STARTUPS AS DRIVERS OF DEVELOPMENT OF SMART CITIES

СТАРТАПИ ЯК ДРАЙВЕРИ РОЗВИТКУ РОЗУМНИХ МІСТ

Hnedina Kateryna
PhD in Economics, Associate Professor,
Chernihiv Polytechnic National University
ORCID: https://orcid.org/0000-0001-9471-0932

Soroka Anastasiia
Student,
Chernihiv Polytechnic National University
ORCID: https://orcid.org/0000-0001-9197-158X

Mazur Sergei
Master's Student,
Chernihiv Polytechnic National University
ORCID: https://orcid.org/0009-0007-1133-2296

Гнедіна Катерина Володимирівна
кандидат економічних наук, доцент,
Національний університет «Чернігівська політехніка»

Сорока Анастасія Володимирівна
здобувачка вищої освіти,
Національний університет «Чернігівська політехніка»

Мазур Сергій Олександрович
магістрант,
Національний університет «Чернігівська політехніка»

The article is devoted to the definition of the role of startups in the formation and development of smart cities. It was found that modern smart cities act as centers of innovation and technological development, adapting various smart solutions in order to improve the quality of life of residents and optimize infrastructure. The effective implementation and use of advanced technologies such as the Internet of things (IoT), artificial intelligence, data analysis and automation are one of the most important aspects of the concept of a smart city. Startups, according to their flexible and innovative approach, ensure the development of innovative informational and technological solutions in the field of smart cities. A review of the international experience of startup entrepreneurship was conducted, the results of which indicate that startups are actively implementing innovative solutions in such areas as transport, energy supply, ecology, health care, and others. Cooperation between government structures, business and startups contributes to the development of sustainable infrastructure solutions for smart cities. This approach contributes to the integration of advanced technologies, the development of innovative solutions and the creation of a balanced ecosystem environment, which helps not only to optimize the functioning of cities, but also to increase their resistance to challenges and ensure a high quality of life for residents. Conclusions were made that startup entrepreneurship can make a significant contribution to improving the indicators of a smart city and, accordingly, raise its position in the ratings. The research offers a conceptual view on the essential role that startups play in the formation and development of smart cities, generating innovative ideas, accelerating technological progress, and contributing to the improvement of the quality of life of residents.

Keywords: smart city, startup, urban development, quality of life, innovation, technological transformation, digitalization, sustainable development.

Стаття присвячена дослідженню ролі стартапів у становленні та розвитку розумних міст. З'ясовано, що сучасні смарт-міста виступають центрами інновацій та технологічного розвитку, пристосовуючи різноманітні інтелектуальні рішення з метою поліпшення якості життя мешканців та оптимізації інфраструктури. Один з

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важливих аспектів концепції смарт-міста полягає в ефективному впровадженні передових технологій, таких як Інтернет речей (IoT), штучний інтелект, аналіз даних та автоматизація. Стартапи, завдяки своєму гнучкому та інноваційному підходу, забезпечують розробку новаторських інформаційних та технологічних рішень у сфері смарт-міст. Проведено огляд міжнародного досвіду стартап-підприємництва, результати якого свідчать про те, що стартапи активно впроваджують інноваційні рішення в таких сферах, як транспорт, енергозабезпечення, екологія, охорона здоров'я та інші. Співпраця між урядовими структурами, бізнесом та стартапами сприяє розробці стійких інфраструктурних рішень для смарт-міст. Цей підхід сприяє інтеграції передових технологій, розробці інноваційних рішень та створенню збалансованого середовища, що не лише оптимізує процеси функціонування міст, але й забезпечує підвищення їх стійкості до викликів та зростання якості життя мешканців. Визначено напрями потенційної співпраці стартапів з бізнес-сектором та державними установами. Зроблено висновки про те, що стартап-підприємництво може зробити суттєвий внесок у поліпшення показників смарт-міста та відповідно посилити його позиції у рейтингах. Розкрито концептуальне уявлення про роль, яку відіграють стартапи у становленні та розвитку смарт-міст, формуючи інноваційні ідеї, прискорюючи технологічний прогрес і сприяючи поліпшенню якості життя мешканців.

Ключові слова: розумне місто, стартап, міський розвиток, якість життя, інновації, технологічна трансформація, цифровізація, сталий розвиток.

Introduction. The modern world is undergoing an exceptionally active process of global urbanization. According to United Nations forecasts, by 2050, cities will be home to two-thirds of the world's population [1]. As McKinsey & Company experts predict, cities will become key players in the world economy, contributing up to 80% of the world's GDP [2]. This upward trend in the urban population poses significant challenges and opportunities for our society. For today cities serve as centers of resource consumption and emissions of pollutants. Statistics show that cities meet almost two-thirds of global energy demand and are also responsible for more than 50% of solid waste and 70% of greenhouse gas emissions [3]. This situation underlines the relevance of forming new strategies for city management.

Considering these trends, it is crucial to explore the possibilities of creating smart cities that use innovative approaches and technologies to reduce the impact on the environment and optimize the use of resources. The development of smart cities is becoming a necessity to conserve resources and reduce emissions, contributing to the sustainable development of urbanized areas.

Smart cities require the integration of cutting-edge technologies for effective urban and resource management, creating a demand for innovations and new solutions. Modern startups can play pivotal roles in the development of smart cities, bringing innovative approaches and solutions in such areas, as IT, transportation, energy, healthcare, and many others. Their activities also contribute to the formation and increase of job opportunities, fostering sustainable economic development. Startup teams find and create intelligent solutions that increase the level of automation and efficiency of city infrastructure.

Cooperation between startups and smart cities also contributes to achieving environmental and climate sustainability. By developing innovative energy-efficient technologies and implementing environmentally friendly solutions, startups contribute to the reduction of CO_2 emissions and other pollutants, making smart cities more environmentally friendly and resilient to climate change. In this context, startups contribute to the creation of a climate-neutral and low-carbon future for smart cities, where efficient use of resources and environmental sustainability are the central principles of development. Understanding the role of startups in this context becomes essential factor for the further development and enhancement of the quality of urban life in smart cities.

Analysis of recent researches and publications. The issue of the efficiency of smart cities and their future potential has become a research focus for numerous Ukrainian and international scientists, among them: Pushkar T., Sevastyanov R., Tymoshevska I., Chukup S., Sanchez A., Peres I., Zhang L. and others. Scientists conduct an analysis of modern smart cities and their contribution to improving the quality of urban life. Experts from various scientific fields delve into the technological and innovative aspects of smart cities, describing their significant role in the development of modern urban environments.

Identification of previously unresolved parts of the general problem. Despite the explored aspects of the positive contribution and benefits of transitioning to smart technologies, there are unresolved problems that require further investigation. In particular, there is a need for a complex analysis and definition of the role played by startups in the development of smart cities.

Formulation of the article's objectives. The focus of the article is to investigate the role of startups in the formation and development of smart cities in the modern world. The article aims to identify trends in the development of smart cities and to highlight the international experience in using startups to achieve the sustainable development goals in the urban environment. Attention is focused on the question of how innovative solutions of startups contribute to improving the quality of life for residents and the creation of resilient urban infrastructures.

Summary of the main research material. Smart cities are urban areas where advanced technologies, innovations and digital solutions are used to improve residents' well-being, manage resources efficiently, and optimize urban infrastructure.

The significance of smart cities lies in their ability to address a range of modern challenges, such as environmental pollution, resource scarcity, traffic congestion, and many others. They contribute to the creation of more environmentally friendly and technologically advanced urban environments.
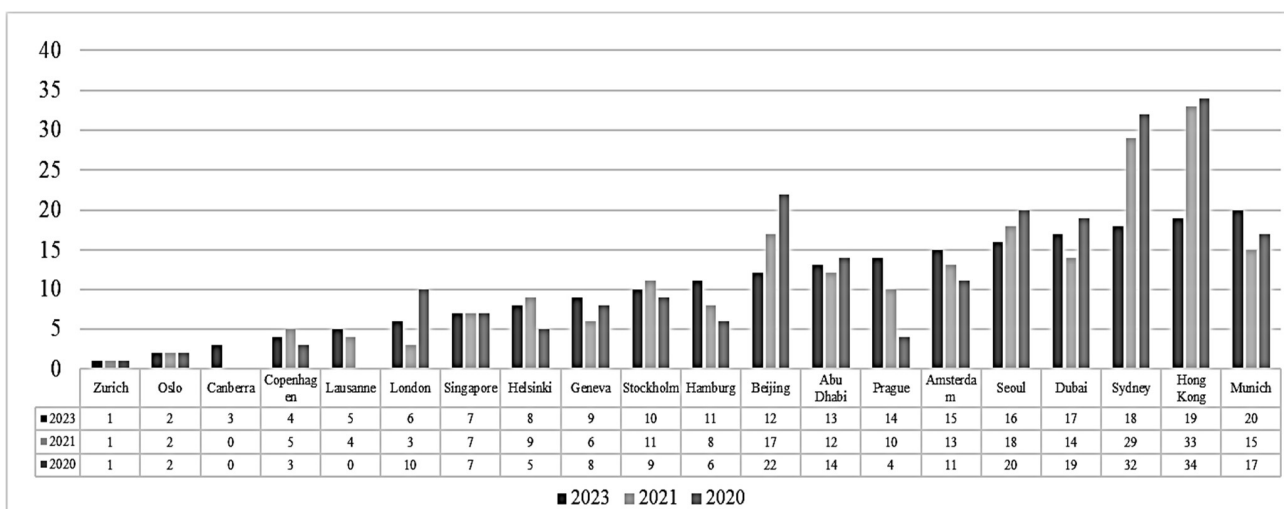
The Smart City Index, developed by The Smart City Observatory at the IMD World Competitiveness Center, serves as a tool for assessing and comparing the level of development of smart cities. It uses rigorous statistical data and survey results to determine the extent to which technologies contribute to cities in addressing challenges and achieving an improved quality of life for their residents. This index aims to measure and analyze the effectiveness of smart cities in aspects such as innovation, sustainability, inclusivity, and openness [4].

Since 2020 the leadership in the ranking has belonged to Zurich, while Oslo has been in 2nd place. Simultaneously, Canberra, the capital of Australia, entered the leaders for the first time in 2023, taking the third position. The list of TOP-20 smart cities also includes Copenhagen, London, Singapore, Helsinki, Stockholm, Prague, Abu Dhabi, Dubai, and others (Figure 1).

Today's smart cities are characterized by a high level of innovations and technology integration aimed at improving the quality of life for citizens. According to research conducted by the consulting agency Navigant Research, the concept of a "smart city" encompasses several key components [6]. Specifically, they implement solutions to optimize energy usage (Smart Energy), manage water resources and environmental safety (Smart Water), equip buildings with integrated systems for resource management efficiency (Smart Buildings), optimize transportation and logistics systems (Smart Transportation), and uses technologies to enhance the functioning of government entities and provide public services (Smart Government) (Table 1). These components work together as a system, contributing to the creation of smart cities that provide citizens with a more comfortable and sustainable environment for living and development.

Modern solutions in the field of smart energy include the use of renewable energy sources, energy efficiency programs, and smart energy consumption management. These innovations contribute to reducing CO_2 emissions, increasing

	Zurich	Oslo	Canberra	Copenhagen	Lausanne	London	Singapore	Helsinki	Geneva	Stockholm	Hamburg	Beijing	Abu Dhabi	Prague	Amsterdam	Seoul	Dubai	Sydney	Hong Kong	Munich
2023	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2021	1	2	0	5	4	3	7	9	6	11	8	17	12	10	13	18	14	29	33	15
2020	1	2	0	3	0	10	7	5	8	9	6	22	14	4	11	20	19	32	34	17

■2023 ■2021 ■2020

Figure 1. TOP-20 smart cities at the global level

Source: formed by the authors based on [5]

Table 1

Key components of the concept «smart city»

Component	Description
Smart Energy	Implementation of measures related to the provision and conservation of energy, including programs for demand-side management, improving energy efficiency, and integrating alternative energy sources.
Smart Water	Control and optimization of water resource utilization, including improving water supply systems, monitoring water consumption across various sectors, implementing systems for environmental safety, and flood prevention.
Smart Buildings	Modern buildings equipped with integrated technologies and management systems that enhance efficiency and comfort, while also ensuring more effective resource management, such as energy and security. They use sensors and automation to improve people's lives and work, as well as to reduce the negative impact on the environment.
Smart Transportation	Integration of advanced technologies and data-driven solutions in the transportation sector to enhance efficiency, safety, and resilience. This encompasses initiatives such as intelligent traffic management systems and improvements to public transportation aimed at creating a more seamless and environmentally friendly transportation network. Additionally, this component often includes smart parking and notification services for public transportation.
Smart Governance	Application of innovative technologies and data-driven approaches to enhance the efficiency, transparency, and responsiveness of government operations and services. This encompasses initiatives such as e-governance, open data, digital platforms, and citizen engagement tools to deliver public services to a broad audience and optimize the functioning of various departments.

Source: formed by the authors based on [6]

the reliability of energy supply, and reducing costs for the city. The implications of smart energy have long been practiced in major global cities. In New York, modern smart technologies have been implemented to optimize street lighting. A specialized system interacts with sensors that monitor road and street space occupancy. Based on the collected data, this system develops an optimal operating mode for streetlights, ensuring efficient and cost-effective city lighting [7]. In Barcelona, an intelligent lighting system also operates, allowing municipal authorities to save over 10 billion dollars annually on electricity costs in the near future. The city's lighting fixtures, equipped with smart systems, can measure various parameters such as noise levels, traffic intensity, pollution levels, crowd density, and even the number of photos taken on a particular street and uploaded to the network [7]. The Smart Grid is a key component in the creation of modern smart cities. This advanced system, built on cutting-edge technologies, enables efficient management of electricity production, transmission, and consumption, notably through smart meters that transmit real-time energy consumption data. It also allows for the rapid detection and automatic restoration of power supply in case of outages. The Smart Grid promotes the integration of renewable energy sources, such as solar and wind power stations, into the energy system, contributing to the development of a sustainable energy infrastructure [8]. This smart system is essential for ensuring energy efficiency, reliability, and resilience in urban power supply, fostering sustainable development and economic benefits for cities.

Smart buildings and innovative water and waste management systems have become crucial elements in modern cities, where technologies have seamlessly integrated, transforming the way resources are utilized. Barcelona, experiencing low humidity during summer, has implemented an automated irrigation system to efficiently use water resources [7]. Dubai, known for its technological initiatives, including the construction of skyscrapers over 10 meters high using 3D printing, represents pilot projects for the future of buildings in the Emirates [9]. In New York, cameras and sensor networks are installed everywhere to detect sound vibrations. In case of negative trends, an emergency signal is immediately sent to the police. Additionally, the city uses a smart waste management system: trash containers equipped with special sensors that notify when garbage needs to be collected. This system helps allocate manpower and equipment efficiently, saving resources and

ensuring cleanliness in the city [7]. In the future, Toronto in Canada plans to become a hub for ecological initiatives, including the installation of an automated underground waste disposal system. Furthermore, the city envisions sidewalks with integrated heating systems to automatically melt snow, eliminating the need for manual snow removal [10]. The Edge in Amsterdam stands out as a smart building recognized as the most environmentally friendly and sustainable in the world. With 28,000 built-in sensors, it interacts with residents through a mobile app, providing instructions for optimal workspace usage and managing their schedules [11]. A notable smart project in Singapore involves a monitoring system for the elderly people that uses special sensors to detect suspicious situations and sends notifications to relatives or support services. Another significant startup, Virtual Singapore, focuses on creating a highly detailed 3D model of the city, enabling real-time monitoring of various aspects of urban life, including traffic, population density, spread of infectious diseases, and air quality [12]. Copenhagen is renowned for its urban design, mandating green roofs on new buildings since 2010. This not only enhances the city's aesthetics but also purifies the air and facilitates rainwater collection, absorbing 80% of rainfall. Parks and green areas cover a quarter of the city's area, making Copenhagen one of the greenest cities in the world [13].

Smart Transportation is a key component in the development of future cities. For example, Oslo is creating conditions to promote electric vehicles, with over 2,000 charging stations and tax incentives for owners, contributing to the development of sustainable transportation [9]. Singapore is known for advanced technological solutions to enhance urban transport. Its smart traffic lights can analyze traffic intensity, adjusting signal timing to optimize traffic flow automatically based on traffic intensity. Most pedestrian crossings are equipped with systems that automatically extend green light time for elderly citizens and people with limited mobility. Smart parking technology uses special sensors to determine available parking spaces and sends this information to mobile app, simplifying the parking process [7]. Additionally, a "smart" transportation system is about not only modern transport infrastructure but also innovative startups, such as nuTonomy, which, in cooperation with the government, are developing and testing autonomous vehicles [14]. The attempt to implement this advanced technology in Singapore reflects ambitious plans to transform the city into an even more efficient and intelligent one in the future. In London, the Foster+Partners SkyCycle project is being considered to create elevated bike paths that will run above the city's railway tracks [7]. This initiative is focused on improving cyclist safety and reducing car traffic on public roads.

Smart Governance also contributes to improving the efficiency of city and state management, simplifying citizens' access to information and services. In many modern smart cities, platforms are emerging for interaction and idea exchange among various stakeholders. Estonia's Tallinn is one of the most effective in applying blockchain technology, where residents actively vote in elections, pay taxes, and communicate with authorities online, ensuring maximum security and privacy [12]. Singapore provides 650 online services through its government portal, where municipal services are available in one mailbox for the convenience of citizens. Dubai had an ambitious plan to digitize all government services, covering a wide range of sectors from transportation to economic services. New York uses big data technology to process information from various sources, including water consumption and safety data [15].

Smart cities often rely on partnerships with large technology companies offering innovative solutions. Modern smart cities heavily depend on innovative approaches and technological solutions, and startups play a crucial role in implementing smart strategies in cities. For example, such projects as "Amsterdam Smart City," "Vienna Smart City," and "Smart London" actively operate on cooperation platforms [16]. These projects bring together all branches of government, businesses, civil society, and the academic sector to develop the smart city and its infrastructure, mobilizing public, commercial, and scientific resources. They engage new startups to develop and implement innovative technologies that enhance the quality of life for residents and optimize the functioning of the urban environment. These processes underline the importance of startups in fostering the establishment and development of smart cities, where technological innovations play a dominant role in urban management and improving residents' lives.

Modern startups can make a significant contribution to the development of smart technologies in cities, contributing to the achievement of their strategic goals in terms of efficiency, sustainability, and improving residents' quality of life. They actively develop

software solutions to optimize transportation systems, implement data monitoring systems to enhance the environment and water supply, and create mobile applications to improve interaction between residents and authorities. Additionally, startups play a crucial role in promoting inclusive development in smart cities by addressing issues of accessibility and providing services for all segments of the population. They create innovative solutions aimed at improving the quality of life for people with special needs and consider social aspects in their projects. Through partnerships with companies and support from local governments, startups could actively contribute to the development of smart cities, helping them to become more sustainable, efficient, and comfortable for residents.

To ensure the survival of a startup in the modern urban environment, it is advisable to transform it into a scaleup, meaning expansion with realistic growth plans. Scaleups are an ideal option for modern cities seeking sustainable and effective solutions to improve citizens' quality of life. They focus on gradual development and adaptation, thereby exposing themselves to less risk compared to most startups which overemphasize only the development phase. Successful examples of this approach can be seen in Mexico City. By developing a mobile app model for shared electric scooters, Econduce saved over 300 tons of CO_2 and created 54 jobs. It demonstrates a progressive and gradual approach, forming positive social and environmental impacts and fitting seamlessly into new urban landscapes where it is crucial to develop efficient and sustainable solutions [17].

Startups play an important role in creating and implementing smart solutions for charter cities. The example is Ithana in Nigeria, which has its own management system and autonomy. This type of urban governance is practiced worldwide, with Hong Kong being an example. Despite criticism related to protectionism and autonomy, these cities serve as laboratories for implementing innovative solutions and technologies, allowing for the refinement of approaches to urban planning and development [18]. They can independently create models for efficient resource usage, enhance ecological sustainability, and improve the comfort of their citizens through smart solutions.

The UNITAC Hamburg Technology Center in Germany plays a key role in leveraging digital technologies to promote sustainable urban development. This accelerator uses innovations and research to create solutions aimed at improving conditions in cities and fostering urbanization. In recent years, digital innovations such as civic technologies, geographic information systems, and open data have transformed the approach to city management [19]. These processes create a favorable environment for the development of startups that can accelerate this process and bring innovation to smart cities.

There is a well-founded area of debate regarding the transition to digital technologies and smart cities, where a significant portion of opponents claims potential job losses. However, scientific research conducted by the McKinsey Global Institute suggests that the impact of digital technologies on employment may have the opposite effect. According to these studies, for every job lost due to automation and digitization, 2.4 new jobs are created [20]. Therefore, the transition to smart cities and the use of digital technologies contribute to creating new opportunities for employment and economic development. Green transformation and the transition to sustainable, low-carbon, and climate-neutral economies significantly impact the labor market, fostering the emergence of a new type of employment known as "green jobs." These jobs arise in renewable energy, energy efficiency, eco-friendly construction, waste management, and more. According to the European Union, by 2030, an additional 160,000 green jobs are planned to be created in the construction sector and other environmental industries [21]. In this context, startups play a crucial role by developing innovative approaches and technologies aimed at supporting green initiatives. Specialized startups can create new jobs by implementing projects in renewable energy, the production of environmentally friendly technologies, and resource-efficient practices. Green initiatives require new skills and specialized training for workers, and startups can contribute to this process by offering training programs and requalification initiatives.

The synergy between innovation-oriented startups, corporate structures, and the public sector is a key aspect of prospective cooperation, defining new paths for development. Startups, with their flexibility and technological progressiveness, can accelerate the implementation of innovative solutions in business and society. Corporate structures can provide startups with resources and expertise, ensuring a mutually beneficial partnership. When the government supports such initiatives, it creates a favorable environment for innovation and accelerates economic

growth. Table 2 outlines the perspective directions for cooperation between startups, the business environment, and the government. Such partnership and cooperation not only strengthen the country's competitiveness but also contributes to the creation of a sustainable and efficient environment enhanced through innovative technologies [22].

In recent years, the increasing frequency of natural disasters emphasizes the importance of preventive measures and mitigating their consequences. Smart city technologies, using sensors and data analysis, are revolutionizing cities' disaster preparedness and effective response. Sensors monitor and predict natural disasters, and the data is used to develop effective prevention and recovery plans. Smart cities not only respond promptly in real-time with coordinated crisis management services but also actively contribute to the recovery of affected areas. Startups play a crucial role in advancing these technologies by introducing innovative solutions and driving progress in safeguarding cities against natural disasters [23].

Japan serves as an example of a country where startups in the field of forecasting and preventing natural disasters actively develop and implement intelligent solutions, considering the history of earthquakes, tsunamis, volcanic cataclysms, and floods. In response to extreme weather conditions, Japanese startups leverage advanced technologies, including artificial intelligence, satellite imagery, and Internet of things devices, to reduce the impact of natural disasters [24]. Kast RTi is one of such startups, which is originated at Tohoku University. It uses a supercomputer-based system that analyzes the scale and speed of tsunamis. Responding to earthquakes, it predicts potential impacts and damages, providing immediate information to local authorities [25]. Another Japanese startup,

Spectee, has developed a platform that swiftly gathers information after natural disasters or emergencies from satellites, live broadcast cameras, and social media to provide a comprehensive overview of damages within one minute. The information visualized on the map enables users to efficiently filter data, and a team of experts verifies the accuracy of the information before publishing it on the platform [24]. The startup Terra Labo, in cooperation with the government and local authorities in Japan, uses unmanned aerial vehicles (UAVs) for disaster support systems during massive catastrophes. UAVs have become a cost-effective alternative in aerial photography with low operational costs and enhanced technical functionality. Additionally, Terra Labo is developing the crowd platform "Terra Crowd" to exchange data collected by its UAVs, contributing to the digital transformation of emergency management. The platform has already been used during various disasters, including the 2021 Fukushima earthquake [24].

Startups can also be the drivers of the transition to smart technologies in the framework of green recovery of Ukraine. The reconstruction of Ukraine should be based on innovations, which determines the importance of the role of startups in these processes. A key role in the green reconstruction of Ukraine is played by startups in the field of energy efficiency, RES-energy, green construction, systems of national security and city management, green education, etc. Higher educational institutions of Ukraine play a core role in providing the country with highly qualified personnel, which necessitates their eco-transformation and development of green education. In addition, higher educational institutions of Ukraine can act as a powerful platform for the development of startup culture, the startup movement, and the formation of innovative solutions, which will be

Table 2

Directions for cooperation between startups, corporate structures, and the government

Areas of cooperation	Characteristics
Funding of startups	Government scholarships, grant initiatives, targeted lending, venture capital investments
Mentorship and informational support for startups	Expert councils, academic programs, integrated networks of highly qualified scientists and managers
Infrastructure and resource integration	Business incubators, technology hubs, access to computing and research resources
Regulatory support for startups and legal consulting	Favorable legal mechanisms, simplification of business registration procedures, minimizing administrative restrictions, providing tax incentives, and consulting

Source: formed by the authors based on [22]

extremely important for the sustainable recovery of Ukrainian cities in the post-war period and implementation of smart technologies. This, in turn, determines the relevance and urgent need for the formation and development of startup ecosystems in higher educational institutions in Ukrainian cities [26].

Conclusions. The results of the research clearly demonstrate that startups play an important role in the process of formation and evolution of smart cities. Analysis of existing smart city models reveals that the implementation of innovative startup solutions demonstrates high effectiveness in such areas as Smart Energy, Smart Water, Smart Buildings, Smart Transportation, and Smart Governance. Startups are actively contributing to improving the lives of urban residents today, transforming cities into convenient and sustainable centers. Smart cities increase the convenience and safety of city dwellers, promote environmentally friendly development, and achieve sustainable urban infrastructure, reducing the environmental footprint by implementing low-carbon technologies and resource optimization. This approach ensures the environmental sustainability of cities and enhances the overall quality of life for their residents, providing access to more convenient and efficient city services. There processes include improvements in mobility, access to green spaces, optimization of energy and water usage, as well as waste management enhancements. In addition, startups have a huge potential to create new jobs in the field of smart technologies that meet the needs of the economy and society. Startup initiatives contribute to economic growth and provide skills for future generations.

However, further scientific research in this direction will require addressing key challenges, such as creating incentives for innovation and resolving regulatory issues. Partnership and cooperation between startups and municipal authorities, corporations, and academic institutions is crucial for the successful implementation of smart technologies. Open innovation markets and fostering partnerships between startups, businesses, and government can create synergy that contributes to the development of sustainable and intelligent city infrastructure. Thus, the dynamics of the formation of smart cities indicate that startups are essential not only as innovative players but also as partners of local authorities and communities in building a future where technology coexists with sustainable development, opening pathways for new perspectives on smart cities, where every resident can participate in the implementation of digital solutions, improving the quality of life and contributing to global sustainable development. Definition of the role of startups in the formation and dynamic development of smart urban ecosystems becomes an essential focus of contemporary scientific and practical activities. This issue belongs to strategic priorities, creating opportunities for the transformation of urban space, expanding the city's innovative potential, enhancing the efficiency of resource and service management, and addressing urgent challenges faced by modern cities, including environmental issues, ensuring safety, optimizing transportation systems, and increasing competitiveness.

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