



On the Issue of “Smart Cities” and “Citizen Science”

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Abstract: This article examines approaches to the creation of “smart cities” and the characteristics of the development of “citizen science”. The concept of a “smart community” was first formulated as early as 1993 and was presented in the “Guide to Creating “Smart” Communities ...” by San Diego State University in 1997. This approach formed the basis of the European vision of the “smart city” and was described in 2007 by the Centre for Regional Science at the Vienna University of Technology. Thus, the concepts of “smart cities” and “citizen science” have been actively discussed for over 30 years. Market players and public institutions viewed “smart cities” as a common topic for discussion and a new area for cooperation. City administrators announced “smart city” strategies or projects to raise the city’s profile, attract investment and attract high-tech businesses, whilst companies were tasked with solving local problems in urban services. As a result, the solutions tested were isolated, and the experience of digitalizing one municipal service proved difficult to transfer to others. The development and widespread adoption of information and communication technologies have led to the emergence of new forms of citizens’ digital participation in socio-political processes and to a broadening of the range of people involved in these processes. A modern “smart city” consists of a set of isolated, vertical solutions. Integrating these solutions on the basis of unified digital platforms is a pressing and complex challenge for businesses and local authorities. In this article, the concept of a “smart city” is examined as an intelligent system that is designed and managed at a new level of efficiency, whether from a purely technological or a socio-urban perspective. It is demonstrated that, to ensure the effectiveness of digital platforms for public participation in governance, attention should be paid not only to their technical parameters and the forms of public participation employed (information provision, consultation, dialogue), but also to the public significance of the issues under discussion. Indicators of technical capabilities, the degree of public participation, and the public significance of the issues under discussion will help to assess the effectiveness of e-participation platforms and can be used in their evaluation and comparative analysis at the state level. The study will be of interest to government officials and business representatives involved in the development, implementation and improvement of existing information and communication technologies with a view to promoting citizens’ socio-political participation.

Keywords: Information technology, citizen science, smart city, public participation, digital platforms, urban development.

INTRODUCTION

The Internet era began on 29 October 1969, when scientists sent the very first message over the ARPANET network, moving towards modern communication standards in 1983 and opening up to the world with the creation of the World Wide Web in 1991. The Internet has radically transformed economic, political and social relations across the globe. Connection speeds and the volume of information generated within the Internet's information and communications space are increasing exponentially. The impact of computer technology is felt most strongly in cities (rapid urbanization), which are the main centers of human population concentration in virtually every country. According to the United Nations Department of Economic and Social Affairs, by 2050, 68 per cent of the world's population will live in cities, placing an unprecedented strain on urban infrastructure [1].

It is therefore not surprising that the idea of using information technology to improve the quality of life in urban spaces has emerged, and this is precisely how the concept of "smart cities" came about. Although this term can sometimes be highly ambiguous, most definitions of a "smart city" convey the concept of a comprehensive urban environment linked by a basic information network that stimulates and supports its economic, cultural and social development in an environmentally sustainable manner [2]. The "smart city" concept represents one of the most significant paradigms of contemporary urban development, aimed at providing comprehensive solutions to the challenges faced by megacities in the 21st century. The growth of the urban population, increased pressure on infrastructure, environmental challenges and the need to improve citizens' quality of life are driving the search for innovative approaches to urban management. Summarizing definitions from various sources [3-11], it can be concluded that a "smart city" is a strategic approach to the large-scale implementation of technological innovations in the mobile, network and backbone infrastructure of the urban environment, based on the integration of information and communication technologies (including 5G communications technologies), Internet of Things (IoT) and Industrial Internet of Things (IIoT) technologies with edge computing, structured and unstructured Big Data with application programming interfaces (APIs), virtual models of physical objects (digital twins), cloud computing and artificial intelligence models (in particular, intelligent agents) to improve the quality of life for city residents, enhance management efficiency and promote sustainable economic growth.

The concept of the "smart city" has evolved from the simple implementation of information and communication technologies to the creation of a complex, integrated ecosystem in which technology serves as a tool for improving quality of life and promoting sustainable development. However, technological infrastructure alone does not guarantee success. The key factor determining the effectiveness and viability of a "smart city" is the level of engagement of its residents in governance and decision-making processes.

Discussions on best practices in the field of "smart cities", the study of best practices, and the identification of the needs and objectives of regions and individual cities in this area have formed the basis of discussions at numerous forums and conferences held in the United Kingdom, Switzerland, China, Canada, Nigeria, Italy, Turkey, Spain, Thailand, Hungary, Malaysia, Russia, Australia, the Netherlands, the Czech Republic, Chile, France, the United States, Nepal, Indonesia, Portugal, Cyprus, the United Arab Emirates, Saudi Arabia, Morocco, Laos, Austria, India, Pakistan and Japan. The regions covered include North America, Europe, the Asia-Pacific region, the Middle East, Africa, Australia and Latin

America. Thus, the list of countries actively involved in developing the digital infrastructure of their cities and regions once again highlights the onset of a phase of mass implementation and replication of successful “smart city” solutions. Reference [12] notes that the Asia-Pacific region will grow the fastest, with an average annual growth rate of 11.7 per cent, driven by rapid urbanization, national “smart city” programmers and the accelerated roll-out of IoT/5G. China, India and Japan are the leaders in adoption. China is emphasizing the large-scale deployment of platforms and nationwide standards. India is focusing on scalable and cost-effective SaaS pilot projects, whilst Japan and South Korea are prioritizing mature pilot projects, fault tolerance and privacy. Overall, MarketsandMarkets forecasts that the market for “smart city” platforms will grow to US\$39.52 billion by 2030 [12].

Among the upcoming events in the field of “smart cities“, we would like to highlight the leading global forum, the “SmartCitiesWorld Summit 2026“ [13]. The “Cities and Climate Action“ session will examine how cities can make tangible progress towards net-zero emissions and adapt to increasing climate pressures. The “Urban Resilience“ session will focus on how cities can prepare for and withstand interconnected shocks and stresses. The “Smart City Innovations“ session will examine technologies, architectures and data processing capabilities that enable the creation of smarter, more efficient and responsive cities. The Smart City Expo 2026 World Congress is the world’s largest and most influential event dedicated to cities and urban innovation [14]. The “Smart Country 2026“ convention - Germany’s leading event on the digital transformation of the public sector - will examine digital solutions that can contribute to the development of governance, cities and rural areas [15]. The Smart Cities Connect conference will explore strategies, partnerships and technologies that have a long-term impact on urban systems [16]. The Smart City SEE conference will examine public services for “smart cities” that significantly improve all aspects of life for citizens and urban communities, whilst making cities more sustainable and carbon-neutral [17]. The International Conference on Smart Cities (CSC 2026) aims to discuss the social, behavioural, technical, economic and environmental implications of implementing “smart city” applications and services [18].

KEY PRINCIPLES OF CONSTRUCTION

The concept of a “smart city“ goes beyond a simple technological upgrade. It involves transforming governance models, engaging citizens in decision-making and creating new economic opportunities. However, this is not the first time that communication technologies have radically changed the way of life in cities. Undoubtedly, the telephone, radio and television have had an impact on all areas of society. However, the difference now lies not only in the scale and effectiveness, but also in the nature of the communication taking place. The main aim of previous technologies was simply to facilitate direct communication between people. But the market for “smart city“ platforms is evolving from outdated IT projects and fragmented deployments towards integrated, API-based, data-driven ecosystems. These are now comprehensive solutions designed to accelerate the digital transformation of cities. They combine cloud technologies, artificial intelligence, the Internet of Things and big data, enabling real-time city management, intelligent decision-making and improved public services.

An analysis of Russian and international practices reveals several fundamental principles underpinning “smart city” projects:

- A people-centered approach: Technologies are introduced not for their own sake, but to address specific issues faced by residents: saving time, enhancing safety, and improving health and comfort.
- Sustainable development: Optimizing energy and water consumption, managing waste and reducing transport emissions are an integral part of the concept. It is essential to minimize negative impacts on the environment. Environmental sustainability is achieved through continuous monitoring of pollution and modelling of its spread, which is particularly important for large industrial cities.
- Effective management: The creation of a unified digital platform for data collection and analysis enables a shift from reactive management (responding to incidents) to proactive management (forecasting and prevention).
- Cost-effectiveness: The implementation of “smart” solutions should lead to direct savings in public funds through the rational use of resources and a reduction in operating costs. Furthermore, it creates an attractive environment for private investment and the development of the IT sector.
- Security: Ensuring the physical and information security of citizens and critical infrastructure is a prerequisite for the system’s operation. Security is enhanced in two ways. Firstly, AI-powered video surveillance systems and predictive analytics help prevent offences by analyzing crowd behavior and identifying potential threats. Secondly, digital twins play a key role in managing the risks associated with emergencies. For example, they can assess the risk of flooding during heavy downpours, predict power grid overloads, identify buildings requiring urgent repairs, and much more.

It is worth noting that in Russia, the concept of “smart cities” is moving from a stage of piecemeal implementation to a phase of large-scale projects envisaged by government programmers at both federal and sectoral levels. A systematic, comprehensive approach is being developed to the goals, objectives and methods of creating “smart cities”, which involves all stakeholders moving beyond the perception of a “smart city” as merely the “sum of its technologies”. We would like to highlight the inter-ministerial initiative “Smart City and Safe Environment”, which aims to harmonize federal initiatives, regional practices and business solutions to achieve practical results on the path towards a “smart country”. The initiative forms part of the national project “Data Economy and Digital Transformation of the State” [19]. The initiative’s thematic sessions examine case studies of the application of digital twins, predictive analytics and artificial intelligence in urban management, the development of domestic solutions for the “Safe City” concept, and innovative ecosystem-based digital services for citizens and businesses, tailored to the real needs of the urban environment and involving city residents in addressing urban development issues.

Overall, the Russian “smart city” model is characterized by a top-down, centralized approach focused on the efficiency of public administration, centralized departmental management, an emphasis on the integration of departmental data, and the dominant role of state investment. In other words, in Russia, the driving force behind the “smart city” is the state, which aims to improve the manageability and efficiency of existing systems.

TECHNOLOGY ARCHITECTURE AND KEY AREAS

The functioning of a “smart city” is underpinned by a complex, multi-tiered architecture, at the heart of which lies digital infrastructure and computer technology:

- The Internet of Things (IoT) and the Industrial Internet of Things (IIoT). This is a network of billions of physical domestic and industrial objects equipped with sensors, software and communication devices, which collect data in real time on equipment parameters, the environment and the behavior of city residents, and exchange this data without human intervention, paving the way for the automation of production processes and intelligent analytics.
- Artificial Intelligence and Big Data: The raw data collected by sensors is fed into centralized repositories, where artificial intelligence algorithms identify patterns, make predictions and automate decision-making. For example, they enable predictive analytics of traffic flows or the prediction of equipment failures.
- Digital Twin: This is the most sophisticated and comprehensive tool for digital transformation. It is a dynamic virtual replica of a city or region that reflects all ongoing processes in real time: traffic flow, the condition of buildings, pedestrian flows and environmental parameters. This makes it possible to test the consequences of infrastructure changes, manage emergencies and plan development without posing any risk to the real world.
- Fifth-generation (5G) connectivity: High-speed, low-latency networks are essential for ensuring the instantaneous transmission of vast amounts of data from billions of IoT and IIoT devices.
- Cloud computing: This provides the necessary computing power and scalability for data storage and processing.

In practice, the “smart city” concept is implemented through a number of key areas that form the city’s life support system:

- Transport: Intelligent transport systems include adaptive traffic lights, real-time traffic management systems, public transport monitoring, smart parking services and the development of autonomous vehicles. This leads to a reduction in traffic congestion, shorter journey times and fewer accidents.
- Housing and utilities: Smart water, heating and electricity meters ensure accurate metering and transparency of tariffs. Automated systems control street lighting, reducing energy consumption, whilst sensors help to quickly detect leaks in water supply networks.
- Environment and waste management: Air quality and noise level sensors monitor environmental conditions. In the waste sector, bins fitted with fill-level sensors are used, enabling the optimization of refuse collection routes, thereby saving fuel and time.
- Public safety: A unified video surveillance system with facial recognition and behavioral analytics helps law enforcement agencies prevent offences and respond swiftly to incidents. Emergency alert systems inform the public about emergencies.

- E-government services: The digitalization of interactions between citizens and the state simplifies access to services (booking doctor's appointments, paying fines, obtaining documents), improves their accessibility and reduces bureaucracy.
- Healthcare and education: Telemedicine, remote patient monitoring, electronic health records and educational platforms improve the quality and personalization of social services.
- Public administration: A new system of government that utilizes digital technologies, Big Data and Artificial Intelligence to rapidly resolve urban challenges, improve people's lives and ensure the efficient use of resources.

TRENDS AND CHANGES

As noted above, a "smart city" is an ecosystem in which technology manages the environment on the basis of data. A key element is the continuous collection of data from a multitude of sensors integrated into the city's infrastructure. This data forms the basis for analytical platforms powered by artificial intelligence and big data, which enable the modelling of urban processes, the forecasting of events and the optimization of resource use. In particular, this enables real-time threat detection, crowd monitoring and the management of emergency responses, traffic management, the implementation of preventive measures to ensure public safety, and much more. In other words, the Internet of Things forms the physical foundation of the digital city. And here, the Internet of Things is a concept best understood in contrast to the more traditional "Internet of People". When we think of the Internet, we usually picture users connected to the World Wide Web, communicating with one another via email, exchanging information through social media or forums, or sharing content via blogs and video-streaming platforms. However, in the Internet of Things, it is sensors and computers themselves that interact with one another [20]. People may benefit from the final processed data and even have access to it or use it as they see fit, but they do not usually manually input any data into the system. Thus, a "smart city" aims to use the Internet of Things to improve efficiency and enhance the overall quality of life. Sensors can be used to regulate traffic, monitor air and water pollution, reduce unnecessary energy consumption and even monitor people's health.

However, installing sensors everywhere can easily generate huge volumes of data on a daily basis, which would be impossible to store on a single computer, let alone process in any useful or meaningful way. This is where big data solutions come into play [21]. This term refers to new methods developed to process vast amounts of unstructured information using multiple interconnected computers - "cloud computing". It is envisaged that, with more data available, it will be possible not only to understand how cities function better than ever before, but even to automate many tasks by identifying trends and correlations that could not be detected using traditional methods of data analysis and collection.

However, technology alone is not enough to make a city "smart". After all, even if Big Data enabled us to collect information on absolutely everything that happens in a city, it would be an enormous waste, and we would not even know what to do with it without setting clear goals and objectives in advance. Overall, it is extremely important to develop an urban development strategy when attempting to create a "smarter" city [22]. Clearly, the authorities must focus on increasing both the number and the effectiveness of the smart

services they provide. At the same time, it is important to assess the acceptable environmental impact of any new programs, to prioritize where a limited budget should be spent, and to identify any problems as they arise. Without a plan, no advanced technology can have a positive impact on urban spaces.

Thus, a smart city consists of at least two key components: communication technologies and careful management. However, this is still not enough. One could imagine a hypothetical, flawless yet empty city with perfectly regulated smart transport, a fully renewable smart energy system, and the most comfortable smart homes in the world. Nevertheless, there would be little point in striving for this if there were no one to benefit from it. In other words, the third key component of “smart cities” is the residents themselves. And this is undoubtedly not only the most important, but also the most complex element.

After all, the issue is not simply a matter of listening to the demands and feedback of the population. Even within this limited framework, the urban population is heterogeneous, and striking a balance between the needs of different groups can prove to be a very complex task [23]. Moreover, any new urban program must carefully take into account not only explicit requests but also characteristics of the population that may not be so obvious. For example, no sensible solution will work if people do not know how to use it or do not have access to it [22]. Furthermore, citizens may have reasons for being reluctant to accept changes to their environment. They may have concerns about privacy, data security or transparency, to name but a few [24].

It is increasingly argued that sensible decisions are unlikely to be sustainable if citizens remain passive. To achieve not only success but also long-term sustainability, it can be extremely beneficial for citizens to be involved in the management of urban projects [23]. If they become active participants and come to understand the project’s objectives, how it has developed, and what the benefits of a positive outcome would be, then they will be more likely to contribute to achieving that outcome. This will not happen automatically with any project - it only happens with those that genuinely serve the interests of citizens. That is why a truly “smart city” does not view people merely as sources of information for its ubiquitous sensors - it takes steps to involve them in decision-making processes [25]. Thus, the question of how cities should give their residents a meaningful voice in public affairs naturally leads to the topic of citizen participation.

From the perspective of public administration, it has recently become increasingly clear that urban projects must be based on some form of participatory approach or participatory design. This means that, from the very outset, the aim has been to involve ordinary citizens—as the key stakeholders in urban initiatives—in dynamic, active collaboration throughout the entire process [26, 27]. This stands in stark contrast to traditional “top-down” approaches, in which the authorities make all the decisions and, at best, simply inform the public of what has happened. Instead, using this new type of approach, ordinary citizens should be given the opportunity to choose for themselves which issues should be addressed and how they should be resolved.

The rationale behind this is that, more often than not, it is citizens who suffer most from the way public affairs are managed. In reality, it is government institutions that actually hold the power. Without making a concerted effort to engage with the public, government officials may make decisions that do not align with the genuine public interest. In the worst-case scenarios, when corruption within government bodies becomes rampant, the

authorities may seek only to serve the interests of corporations, powerful elites or even themselves. Thus, an approach based on broad participation is a means of improving governance and transparency, as well as ensuring the protection of citizens' rights.

Some of the emerging "smart cities" have recognized the importance of citizen participation and have sought to streamline their approach to participation through a range of solutions collectively known as "e-participation". This term, as one might expect, refers to the use of information technology to engage ordinary people more effectively in policy-making processes [28]. To genuinely engage citizens, a user-friendly, accessible and multifunctional digital infrastructure must be established. Key areas for improving such infrastructure include:

- **Mobile accessibility:** Most city dwellers use smartphones as their primary channel for interacting with digital services. The development of user-friendly mobile applications is critical for achieving widespread reach.
- **Gamification:** The introduction of game-like elements encourages regular use of platforms and transforms routine actions into an engaging process.
- **Personalization:** Providing information and opportunities for participation that are relevant to users' specific neighborhoods and interests makes interaction more meaningful.
- **Building communities, including professional ones:** Infrastructure technologies should facilitate not only vertical "citizen-government" interaction, but also horizontal interaction amongst residents themselves. Creating online groups to tackle local issues strengthens social ties at the micro-level.

At the same time, in theory, it should be much easier to inform people, seek their views and answer their questions via the internet.

E-participation is usually a component of e-government platforms. These are web portals that offer a wide range of public services, often in an automated manner where possible [29]. The appeal of e-government lies not only in improving efficiency but also in enhancing accessibility. After all, accessing public services through traditional channels requires visiting specific buildings during office hours, and usually only on weekdays. E-government, however, can be accessible to everyone, at any time and from anywhere, provided there is an internet connection.

A good example of a "smart city" that has implemented e-participation initiatives as part of its e-government strategy is Moscow [30], which has rolled out the following initiatives:

- The "Our City" website allows people to submit complaints about issues occurring in their neighborhoods. The municipal authorities will provide an official response to any complaint within less than a week. In this way, a feedback loop has been established with the aim of bridging the gap between the public and the public sector.
- The "Active Citizen" portal showcases various projects and strategies currently under consideration by local authorities. Citizens can vote for those they consider to be the most important. This enables the authorities to gather information from the public to determine administrative priorities. Although the portal is sometimes criticized for being overly formal, its very existence and the millions of participants

demonstrate the enormous potential of such tools for gathering opinions and conducting surveys on a wide range of issues - from choosing names for underground stations to setting priorities for urban regeneration.

- Finally, there is “Crowd“, a crowdsourcing platform where citizens can submit their own ideas and projects to local authorities for improving the city [31]. The most promising of these proposals undergo a selection and refinement process, after which they are translated into policy. Although very few ideas have reached the end of this process, it remains a very interesting initiative for empowering the residents of Moscow.

Nevertheless, although there is generally a close link between e-government and e-participation, it is important to note that, in reality, they are not one and the same. Public services cover a wide range of procedures, such as obtaining a driving license or a birth certificate, and many of these have no connection whatsoever with any form of participation. Thus, the state may well offer a reliable e-government platform without taking any steps to create or encourage any form of e-participation at all [32]. In other words, the availability and use of new technologies do not in themselves guarantee citizen participation.

However, even in cases where the authorities are keen to adopt an approach based on broad participation, other obstacles exist. Even with modern technology, most participation initiatives rarely achieve the level of fully empowering citizens or delegating control to them; instead, they most often simply inform them or consult with them. This limited form of participation is so widespread that the term “tokenism” has been coined for it, referring to the concept of a mere token or symbolic involvement [33]. This can probably be explained, at least in part, by logistical difficulties. For example, even the Moscow “Crowd“ initiative mentioned above has implemented only 23 of the more than 100,000 ideas submitted to the platform since 2014 [31]. This is most likely not due to a lack of interest on the part of the authorities; rather, the opposite is true - moving beyond mere “information“ or “consultation“ leads to the involvement of a far greater number of people in the policy-making process. This challenges the traditional dynamics of government bodies, which in the past made decisions unilaterally, and they are clearly not yet fully prepared to work effectively within this new paradigm in collaboration with a potentially large number of citizens with diverse interests and skill sets.

Furthermore, participatory approaches are based on the assumption that citizens are genuinely interested in participating, but it is unclear how often this actually happens [34]. Nor should we forget that e-participation tools require citizens to know how to use the new technologies on which they are based, which is certainly not the case for the entire population [35]. Improving digital and civic literacy addresses several issues:

- It removes barriers to participation for older people and other vulnerable groups.
- It contributes to the generation of higher-quality proposals. An informed resident does not simply suggest “putting in a bench“, but justifies the need to create a fully-fledged leisure area, taking into account pedestrian flows and sunlight exposure.
- It fosters critical thinking, enabling people to distinguish constructive criticism from populism and to participate in discussions at a professional level.

Thus, some of the challenges facing e-participation in “smart cities“ include a lack of motivation, inadequate education and the need to change the outdated dynamics of public administration, which is failing to engage a wider audience. Data breaches can completely undermine public trust. It is essential to ensure equal access to technology for all sections of the population, including older people, low-income families and people with disabilities. We cannot rely solely on digital channels of communication. Traditional forms of engagement - such as public hearings and forums - must be maintained and developed. Administrative efforts should be directed towards running information campaigns explaining exactly how each resident’s voice influences the decisions taken. Citizens must know in advance what issues are being surveyed, how much weight their vote carries, and how the results of the decisions taken will be published. The transparency of this mechanism of ‘influence’ is a key motivating factor. Taking all this into account, one possible way of overcoming these difficulties is to utilize “citizen science“.

CITIZEN SCIENCE

The concept of “citizen science“ refers to an approach that involves ordinary citizens as participants in scientific research, not as subjects of observation, but rather as co-authors [36]. The current stage of development of “citizen science“ is inextricably linked to the development of the Internet and digital technologies. The Internet has become a key tool for coordinating the efforts of thousands of people around the world, enabling them to jointly tackle challenges that would be beyond the capabilities of a single institution. Ordinary people voluntarily assisting scientists is, in fact, not a new phenomenon, but information technology has opened up new possibilities. As a result, the number of citizen science projects has increased significantly in recent years [37]. “Citizen science“ is often seen as a step towards the “democratization of science“, in which all parties involved form mutually beneficial relationships - researchers achieve their academic goals, whilst citizens learn about the scientific process, become actively involved in it, and obtain data that they can use to advance their interests and influence public policy [38].

There is a wide variety of citizen science projects that have emerged through the use of information technology. These can be classified as follows:

- Gamification projects typically ask volunteers to help solve problems that cannot be automated using computer programs, but which are relatively simple for humans to tackle. They are asked to identify objects in an image or decipher text within a picture. Consequently, such projects are conducted entirely online, with participants carrying out all their work via a website, receiving points or some other form of recognition for their achievements. They therefore utilize a robust digital platform tailored to the project’s requirements. Perhaps the best-known gamification project is “Foldit“, which utilizes user input to study protein structure [39].
- In data-collection projects, participants are asked to help gather data on specific topics. The website is used to provide participants with instructions on how to collect the data. In some projects, data may also be submitted online, but occasionally the project team also asks participants to send samples by post. Current results are usually also available on the website. An example of this type of project is

“Community Snow Observations“, which asked travelers to help collect samples and photograph snow in remote areas using a special smartphone app [40].

- Sighting reporting projects are similar to data collection projects, but simpler. Volunteers are simply asked to report when they have witnessed a particular phenomenon, specifying the location and, where possible, providing a photograph if available. Consequently, no complex instructions are required, and the project’s website primarily serves to raise awareness of the project in conjunction with a social media strategy. The data is usually presented in the form of interactive maps. “HerpMapper“ is a good example of this type of project, which creates maps of reptile and amphibian sightings based on user reports [41].
- Sensor-based projects require participants to purchase a sensor, install it, maintain it and keep it constantly connected to the internet. Consequently, the project’s digital platform not only provides instructions and data, but also facilitates, to some extent, the process of making, obtaining or purchasing sensors. “PurpleAir“ is one such project, which provides sensors for monitoring air quality and creating maps using the collected data [42].

Reference [43] presents several “citizen science“ project platforms (services and resources) that may be of interest to those who wish to contribute to various research projects whilst staying at home. Nevertheless, “citizen science“ is not without its own problems. Data quality is an undeniable issue, as are the ethical concerns that arise if a research project simply exploits people willing to volunteer without offering any real support in return [44]. Ultimately, this approach is, unfortunately, often viewed merely as a means of crowdsourcing data. Furthermore, not the entire population is equally involved in “citizen science”; rather, it is limited to those who have both the spare time and the skills required to participate [45]. Moreover, citizen science is regarded as a methodology for carrying out large-scale projects that would otherwise be impossible. For example, projects such as wildlife monitoring covering vast geographical areas [46]. However, such a significant scale and complexity means that projects of this kind are led by large organizations, and are not “bottom-up“ initiatives based on the needs of communities. Furthermore, there is an interrelationship between “citizen science“ and information technology itself. Despite the relative convenience they offer, implementing complex digital approaches may take some time, and this can render online projects unsuitable for addressing urgent situations. For example, the Flint Water study is one of the most remarkable examples of how “citizen science“ can empower marginalized groups [47]. Residents of Flint reported that the drinking water in their neighborhoods was contaminated, but the local authorities paid no heed to these claims. An independent research group (comprising undergraduates, postgraduates and research staff) from Virginia Polytechnic Institute and State University (Vermont) then volunteered their time, resources and expertise to tackle the drinking water issues in Flint, Michigan. They provided Flint residents with kits and training so that they could collect water samples and test for levels of toxic substances themselves. As a result, evidence was provided that the water supply contained unsafe levels of lead, which ultimately prompted the government to take action to resolve the problem. Furthermore, given the urgency of the situation, the research team educated citizens through direct engagement within the city itself. The project’s website was primarily used solely as a repository for news and information. This is a good example of how information technology

is used alongside traditional forms of dialogue to involve residents in addressing the city's issues.

"Citizen science" certainly has potential as a tool for participation, but whether or not it will live up to its potential remains to be seen. Its relationship with other e-participation strategies will continue to evolve as "smart cities" seek solutions to both new and old urban problems. However, we must not lose sight of the fact that the most important element of cities is their residents, and that is precisely why the issue of participation will undoubtedly remain relevant even as new technologies change the way people seek to respond to various challenges.

CYBER THREATS AND VULNERABILITIES

The path to creating truly "smart" cities is fraught with serious challenges. The main one is ensuring cyber security, as the interconnectedness of systems turns any vulnerability into a potential city-wide threat. The more complex and interconnected urban infrastructure becomes, the greater its vulnerability. A "smart city" creates a vast attack surface for cyberattacks, with a wide range of both traditional and specific threats to its infrastructure, as it integrates previously isolated operational systems with information technology and the internet. This vulnerability is exacerbated by the complexity and heterogeneity of the systems, the long life cycle of industrial equipment (Supervisory Control and Data Acquisition, Automated Process Control Systems), which was not originally designed with modern cyber threats in mind, and a shortage of qualified security specialists. Cybersecurity must be built into the architecture of a "smart city" from the outset, rather than being added as an afterthought. Encryption, strong authentication, fault-tolerant systems and the ability to switch to manual control in the event of a failure are essential.

Recognizing the seriousness of the threats, international organizations and governments are developing cybersecurity standards and guidelines. For example, the UK's National Cyber Security Centre (NCSC) has published guidance urging authorities to carry out an inventory of all connected devices, use trusted suppliers and segment urban networks to prevent the spread of attacks [48]. For Russian cities, the challenge of ensuring cybersecurity is particularly acute in the context of import substitution. It is necessary not only to implement domestic digital solutions but also to guarantee their security by creating a closed-loop security system based on Russian technologies.

Legal regulation in the field of cybersecurity is lagging behind the pace of technological development. Complex issues are arising concerning the protection of personal data, liability for malfunctions in autonomous systems, and the legal status of the data collected. Unlike the European Union, where the strict GDPR regulations focused on privacy protection are in force, the legal approach in Russia is more centered on state governance and ensuring national security [49]. Further development of the legislative framework is a prerequisite for scaling up successful cybersecurity practices.

CONCLUSION

The concept of the "smart city" has evolved from a futuristic idea into a practical necessity for modern megacities. It offers an effective set of tools for tackling the complex range of

problems associated with increasing urbanisation - from traffic gridlock to environmental degradation. The following key conclusions can be drawn:

- Digital activism has become more professional. Spontaneous protests are giving way to systematic campaigns with clear political objectives, professional analysis and a long-term strategy.
- Public participation is becoming institutionalised. Governments are no longer viewing e-participation platforms negatively and are beginning to integrate them into their processes to enhance legitimacy, reduce social tensions and obtain high-quality feedback. Hybrid models, combining online tools with traditional forms of dialogue, are proving to be the most successful.
- The effectiveness of e-participation platforms is determined not so much by technological complexity as by the degree of genuine autonomy and influence granted to users. Citizens are willing to participate when they see that their opinion can influence a decision.

Despite the prospects for the digitalization of megacities, their development is hampered by a number of critical barriers. A key risk is cyber security, as the total interconnectedness of systems means that any breach could lead to a large-scale failure of the entire urban environment. Furthermore, for the sustainable roll-out of “smart city” technologies, two fundamental challenges must be addressed: establishing an effective public-private partnership model for investment and adapting legislation to the new realities.

The future of megacities depends not so much on the complexity of the technologies being implemented as on the ability to integrate them harmoniously into the social fabric of the city. The aim must be to make the technology invisible to the end user, creating an environment that intuitively looks after people, whilst remaining safe, efficient and sustainable. The success of this transition will determine the competitiveness and quality of life in cities for decades to come.

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