

Ievgen Buriak,*DrHab (Economics), Associate Professor,*
ORCID 0000-0002-8039-004X
e-mail: burzhen@ukr.net

Kremenchuk Mykhailo Ostrohradskyi National University, Kremenchuk

Stanislav Savin,*DrHab (Economics), Associate Professor,*
ORCID 0000-0002-0405-3244
e-mail: imennostasik@gmail.com;**Daniil Hulak,***PhD (Economics), Associate Professor,*
ORCID 0000-0001-8840-3557
e-mail: danielckua@gmail.com

Kherson National Technical University, Khmelnytskyi

Larysa Moisieienko,*PhD (History), Associate Professor, Visiting Scholar in the Department of History,*
ORCID 0000-0001-6581-6789
e-mail: lmoisieiei@ukr.net

College of Liberal Arts, Purdue University, West Lafayette, USA

CONCEPTUALIZATION AND EVALUATION OF THE «SMART CITY» PARADIGM IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

Introduction. Modern cities are the primary centers of economic growth, innovation, and social development; however, they also face unprecedented challenges related to population growth, resource depletion, climate change, and social inequality. In response to these challenges, the «Smart City» paradigm has emerged as a leading model that integrates information and communication technologies (ICTs) to enhance the efficiency of urban services and improve the quality of life.

Through the implementation of digital technologies, innovative governance models, and citizen interaction platforms, a smart city is designed to mitigate the negative effects of urbanization, improve the quality of life, and expand citizen participation in governance processes. For example, the global «Smart City» market is estimated at ~USD 877.6 billion in 2024 and is projected to grow to ~USD 3,757.9 billion by 2030 with a CAGR of ~ 29.4% (UN, 2025).

Back in the 19th century, Ebenezer Howard proposed the concept of combining city and countryside as a foundation for a better life and balanced development of residents. The integration of the urban environment with the structure of natural and rural areas is becoming even more relevant today due to the global pace of urbanization: according to the United Nations, today more than 55% of the world's population lives in urban areas, and by 2050 this figure is expected to increase to 68% (Smart Cities Market, 2025-2030).

The increase in the number of residents in cities creates pressure on transport infrastructure, production, economy, raw materials, energy, and the ecosystem.

That is why many cities have begun to engage in the idea of creating the so-called «Smart City»— «Smart-City». Thanks to the introduction of effective management, innovation, and digital technologies, smart cities mitigate the negative impact caused by urban population concentration, introduce new forms of communication between residents, and enhance their participation in public administration. The concept of a «Smart City» affects all spheres of society, from infrastructure and urban governance to housing, transport, and the environment, and seeks to create a high-quality and efficient space for current and future generations, calling for scientific research into this process.

Purpose of the article is to reveal and expand the concept of «Smart City» in the context of sustainable development and taking into account the problems of urbanization.

Literature review. The evolution of the «Smart City» concept demonstrates a gradual transition from a technocratic vision of the city as a management system to a comprehensive socio-ecological model of sustainable development. In the early stages (1950–1970s), the foundation was laid by the ideas of cybernetics and the systems approach (Wiener, 1948; Forrester, 1969), which viewed the city as an interconnected system of flows of information, energy, and people. During this period, the foundations for future digital urban models are being formed.

Particular attention in modern research is paid to the theories of spatial justice developed by E. Soja (2010) and A. Lefebvre (1974), which have significantly influenced the understanding of urban space as not only



a physical territory but also a socially constructed system of relations, resources, and opportunities. Their ideas about the «right to the city» and the «production of space» have become the basis for a critical reevaluation of digital urbanism, particularly in the context of addressing digital and territorial inequalities.

Within the «Smart City -4.0» paradigm, these concepts are transformed into practical approaches to urban development planning that combine technological innovation with social inclusion and environmental sustainability. Thus, spatial justice is considered not only a philosophical category but also an analytical tool for shaping smart city policies focused on the fair distribution of digital, economic, and spatial resources. This contributes to the transition from the technocratic «Smart City» model to a human-centric and value-oriented model of urban development, where «smartness» is determined not only by the level of digitalization, but also by the quality of life and the level of community participation in decision-making.

In the 1980s and 1990s, under the influence of M. Castells (1996) and other researchers, the concept of an information city emerged - an environment where knowledge is the key resource and network technologies form the basis of the new economy. Gradually, the emphasis shifted from physical infrastructure to digital, and the city began to be understood as a space for communication and data exchange.

The beginning of the 2000s marked the transition from a «digital» to a «Smart City» (Mitchell, 1999; Komninos, 2002). «Smart City» is currently perceived primarily as a tool for increasing management efficiency through the implementation of ICT. However, already in the 2010s (Giffinger, Hollands, Caragliu, Batty), the understanding of the concept is expanding, with social, economic, and environmental dimensions being added to the technical dimension. Indices of «smartness» of cities are formed, and the idea of sustainability begins to dominate.

In recent years (since 2016), there has been a critical review of the model. Authors such as Florida (2017), Barns (2020), and Kitchin (2021) emphasize the need for a human-centered and inclusive approach. Since the 2020s, the Smart City 4.0 paradigm has been emerging, combining technological efficiency with social justice, environmental sustainability, and spatial convergence [34, 23, UN-Habitat, 2023]. This approach sees the «Smart City» as a platform for achieving digital balance and overcoming territorial disparities.

The issues of regional growth and convergence are attracting increasing attention from scholars. In particular, the question of whether poorer regions are catching up with richer ones plays a crucial role in regional policy. This is even more relevant in Europe, given the significant regional disparities and the EU's primary objective of promoting economic and social cohesion by reducing these disparities. Several theories explain the convergence process in various ways.

The discussion on the relationship between economic growth and convergence began with the work of Solow and Myrdal in the late 1950s. W. J. Baumol (1986) argued that homogeneous groups of countries tend to converge, while heterogeneous ones tend to diverge. The boom in convergence research occurred in the 1990s after the articles by R.J. Barro, X. Sala-i-Martin (1991), and N. G. Mankiw, D. Romer, D. N. Weil (1992), which drew on neoclassical growth theory and extended previous convergence research to include a regional perspective [4, 22].

Part of the explanation for this boom is the growing dissatisfaction during the 1980s that regional disparities were not decreasing as quickly as expected [2]. Armstrong's work appeared immediately after the emergence of new growth theories of the 1980s (endogenous growth theory and Krugman's New Economic Geography [18]). A clear proponent of regional convergence is the neoclassical theory of (conditional) convergence, which, like traditional neoclassical growth theory, assumes convergence of regional differences in GDP per capita.

However, it has several features that distinguish it from the original concept and are important for empirical research [2]. The so-called divergence theories, on which some empirical research is based or whose elements are borrowed, include, in particular, the Polarization Theory, the New Economic Geography, and the Endogenous Growth Theory. Armstrong criticizes the lack of formal implementation of these theories. Notably, the use of smart cities in the urbanization and convergence process has given rise to several contradictory theories that warrant further research [2].

Results and discussion. Cities and towns around the world are increasingly facing complex challenges, such as population growth, transportation problems, resource scarcity, and rising pollution. Urbanization necessitates the adoption of new concepts to enhance the long-term efficiency, sustainability, and comfort of cities and regions. One possible solution is the concept of a «Smart City» aimed at sustainable urban development, which combines areas such as transport, energy and development planning based on collected data, which are evaluated using algorithms and placed in the right context, which can be used, for example, to optimize transport routing in cities based on data or to effectively manage water and energy supplies. With the help of automation technologies, buildings can also be managed in a more energy-efficient and cost-effective way. Thus, «Smart City» initiatives, also thanks to adequate data, should allow cities to allocate and expand their efforts in areas such as quality of life, innovative technologies, and integrated urban planning. Given the European and national climate neutrality targets, as well as the growing importance of cities in reducing CO₂ emissions, these discussions provide a key basis for developing future solutions in the areas of mobility and energy supply.

Table 1. Stages of evolution of the «Smart City» concept

Period	Key authors/sources	Dominant ideas and emphases	Characteristics of the approach
1950–1970s	Norbert Wiener (1948), Jay Forrester (1969), Christopher Alexander (1965)	Cybernetics, systems thinking, urbanism as a complex system	The beginning of understanding the city as a managed system; emphasis on modeling flows and information management.
1980–1990s	Manuel Castells (1989, 1996), Alvin Toffler (1980)	«Information society», network connections, telecommunications	Formation of the foundations of the «information city»; the idea of a city as a network of data and people appears.
1998–2007	William J. Mitchell (1999), Graham & Marvin (2001), Komninos (2002)	«Digital city» and «Intelligent city» – urbanism based on ICT	Shifting attention to the use of ICT for infrastructure management, transport, energy.
2008–2015	Giffinger et al. (2007), Hollands (2008), Caragliu & Del Bo (2011), Batty (2013)	Conceptualization of «Smart City» – integration of technologies, economy, environment, management	Rankings of «smart cities», indices and assessment methods appear. Emphasis on efficiency and sustainability.
2016–2020	Richard Florida (2017), Barns (2020), Kitchin (2021)	Rethinking: «human-centric» city, «data-driven governance», social inclusion	Transition from the technological to the social dimension of the «Smart City». Criticism of «technological determinism».
2021–present	Repette et al. (2021), Kolodiziev et al. (2024), OECD (2022), UN-Habitat (2023)	«Smart City-4.0», sustainability, digital balance, spatial alignment	Integration of the concepts of the «green» economy, digital inclusion, environmental management. The «Smart City» becomes a component of spatial convergence.

Source: summarized by the authors

However, urban growth not only brings with it environmental challenges, but also social challenges arising from the corresponding demographic changes. Urbanization leads to several problems that affect all urban areas. Firstly, the focus on maximizing production has led to the depletion of natural resources. Firms and enterprises are motivated by competition and profit, which in turn leads to a focus on revenue rather than on environmentally friendly production. To achieve the goal of urban sustainability, particularly within the framework of the smart city concept, it is crucial to address the social aspects of these problems and plan cities with the active involvement and participation of citizens themselves. From this perspective, the term «Smart City» is often used in professional literature to refer to a city's ability to respond quickly to the needs of its citizens and adapt to sustainable development. Smart cities consider the quality of life and development of settlements, which are influenced by transportation, public services, education, public safety, and health. Therefore, when analyzing the concept of «smart city», it is necessary to take into account several aspects, from the main areas of activity to the quality of life and sustainable development. Research in this direction can be found in various fields, including education, healthcare, transportation, and public administration. These areas contribute to improving the quality of life in the city and ensure sustainable development.

«Smart City» is a concept based on the full use of the potential of existing resources, reducing energy consumption, and limiting the negative impact of cities on the environment. They are also often defined as those who utilize solutions provided by information and communication technologies to design cities, deliver local services, and formulate policies based on the principles

of participation, openness, and sustainable development, with a focus on people. The concept of a «Smart City» also aims to ensure sustainability and viability, accelerate bureaucratic processes by combining information and communication technologies with Web 2.0 technologies and other organizational and planning efforts, and offer innovative solutions to address specific urban problems. A «Smart City» is actually a comprehensive concept that encompasses smart urbanism, smart economy, a smart and sustainable environment, smart technology, smart energy, smart mobility, smart healthcare, and several related sub-themes. There are two different approaches to planning and implementing smart cities:

1. An approach to urban development that considers a goal-oriented solution (e.g., reducing emissions and using natural resources economically) and then achieves it with the help of specific digital technologies.

2. Technology-oriented approaches rely on the comprehensive digitalization of the city.

Regardless of the chosen strategy, the long-term goal is to implement concepts that are as integrated as possible, since a comprehensive network offers the greatest possible potential, and the digital concept has great potential to improve the quality of life of residents and build an efficient and sustainable infrastructure [11, 35, 15].

It is also important to consider that digital technologies can streamline and make urban operations more accessible (not least because they are available online, wherever we are), as well as in terms of data generation and access. Additionally, people now have access to a vast amount of information, which enhances their mobility and purchasing power. (e.g., booking tickets, viewing and submitting applications, making appoint-

ments with doctors, and shopping online) without leaving home or traveling. All of this is a leading principle of a smart economy based on managed technologies. Further benefits arise because people communicate and can more easily form interest groups and can more effectively influence (or be influenced by) the decisions of local authorities and citizens [3].

However, the technologies used to create and support «Smart Cities» can also cause social problems. For example, excessive use of digital technologies can create inequality, as not everyone in cities can afford to buy the latest gadgets and learn how to use them. There are also concerns about the uninterrupted provision of smart cities with the ever-increasing amount and speed of internet or electricity required. Therefore, technology can be a useful tool, but it should never be the main (or only) reason for a city to be considered smart. As a result of discussions in academic circles, it was concluded that a «Smart City» is a combination of things that aim to improve, but not dictate, the quality of life.

Many cities around the world have developed and implemented various projects that include the word «smart» in their names, focusing on technologies such as green energy, virtual cities, and artificial intelligence. However, «Smart cities» are more than just cities built on the basis of modern technologies. Their goal is to ensure good governance, economic development, educational opportunities, and social equity, thereby improving the society they serve and enhancing the overall quality of life for their residents.

Among the Sustainable Development Goals of the United Nations program, the most important for urban development are «reduced inequality» and «sustainable cities and communities» [30]. Sustainable urban development, in the context of these goals, can be defined as an approach that balances environmental protection with the development of urban areas, focusing on employment, housing, basic services, transportation, and social infrastructure. The sustainability of life cannot be achieved without sustainable local communities, local governments, and citizens, who face the significant challenge of sustainable development [21]. To create smart sustainable cities, the concept of smart cities should be expanded to include investments in human, social, and environmental capital, and go beyond the current focus on technology [25, 33, 36].

«Smart Cities» have numerous advantages, offering solutions to challenges arising from urbanization and convergence, as well as new approaches to optimal policymaking. These advantages become particularly noticeable when considering the various areas of application for smart cities. First, smart cities enable governments to work more efficiently by improving e-government services, including e-taxation and online submission of public documents. They also enhance the role of government in emergency response, transparency, and

public safety [14]. Similarly, «Smart Cities» focus on users, i.e., citizens, to make their lives easier, including public transport that reduces congestion, high-quality education and health services, and increased social cohesion by promoting well-being. Third, «Smart Cities» are designed to enhance the well-being of enterprises by diversifying efficient production based on the needs of different sectors, starting with agriculture, and introducing innovations in business, marketing, and management. Fourth, smart cities enhance environmental protection. «Smart Cities» are ideally based on renewable energy sources and sustainable water supply, reducing all types of pollution. In the context of achieving environmental sustainability, «Smart Cities» implement sustainable infrastructure, including industrial structure and sanitation, which is essential for the long-term prosperity of the city.

Initially, the concept of «Smart Cities» was considered a form of modernization for megacities, relatively wealthy capitals, or regional megacities. Today, we must prepare for the diversification of smart solutions to meet the specific needs of even the most diverse territories, that is, for convergence. For example:

- smart micro-territories, which can be small cities, districts (smart urban village; 15 minutes from the city), or satellite cities near cities, always with small geographical and population dimensions;
- on the other hand, smart regions (strong trend in China and India); multipolar urban conurbation, or the allocation of coordinated new cities.

Therefore, many more urban modernization projects will be needed, at the same time with greater diversity, which will require greater flexibility from entrepreneurs and authorities, as well as functions from a wider range of solutions compatible with more differentiated territories. Such an approach necessitates a theoretical justification of the key principles and main directions of smart city development, considering the conditions and challenges of urbanization and convergence (Fig. 1).

Thus, interest in the concept of «Smart City» has grown dramatically over the past decade, transforming it into a dominant discourse in urban planning and digital transformation. This popularity, however, has led to conceptual blurring. Despite its widespread use, there is still no precise, comprehensive, and concise scientific definition of what exactly «smart» means in the context of a city. Different interpretations range from purely technological efficiency to comprehensive sustainability.

More importantly, there is a critical gap in the common understanding of the forms of governance that should be applied during the convergence of technologies and sustainability policies. As a result, «Smart City» is often seen as a tool for implementing technologies, rather than as a holistic management strategy for achieving sustainable development goals.

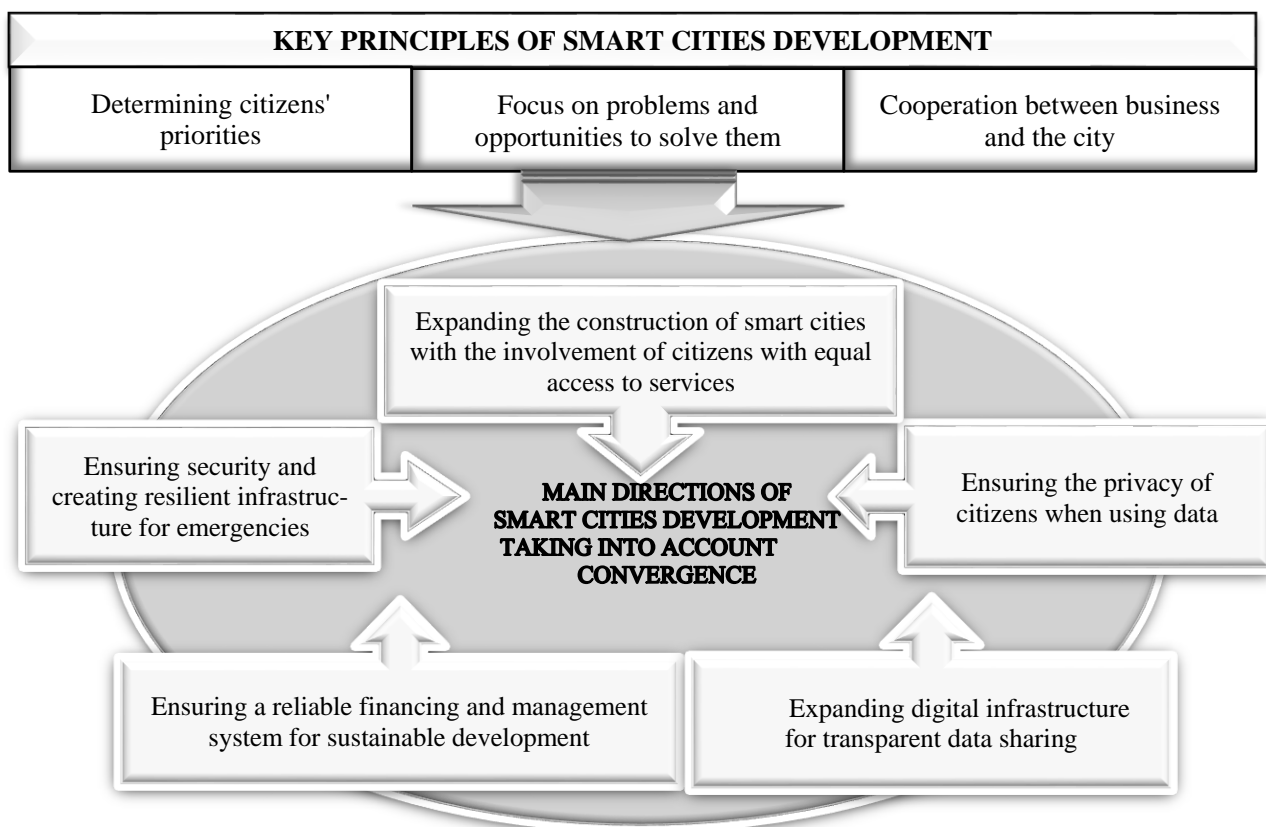


Fig. 1. Key principles and directions of smart city development taking into account urbanization and convergence

Source: developed by the authors in accordance with [30, 32]

As a result, without a clear conceptual framework and a coherent governance model, «Smart City» implementation risks remaining fragmented, focused on narrow technical solutions, and unable to ensure long-term, socially inclusive, and environmentally responsible sustainability.

Conclusions and prospects for further research.

As a result of the research, a comprehensive analysis of the evolution of the «Smart City» concept was conducted, ranging from early urban models of the 20th century to modern approaches that combine technological innovations, sustainability, and the principles of spatial justice.

The article demonstrates that the modern understanding of the smart city extends far beyond the technocratic approach, with human-centricity, inclusiveness, digital equality, and participatory governance becoming key. It is confirmed that technologies can provide a positive socio-economic effect only if integrated with policies aimed at overcoming inequality and ensuring equal access to urban services.

It is demonstrated that the «Smart City-4.0» concept is shaped by spatial justice theories [20, 29], which

emphasize the equitable distribution of resources and opportunities in urban space. The application of these theories enables us to view the smart city as a tool for harmonizing urban development, rather than merely as a technological platform. It is demonstrated that modern approaches to digital urbanization have the potential to reduce spatial disparities, provided that they prioritize inclusiveness and community participation.

It is also substantiated that smart cities are critically important for ensuring sustainable development in the context of rapid urbanization and increasing pressure on urban infrastructure. It is established that the integration of digital tools, open data, sustainable resource management, and participatory practices forms the basis for building efficient, safe, and socially just urban systems.

Thus, «Smart City» appears not only as a technological project, but as a multidimensional socio-economic concept that combines innovation, sustainability, and spatial equality. The results obtained confirm the need for further research to assess the impact of digital technologies on structural changes in urban spaces and the formation of a new paradigm of urban development.

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Buriak Ie., Savin S., Hulak D., Moisieienko L. Conceptualization and evaluation of the «Smart City» paradigm in the context of sustainable development

The article examines the evolution of the «Smart City» concept from its origins in urban and technocratic theories of the 20th century to its contemporary interpretation within the context of sustainable development. The key stages of the evolution of the concept are analyzed – from the idea of a «rational city» to the model of «digital equilibrium». Three main waves of development of the «Smart City» concept are identified: technocratic (1990-2000), socially inclusive (2010-2020), and integration or «Smart City 4.0» (from 2020).

The relevance and need for expanded research on smart city concepts for effective implementation in urbanization conditions are substantiated. The current problems of urbanization are considered, taking into account the main areas of population activity, quality of life, and sustainable development, which encompass areas such as education, healthcare, transportation, and public administration. It is revealed that the modern «Smart City» paradigm is based on a combination of digital and spatial justice. A historical and theoretical typology of approaches to «Smart Cities» is proposed, which can serve as the basis for further research into sustainable urban models.

Different approaches to planning and implementing smart cities are characterized, considering not only modern technologies, but also good governance, economic development, educational opportunities, and social equality. The main advantages of using smart cities in solving problems arising from urbanization are demonstrated. The key principles and directions of «Smart Cities» development are substantiated, taking into account urbanization and convergence in the context of sustainable development.

Keywords: urbanization, digital balance, spatial planning, regional convergence, spatial justice, inclusion, digital justice.

Буряк Є. В., Савін С. Ю., Гулак Д. В., Моїсєєнко Л. М. Концептуалізація та оцінка парадигми «smart city» в контексті сталого розвитку

У статті досліджено становлення концепції «Smart City» від її зародження в урбаністичних та технократичних теоріях ХХ ст. до сучасного трактування в контексті сталого розвитку. Проаналізовано ключові етапи еволюції поняття – від ідеї «раціонального міста» до моделі «цифрової рівноваги». Визначено три основні хвилі розвитку концепції «Smart City»: технократична (1990-2000), соціально-інклюзивна (2010-2020), інтеграційна або «Smart City 4.0» (з 2020).

Обґрунтовано актуальність та необхідність розширеного дослідження концепцій з метою ефективного впровадження в умовах урбанізації. Розглянуто актуальні проблеми урбанізації з урахуванням основних сфер діяльності населення, якості життя та сталого розвитку, що включає такі галузі, як освіта, охорона здоров'я, транспорт, державне управління. Виявлено, що сучасна парадигма «Smart City» базується на поєднанні цифрової та просторової справедливості.

Запропоновано історико-теоретичну типологію підходів до «Smart City», що може бути основою для подальших досліджень сталих урбаністичних моделей.

Охарактеризовано різні підходи до планування та впровадження «Smart City» з огляду не лише на сучасні технології а й з урахуванням належного управління, економічного розвитку, освітніх можливостей та соціальної рівності. Продемонстровано основні переваги застосування «Smart City» при рішенні проблем, що виникають внаслідок урбанізації. Обґрунтовано ключові принципи та напрямки розвитку «Smart City» з урахуванням урбанізації та конвергенції в контексті сталого розвитку.

Ключові слова: урбанізація, цифрова рівновага, просторове планування, конвергенція регіонів, просторова справедливість, інклюзія, цифрова справедливість.