcomings of smart cities and find solutions to them so that the implementation of smart cities minimizes risks. One of the most effective ways to overcome the financial burden in finance is to attract private investors and international grant programs. This approach, in particular, is being actively implemented in several European countries, where cities create unique public-private partnerships that allow them to share costs and profits among several parties. At the same time, the search for innovative financing models, such as the issuance of green municipal bonds or crowdfunding platforms, can help attract additional resources without overburdening the local budget.

The second significant drawback is the issue of cybersecurity and data privacy (Braun, 2018). To be more precise, this process should not be considered a disadvantage; it is better described as an exposure. High volumes of collected data increase the risks to people's privacy due to the need for constant data collection. Similarly, interconnectedness leads to information technology security risks for companies. Thus, they must increase their cybersecurity spending to protect their private data. Smart cities must access and use big data, which raises privacy concerns. In different countries, much of the discussion on data management has focused on data sharing and access. This is logical, given that there is an internal/external flow in data collection and use. Such flows inevitably raise questions about the range of people who have access to them and the limits of use. OECD Urban Studies (2023) expresses some skepticism about the usefulness of data sharing.

According to the Cybersecurity Ventures annual report, the total number of cyberattacks on municipal systems increased by 28 % (Secureworks, 2023). In addition, attacks on networks that process citizens' data have become 1,5 times more frequent than in previous years. This risk is hazardous for countries at war or with a high threat of terrorism, as it can endanger a large number of people. An example is the recent large-scale cyberattack on Ukrainian state registries in late 2024. As a result of the attack, the Unified and State Registries, which are under the jurisdiction of the Ministry of Justice of Ukraine, were temporarily suspended. The government stated that it was a systemic attack by Russian hackers. The significance of this vulnerability for citizens can be estimated (Andalitska, 2024).

The vulnerability of city databases is particularly dangerous given the scale of the information collected. In case of a personal data leak, hundreds of thousands of people may be affected simultaneously, which causes additional social tension. It also requires additional costs, which brings us to the first disadvantage. In addition, it should not be forgotten that technological capabilities are growing every day, and with them come new vulnerabilities. This means that ensuring cybersecurity is a long-term, continuous process that requires qualifications and high financial costs.

Accordingly, solving this problem requires constant work to improve municipal cybersecurity. However, several steps can be taken to minimize leaks. For example, you should implement multi-level threat detection systems and mandatory security audits. One effective solution is to conclude clear data protection agreements with hardware and software vendors. Such acts will regulate the responsibility of each party in the event of a leak. At the same time, it is worth investing in training specialists and creating local cyber incident response competence centers capable of quickly and professionally tracking new threats.

Another disadvantage is that Smart Cities can unnecessarily increase digital inequality. In megacities with advanced technological solutions, there is a need for new knowledge and competencies to use innovative services. However, research by the European Commission (2023) shows that about 15 % of the urban population does not have adequate access to high-speed internet or relevant digital skills—problems arising from implementation slow down the transition to sustainable urban living. Silva et al. (2018) note that inclusiveness through the ease of use of smart city infrastructure is particularly difficult to achieve in fast-growing cities with diverse populations. As a result, some groups of the population enjoy all the benefits, while others are effectively left out of the digital space, which deepens social inequality.

Thus, according to expert estimates of the Boston Consulting Group, in 2011-2015 alone, the digital gap between the leading countries of the digital revolution and the lagging countries increased by 1,7 times. It should also be noted that the most significant influence on the deepening of the digital divide in the global economy is currently exerted by two countries – the United States and China, which together account for 75 % of all blockchain-related patents, 50 % of global spending on the Internet of Things and more than 75 % of the global market for open technologies and cloud computing. The usage gap results from various online activities—for example, the adoption of online services, digital media, consumption, education, and business. While the

gaps in internet coverage and physical access are slowly closing, the gaps in digital literacy and usage are widening. Since this digital divide exists in all digital technologies, it has the potential to worsen. (Bulatova et al., 2023). The priority is developing and implementing innovative management solutions to ensure balanced outcomes in the digital transformation of economic activity.

The problem of the digital divide goes far beyond the Smart Cities Concept. It is global and cannot be solved. However, it is within city authorities' competence to implement affordable or free Internet programs in public places. Some cities (such as the suburbs of large European agglomerations) have already introduced digital buses and mobile classrooms. They travel to remote areas with the necessary equipment and help people learn essential online services. Such initiatives support equality of opportunity in using innovative technologies and help narrow the gap between different social groups.

Finally, the complexity of introducing technology into the urban environment cannot be ignored. For many governing bodies, integrating innovative solutions becomes a long and cumbersome process, especially in regions with limited resources. This process requires an appropriate legal framework and a professional staff of developers and consultants. According to data released in 2022 by the International Telecommunication Union (hereinafter referred to as ITU), 35 % of cities that launched a digital transformation program failed to move to the second phase of the project due to a lack of funding, specialists, and a regulatory framework (International Telecommunication Union, 2022).

DISCUSSION

The cumbersome process of implementing new solutions also requires special attention. One promising approach is to start with pilot projects in small city areas. This will help test the idea's viability and estimate the actual costs. Success at the local level often becomes a convincing argument for scaling up. In addition, the experience gained during the pilot phase allows for simplified implementation procedures. In addition, local legislation must be adapted to new technologies promptly. Creating working groups or expert councils involving lawyers, IT professionals, and government representatives is important. This approach will help to align regulations with the rapid pace of digitalization and systematically address the problems that hinder the development of Smart Cities.

Thus, despite the large-scale benefits of the Smart City concept, many problematic aspects require separate studies and systemic solutions. Only with a comprehensive approach can there be hope for a complete and lasting implementation of innovative technologies in modern cities. Nevertheless, some steps can be taken to improve the situation. Some of them are listed below. In addition, vivid examples of Smart Cities already exist worldwide, and a more detailed focus will be placed on the practical implementation of some of them.

As already mentioned, the concept of a Smart City is being actively promoted worldwide. Today, many leading countries are creating smart infrastructure. Some examples have already been briefly mentioned earlier. The focus will now shift to individual European projects that serve as vivid examples of innovative initiatives, emphasizing European countries. Their analysis is important, as it will help formulate recommendations for Ukraine based on these examples.

The analysis will begin with Spain, one of the European leaders in implementing Smart City solutions. The official National Strategy for Smart Cities, launched in 2015 by the Ministry of Industry, Energy and Tourism, provides funding for various projects, including energy, transportation, e-government, and open data. Thus, by 2023, more than 80 Spanish cities will have implemented at least one innovative solution, and the total investment in this sector will exceed €1.5 billion (European Court of Auditors, 2023). Moreover, in this country, two smart cities have attracted our attention. First, let us note the previously mentioned Barcelona (Agencia Andaluza de la Energía, 2024).

It is developing an Internet of Things system with sensors for monitoring environmental indicators, logistics, and utilities. According to official data from the municipality, using such sensors to track the fullness of garbage containers has reduced waste disposal costs by more than 15 % (Garcia et al., 2020). In addition, automated water meters have helped reduce water consumption by almost 30 % (University of Barcelona, 2024). It is worth noting that the Barcelona municipal authorities have allocated EUR 90 million for the ten years 2015-2025 from the city budget to implement innovations in the urban utilities of smart cities (Orejon-Sanchez et al., 2022).

The following Spanish city is Malaga. It has implemented a large-scale initiative to develop energy-saving technologies and renewable energy (Naim, 2021). It operates a smart microgrid that combines solar panels, battery energy storage, and an intelligent consumption management system. This approach helps to avoid overloads in the power grid during peak hours. It also reduces the population's electricity cost. As a result, the city has reduced CO_2 emissions by more than 10 % over the past three years. In turn, the share of renewable energy in the city's overall balance has exceeded 20 % (Alda, 2023). In general, Spain has a strong commitment to sustainable development. Both national strategies and financial support from the EU support this. An integrated approach to technology allows cities to solve several important problems simultaneously. Their Smart model is becoming a benchmark for many countries around the world.

The following three cities were selected based on the opinions of leading experts, and they became known as Amsterdam, Copenhagen, and Vienna. Most researchers consider them the best examples of smart European cities (Joss et al., 2017; Roblek, 2019; Orejon-Sanchez et al., 2022). Therefore, let us analyze the first of them - Amsterdam (the Netherlands). Amsterdam is widely recognized as one of the first European smart cities. Articles related to the Amsterdam Digital City have been published since 1994 (Angelidou, 2014). The concept of a digital city was first born when ICTs were used to help Amsterdam residents participate in political elections (Orejon-Sanchez et al., 2022). Then, it was actively developed. The city has implemented a comprehensive program called Amsterdam Smart City.

The key focus is sustainable transport: Besides an extensive network of bicycle paths, the city is actively developing infrastructure for electric vehicles. In 2022 alone, Amsterdam installed about 700 new electric vehicle charging points, bringing the total number to more than 3,000 (Altamirano, 2024). As a result, almost a third of car owners have switched to electric cars or hybrids, which has reduced transport emissions. This, in turn, has had a positive impact on environmental indicators.

It is also worth noting the existence of Urban Labs, where pilot projects are developed to solve problems in various fields and then tested in real life. Such characteristics allow the creation of an infrastructure for knowledge exchange and learning between companies and citizens. The efforts of the Amsterdam municipal authorities have been repeatedly recognized with honorable awards. In particular, in 2009, Forbes ranked the city among the Ten World's Smart Cities (Kotkin, 2009). In 2014, the European Parliament recognized Amsterdam as one of the six most successful EU cities.

Copenhagen (Denmark) has an advanced cycling infrastructure and a system of bright traffic lights. They give priority to cyclists during peak hours. Such measures actively contribute to reducing CO_2 emissions. Due to the 2023 data, the number of daily bike trips has increased by 10 % over the past two years. In addition, the municipality is actively investing in green energy. The city is introducing a remote-control system for street lighting and heating networks. This program has saved the municipality approximately 15 % of its annual energy budget.

The last example we will consider is Vienna (Austria). The Austrian capital promotes the idea of Smart City Wien. The concept combines the development of digital services and support for social equality. Among the most notable projects is a platform integrating services from various government agencies, including tax, utility, and licensing authorities. According to official city statistics, this unified e-governance system has reduced the processing time of citizen applications by about 35 %, which increases trust and satisfaction with municipal services (Orejon-Sanchez et al., 2022). In addition, local authorities are very focused on environmental issues.

Thus, the experience of individual European cities demonstrates that the systematic implementation of bright city elements can transform the urban environment into a dynamic and comfortable ecosystem. In such a city, considerable attention is paid to efficiency and sustainable development. It should be noted that the data obtained is important for our future research. Based on these, options for the stratification of Ukrainian cities would be proposed. However, first, we propose considering the extent to which the domestic environment is ready to borrow and adapt approaches that have proven effective in European cities.

Ukraine has also joined the global trend of adoption of innovative technology. The first stratification projects have been launched in many cities. For example, in some regions, electronic services for residents were introduced, platforms for monitoring the load on transport infrastructure were launched, and experiments with bright lighting were carried out. However, the active development of many of these initiatives slowed down significantly after the start of the full-scale Russian invasion, as local authorities and technology companies were forced to reformat their resources to address security and humanitarian challenges. Despite the difficult circumstances, many digital solutions in Ukraine can still be categorized as innovative technologies.

One of the most well-known examples is the Diia app, which combines several government services in a single electronic space. According to the Ministry of Digital Transformation, as of early 2023, the number of Diia users exceeded 18 million. The list of available services includes administrative services, submission of various applications, declarations, etc. The app also contains electronic personal identification documents with the same legal force as paper versions. Ukraine also became the first country in the world to introduce the possibility of getting married online through Diia. This revolutionary service allows you to get married in just a few clicks (World's first online marriage through Diia: Ukrainians can now get married via video, 2024).

Another successful project is Kyiv Digital. This is a universal city application introduced by the Kyiv authorities long before the current difficulties. However, it has been particularly active in recent years. The app allows you to pay for parking, track public transportation, purchase a single ticket, and notify utilities of problems in the city. It also ensures the safety of Kyiv residents during the war. It signals an air raid alert and contains a map of shelters. This also allows us to point out another significant advantage of smartification – ensuring safety and alerting the population in case of threats. The app also informs about air pollution and the closure of certain roads for repairs. Such initiatives can generally be adapted to warn citizens about threats, natural disasters, deteriorating weather conditions, etc. With more development, they can inform about traffic jams,

road accidents, etc. In addition, the app allows voting on city initiatives and budget allocation. This allows citizens to participate in improving the city and increases public participation and control.

According to the Kyiv City State Administration, more than 2 million users have installed Kyiv Digital, and the total volume of non-cash transactions within the service has tripled in the last year alone (Balyukh, 2024). In addition to the aforementioned initiatives, some regions of Ukraine are successfully implementing projects on bright street lighting, e-health, electronic housing, and utility management systems. Although the scale and pace of implementation of such technologies are currently uneven, so are their effectiveness and popularity among the population. Naturally, describing all the smart innovations in one study is difficult. In Table 1, we have summarized the most prominent brilliant introductions by the Ukrainian government and local municipalities.

Table 1. Smart city projects in Ukraine

Project	Main direction	Key options (achievements)	Statistical data
Diia	E-governance, public services.	Digitization of public services; electronic documents; submission of declarations, applications; business registration; car sales; marriage registration, etc.	More than 18 million users; the number of services is growing every year (hundreds of available services).
Kyiv Digital	Urban ecosystem; public transportation; utility bills; public notification.	Paying for parking; fares; public transportation tickets; contacting public utilities; voting for budget initiatives; and public notifications.	More than 2 million users; cashless transactions increased 3 times in a year.
Trembita	Interagency document flow; data exchange.	Combining different state registers; automating data verification; conveniently obtaining confirmations from different databases.	It is used by most e-services; a significant reduction in the time for interdepartmental requests.
E-Health	Healthcare.	Electronic prescriptions for medicines; doctor's appointments (offline and online); vaccination records; medical certificates.	Thousands of e-prescriptions every week; expansion of the service to rural and remote areas.
Smart Lighting	Energy saving and street lighting	Automatic switching on/off of lights depending on the time of day and traffic; brightness control; reduction of energy consumption and maintenance costs; replacement of incandescent bulbs with energy-saving media.	In some cities (e.g., Vinnytsia, Dnipro), energy savings of 20-30 %; reduced infrastructure maintenance costs.
Electronic utility management systems	Utilities; resource allocation.	Online accounting of consumption indicators; automatic generation of bills; analysis of costs and repairs.	Up to 25 % reduction in emergency situations in buildings connected to monitoring systems.
Mobility as a Service	Logistics	Bus tracking and electronic displays; a single ticket for different types of transport; parking systems with occupancy sensors.	In Kyiv and Lviv, there is a 15-20 % reduction in traffic intervals during rush hours; the introduction of new services in the regions is gradual.

Source: Balyukh (2024).

Thus, it is clear that Ukraine has taken significant steps to create smart cities. Some of them were advanced and not used in any other country. Many of them arose as a result of the country's tragic circumstances. Military aggression has significantly halted the development of smart cities. However, the government has successfully adapted existing initiatives and continues to implement new ones partially.

Nevertheless, Ukraine can still adopt several practical initiatives in this context. To this end, we have previously reviewed some of the smart cities in Europe to identify the most effective projects and adapt them to Ukrainian realities. Of course, many will not be implemented now, but they will become a real boon after the war ends and the destroyed cities and infrastructure are rebuilt. Below are the initiatives identified and the possibilities for their adaptation.

Thus, the table demonstrates how individual innovative initiatives can be implemented in Ukraine and how they look holistic. Of course, all of these strategies may not seem entirely realistic today. Indeed, most of these projects require significant funding. However, they have high payback and long-term effectiveness. In addition, it should be borne in mind that Ukraine needs to be rebuilt in any case, especially those cities that were almost destroyed as a result of the invasion. Such reconstruction is best done immediately, considering the Smart City concept and implementing its projects. Many foreign countries have committed to investing in the

reconstruction of individual cities after the end of hostilities. Such investments can be used for amortization and immediate planning for rebuilding cities in an innovative format. Moreover, Ukraine already has many examples of convenient and successful smart infrastructure. It should be consolidated and not fragmented. This gives Ukraine a great chance to join the list of advanced innovative countries.

Table 2. European smart initiatives in Ukraine: prospects and adaptation

European city and initiative	Nature of the smart project	Status in Ukraine	Steps to adapt (if not yet implemented)
Barcelona: smart monitoring of waste and water consumption	Installing IoT sensors to track the fullness of garbage containers and introducing automated water meters. This reduces the frequency of waste collection and water consumption.	It is partially implemented in some projects, for example, smart recycling bins in some cities; e-meters for water are being piloted.	Expand the geography of pilot projects by introducing sensor systems in large cities and communities; disseminate the experience of advanced cities (e.g., Vinnytsia, Dnipro) to other regions through funding programs (including through external investment).
Malaga: Smart Grid	Combining solar panels, battery energy storage and a consumption management system.	Currently, such systems have been implemented in a sporadic manner (as separate initiatives). There is no integrated smart grid on a citywide scale.	To develop comprehensive projects of smart microgrids with the support of the state and donor organizations; to stimulate the construction of "green" power generation in cities (tax incentives, cheap loans); to implement a unified monitoring and management system for energy consumers and suppliers.
Amsterdam: mobility and Urban Labs	An extensive network of charging stations and a convenient network of public automated transport. Urban centers for testing pilot innovations in real-world conditions.	In large cities (Kyiv, Lviv, Odesa), the number of charging stations is partially increasing, but not yet close to Amsterdam's figures; the network of electric charging stations on intercity roads is underdeveloped; the Urban Labs format is underdeveloped.	Expand the infrastructure of high-speed charging stations with government support or through public-private partnerships; initiate the creation of centers in each major city with the participation of municipalities, universities and businesses to test innovations (can be provided through investment).
Copenhagen: smart traffic and bicycle infrastructure	Smart traffic lights that prioritize cyclists, which reduces congestion and CO_2 emissions. The city also has an advanced green infrastructure.	There are local projects in Lviv, Kyiv, and Ivano-Frankivsk (bicycle lanes, initiatives with smart lights), but the scale is still small. The culture of bicycle use itself is low.	Develop a strategy for the development of bicycle infrastructure at the state level, taking into account smart solutions; introduce traffic light priority systems for public transport and bicycles in cities with high traffic congestion; create a program to encourage the transition to bicycles (reimbursement of part of the cost of purchased bicycles; introduction of additional taxes on cars).
Vienna: integrated e-urbanism (Smart City Wien)	A single e-governance platform that integrates services from various government agencies; accessible to all population groups.	This has been partially implemented through Diia, Kyiv Digital, and some local platforms (e.g., e-petitions). However, integration is still fragmented.	Unify and connect databases of different ministries and agencies within one platform; strengthen the process of information exchange between municipalities (systems like Trembita) to expand the list of available online services.

CONCLUSION

The Smart City concept is an effective tool for addressing the urban environment's current challenges. The number of urban residents is constantly growing, which means that municipal authorities are tasked with creating the most comfortable living conditions for residents. Its implementation helps to optimize urban infrastructure and increase environmental efficiency. In addition, smart cities provide an opportunity to expand citizens' access to public services and strengthen public participation in governance processes. An analysis of European experience shows that such solutions not only improve citizens' quality of life but also contribute to economic growth and sustainable development.

The Smart City concept has significant advantages. However, it is not without its drawbacks. The high cost of building infrastructure and modernizing urban systems is a significant financial barrier, especially for countries with limited resources. Additional challenges include cybersecurity threats arising from processing

large amounts of personal data. There is also the issue of digital inequality, which limits access to innovative technologies for certain groups of people.

In some cases, the complexity of project management and insufficient regulatory frameworks also pose obstacles to implementing innovative solutions. Most of them, such as cybersecurity or financial inequality, go deeper than smartification. They cannot be solved wholly and unambiguously. However, steps can be taken to minimize risks and improve the overall situation.

The studied examples of smart cities in Europe demonstrate the effectiveness of implementing innovative solutions in various industries. Statistics show significant gains from these innovations. They provide both financial efficiency and comfortable living. Despite the difficult conditions, Ukraine has also made significant progress in implementing innovative technologies. At the same time, the country faces several obstacles, such as limited resources and the effects of the war. To successfully develop the concept, it is necessary to borrow the best European practices, adapt them to local realities, and attract international support and investment. The Smart City concept should become the basis for restoring and modernizing Ukrainian cities. It will create an environment that meets the needs of citizens and ensures resilience to future challenges. A holistic approach to implementing innovative solutions can restore infrastructure and create new opportunities for the country's sustainable growth in the modern world.

It can be emphasized that smart cities are not only technologies but also a transformation of the approach to governance based on the principles of transparency, inclusiveness, and sustainable development. They open up new opportunities for improving the quality of life. Such cities ensure the formation of an innovative environment and generally contribute to the development of the state.

REFERENCES

1. Adenekan, O. A., Ezeigweneme, C., & Chukwurah, E. G. (2024). The evolution of smart cities: Integrating technology, governance, and sustainable development. International Journal of Applied Research in Social Sciences, 6(5), 891-902. https://doi.org/10.51594/ijarss.v6i5.1131

2. Agencia Andaluza de la Energía (2024). Andalusian energy statistics. Retrieved from: https://www.agenciaandaluzadelaenergia.es/en/informacion-energetica/andalusian-energy-statistics

3. Alda, M. (2023). Smart Cities – Spain. Retrieved from https://www.statista.com/outlook/tmo/internet-of-things/smart-cities/spain

4. Altamirano, J. (2024). Top 5: How Are European Cities with the Most Charging Points Progressing? Retrieved from https://mobilityportal.eu/top-5-european-cities-charging-points/

5. Amine, R. (2024). Smart Cities: Development and Benefits. In: Belaïd, F., Arora, A. (Eds). Smart Cities. Studies in Energy, Resource and Environmental Economics (pp. 45-53). Berlin: Springer. https://doi.org/10.1007/978-3-031-35664-3_4

6. Andalitska, I. (2024). Cyberattack on Ukrainian registries: MP believes bribery of officials may have been involved. Retrieved from https://www.unian.ua/society/kiberataka-na-ukrajinski-reyestri-zlam-mig-statisya-cherez-pidkup-sluzhbovciv-12861855.html#goog_rewarded

7. Angelidou, M. (2014). Smart city policies: A spatial approach. Cities, 41, S3-S11. https://doi.org/10.1016/j.cities.2014.06.007

8. Anthopoulos, L. G. (2017). Understanding smart cities: A tool for smart government or an industrial trick? (1st ed.). Berlin: Springer. https://doi.org/10.1007/978-3-319-57015-0

9. Bachanek, K. H., Tundys, B., Wiśniewski, T., Puzio, E., & Marouškova, A. (2021). Intelligent Street Lighting in a Smart City Concepts — A Direction to Energy Saving in Cities: An Overview and Case Study. Energies, 14(11), 3018. https://doi.org/10.3390/en14113018

10. Balyukh, N. (2024). More than 2.7 million users: Kyiv Digital app turns 3 years old. Retrieved from https://suspilne.media/kyiv/719396-ponad-27-mln-koristuvaciv-zastosunku-kiiv-cifrovij-vipovnuetsa-3-roki/

11. Benevolo, C., Dameri, R. P., & D'Auria, B. (2016). Smart mobility in smart city. In T. Torre, A. Braccini, & R. Spinelli (Eds.), Lecture Notes in Information Systems and Organisation: Vol. 11, Empowering organizations. Berlin: Springer. https://doi.org/10.1007/978-3-319-23784-8_2

12. Braun, T., Fung, B. C. M., Iqubal, F., Shah, B. (2018). Security and privacy challenges in smart cities. Sustainable Cities and Society, 39, 499-507. https://doi.org/10.1016/j.scs.2018.02.039

13. Bulatova, O. V., Reznikova, N. V., Ivashchenko, O. A. (2023). Digital divide or digital inequality? New dimensions of global asymmetries of socio-economic development and international trade in the conditions of technoglobalism. Economics, 25, 45-57. https://doi.org/10.34079/2226-2822-2023-13-25-45-57

14. Deloitte. (2022). Ninth annual global survey of multinationals. Retrieved from https://www.deloitte.com/cy/en/services/tax/research/beps-global-survey.html

15. Diorditsa, I.V., & Zhuravel, Y.V. (2023). Innovativeness of the Smart city concept and legal mechanisms for ensuring its cybersecurity in the context of reforming territorial communities in Ukraine. Actual problems of national jurisprudence, 1, 99-105. https://doi.org/10.32782/39221437

16. Dziundziuk, K. V. (2023). Experience of Implementing the Concept of a Smart City in Developing Countries. Public management and administration, 7, https://doi.org/10.54929/2786-5746-2023-7-02-01

17. European Commission (2018) Smart cities. Retrieved from https://commission.europa.eu/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en

18. European Commission (2023). Report on the state of the Digital Decade 2023. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52023DC0570

19. European Court of Auditors (2023). Smart cities Tangible solutions, but fragmentation challenges their wider adoption. Retrieved from https://www.eca.europa.eu/ECAPublications/SR-2023-24/SR-2023-24_EN.pdf

20. European Union (2021). Future of Europe 2021. Retrieved from https://europa.eu/eurobarometer/surveys/detail/2554

21. Garcia, D., Puig, V., & Quevedo, J. (2020). Prognosis of Water Quality Sensors Using Advanced Data Analytics: Application to the Barcelona Drinking Water Network. Sensors, 20(5), 1342. https://doi.org/10.3390/s20051342

22. Gramchuk, M., Nikitenko, V. (2023). Present Trends and Prospects of Smart City Development. Humanities Studies, 14(91), 33-41.

23. Hajduk, S. (2016). The Concept of a Smart City in Urban Management. Business Management and Education, 14(1), 34-49. http://doi.org/10.3846/bme.2016.319

24. Heineke, K., Kloss, B., Von Rüden, M. A., Möller, T., & Wiemuth, C. (2023). Shared mobility: Sustainable cities, shared destinies. Retrieved from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/shared-mobility-sustainable-cities-shared-destinies

25. International Telecommunication Union (2022). Internet more affordable and widespread, but world's poorest still shut off from online opportunities. Retrieved from https://www.itu.int/en/mediacentre/Pages/PR-2022-11-30-Facts-Figures-2022.aspx

26. Joss, S., Cook, M., Dayot, Y. (2017). Smart Cities: Towards a New Citizenship Regime? A Discourse Analysis of the British Smart City Standard. Journal of Urban Technology, 24(4), 29-49. https://doi.org/10.1080/10630732.2017.1336027

27. Kotkin, J. (2009). The world's smartest cities. Retrieved from https://www.forbes.com/2009/12/03/infrastructure-economy-urban-opinions-columnists-smart-cities-09-joel-kotkin.html

28. Krasyliuk, V. F. (2024). The concepts of smart cities and smart community: content and features of implementation. Current Policy Issues, 73, 54-61. http://doi.org/10.32782/app.v73.2024.8

29. Lea, R. (2017). Smart cities: An overview of the technology trends driving smart cities. IEEE Advancing technology for Humanity, 3, 1-16.

30. Macedo, E., Teixeira, J., Sampaio, C., Silva, N., Coelho, M. C., Glinos, M., & Bandeira, J. M. (2021). Real-time information systems for public transport: user perspective. Transportation Research Procedia, 52(3), 732-739. http://doi.org/10.1016/j.trpro.2021.01.088

31. Manoharan, G., Durai, S., Rajesh, G. A., Razak, A., Rao, C. B. S., Ashtikar, S. P. (2023) A study on the perceptions of officials on their duties and responsibilities at various levels of the organizational structure in order to accomplish artificial intelligence-based smart city implementation. Artificial Intelligence and Machine Learning in Smart City Planning, 1, 1-10. http://doi.org/10.1016/B978-0-323-99503-0.00007-7

32. Mohanty, S. P., Choppali, U., Kougianos, E. (2016). Everything You Wanted to Know About Smart Cities. IEEE Consumer Electronics Magazine, 5(3), 60-70. http://doi.org/10.1109/MCE.2016.2556879

33. Naim, N. H., Adnan, M. S. G., Zannat, K. E., Dewan, A. (2021). Assessing the performance of public transport services in a developing country: A case study using data envelopment analysis. Growth and Change, 53(1), 377-409. http://doi.org/10.1111/grow.12588

34. OECD Urban Studies (2023). Smart City Data Governance Challenges and the Way Forward. Retrieved from https://www.oecd.org/content/dam/oecd/en/publications/reports/2023/10/smart-city-data-governance_fc19e878/e57ce301-en.pdf

35. Orejon-Sanchez, R. D., Crespo-Garcis, D., Andres-Diaz, J. R., Gaso-Calderon, A. (2022). Smart cities' development in Spain: A comparison of technical and social indicators with reference to European cities. Sustainable Cities and Society, 81(1), 103828. https://doi.org/10.1016/j.scs.2022.103828

36. Paroutis, S., Bennett, M. Heracleous, L. (2014). A Strategic View on Smart City Technology: The Case of IBM Smarter Cities during a Recession. Technological Forecasting and Social Change, 89, 262-272. http://doi.org/10.1016/j.techfore.2013.08.041

37. Pereli, D. D. (2023). The Concept of a Smart City in the Conditions of the Information Society Development. Public Management and Administration in Ukraine, 33, 136-140. http://doi.org/10.32782/pma2663-5240-2023.33.25

38. Roblek, V. (2019). The smart city of Vienna. Smart city emergence. Elsevier, 105-127. https://doi.org/10.1016/B978-0-12-816169-2.00005-5

39. Secureworks. (2023). Boardroom cybersecurity report on cybercrime. Retrieved from https://www.secureworks.com/resources/rp-boardroom-cybersecurity-report-2023

40. Silva, B. N., Khan, M., & Han, K. (2018). Toward sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities. Sustainable Cities and Society, 38, 697-713. https://doi.org/10.1016/j.scs.2018.01.053

41. University of Barcelona (2024). The University of Barcelona maximizes measures to reduce the use of water and starts an awareness campaign. Retrieved from https://web.ub.edu/en/web/actualitat/w/estalvi-aigua

42. Woetzel, L., Remes, G., Boland, B., Sinha, S., Strube, G., Means, J., Law, J., Cadena, A., & Von der Tann, V. (2018). Smart cities: Digital solutions for a more livable future. Retrieved from https://www.mckinsey.com/capabilities/operations/our-insights/smart-cities-digital-solutions-for-a-more-livable-future

43. World Economic Forum. (2022). The Global Competitiveness Index. Retrieved from https://www.weforum.org/about/the-global-competitiveness-index-gci-5-0/

44. Yin, C. T., Xiong, Z., Chen, H., Wang, J. Y., Cooper, D., David, B. (2015). A literature survey on smart cities. Science China Information Sciences, 58(10), 1–18. https://doi.org/10.1007/s11432-015-5397-4

FINANCING

None.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

Conceptualization: Olha Yatsun.
Formal analysis: Olha Yatsun.
Research: Olha Yatsun.
Writing - original draft: Olha Yatsun.
Writing - proofreading and editing: Olha Yatsun.

https://doi.org/10.62486/gen202585 ISSN: 3046-4137