

# The Role of Citizen Science in Enhancing Resilience and Environmental Security of Ukrainian Cities

## Роль громадянської науки у підвищенні стійкості та екологічної безпеки українських міст

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Received: February 09, 2026 | Revised: February 25, 2026 | Accepted: February 28, 2026

UDC 614.84:35.072

DOI: <https://doi.org/10.33445/sds.2026.16.1.18>

**Purpose.** To substantiate the concept of a citizen science city as an instrument for post-war recovery and sustainable development, as well as to develop a governance approach to integrating citizen science into urban planning processes, environmental monitoring, and civil security in Ukraine.

**Method.** A theoretical and analytical approach was applied, including a systematic review of academic sources, analysis of international experience in disaster citizen science, comparative analysis of European Union strategic documents and international standards, and conceptual modeling of management mechanisms based on a process-oriented approach.

**Findings.** The feasibility of integrating citizen science into the urban governance system of Ukraine is substantiated. The potential of disaster citizen science to ensure rapid collection of localized data under conditions of limited institutional capacity is demonstrated. The concept of a citizen science city and a management model for citizen science projects based on the Plan–Do–Check–Act cycle are proposed.

**Theoretical implications.** The conceptual foundations for integrating citizen science into the system of sustainable urban development and post-war recovery are further developed.

**Practical implications.** The results of the research can be used by state authorities and local self-government bodies in developing urban recovery and development strategies, environmental monitoring programs, and mechanisms for citizen participation in decision-making.

**Originality of the research.** An institutionalized model of a citizen science city for wartime conditions and post-war recovery is proposed.

**Future research.** The study opens avenues for further empirical validation and the development of practical recommendations for state authorities and local self-government bodies.

**Paper type.** Theoretical.

**Мета дослідження.** Обґрунтування концепції міста громадянської науки як інструменту повоєнного відновлення та сталого розвитку, а також розробка управлінського підходу до інтеграції громадянської науки в процеси міського планування, екологічного моніторингу та забезпечення цивільної безпеки в Україні.

**Метод дослідження.** Застосовано теоретичний та аналітичний підхід, що включає систематичний огляд наукових джерел, аналіз міжнародного досвіду громадянської науки катастроф, порівняльний аналіз стратегічних документів Європейського Союзу та міжнародних стандартів, а також концептуальне моделювання механізмів управління на основі процесного підходу.

**Результати дослідження.** Обґрунтовано доцільність інтеграції громадянської науки в систему міського управління України. Показано потенціал громадянської науки катастроф для забезпечення оперативного збору локалізованих даних в умовах обмеженої інституційної спроможності. Запропоновано концепцію міста громадянської науки та модель управління проектами громадянської науки з використанням циклу Плануй-Виконуй-Перевір-Дій.

**Теоретична цінність дослідження.** Розвинені концептуальні засади інтеграції громадянської науки в систему сталого міського розвитку та повоєнного відновлення.

**Практична цінність дослідження.** Результати роботи можуть бути використані органами державної влади та місцевого самоврядування при формуванні стратегій відновлення та розвитку міст, програм екологічного моніторингу та механізмів участі громадян у прийнятті рішень.

**Оригінальність дослідження.** Запропоновано інституціолізовану модель міста громадянської науки для умов війни та післявоєнної реконструкції.

**Майбутні дослідження.** Робота відкриває шляхи для подальшої емпіричної апробації та розробки практичних рекомендацій для органів державної влади та місцевого самоврядування.

**Тип статті.** Теоретична.

**Key words:** Citizen Science Project, Environmental Monitoring, Post-War Recovery, Citizen Participation, Sustainable Development.

**Ключові слова:** проект громадянської науки, моніторинг довкілля, повоєнне відновлення, участь громадян, сталий розвиток.

### Introduction

Ukraine’s European integration choice has set a course toward the sustainable development of cities and the country as a whole. These issues are particularly relevant in the context of post-war recovery and the development of national and regional strategies and visions. The Leipzig Charter on sustainable European cities, adopted by EU ministers in 2020 (European Commission, 2020), is

the European Union's primary urban development strategy. Among other things, the Charter builds on the EU Urban Agenda (United Nations Conference on Housing and Sustainable Urban Development [Habitat III], 2016), which seeks to achieve smart, sustainable, and inclusive growth, as well as on the implementation of the UN 2030 Agenda for Sustainable Development (United Nations, 2015). All stakeholders, including public authorities, educational institutions, analytical and research institutions, industry, businesses, NGOs, experts, and others, are invited to participate in and contribute to sustainable development, digital transition, circular economy, etc.

In addition to the fact that Sustainable Development Goal (SDG) 11 – Make cities and human settlements inclusive, safe, resilient and sustainable, directly addresses urban development challenges, leading European cities increasingly integrate sustainable development and environmental security principles into their strategic visions. For example, the Barcelona 2030 (Agenda Ajuntament de Barcelona, 2021), the Barcelona Metropolitan Strategic Plan (Metropolitan Strategic Plan of Barcelona [PEMB], 2025), the Barcelona Climate Plan 2018-2030 (Barcelona City Council, 2018) and other documents emphasize economic and social development driven by innovation and sustainability, as well as the reduction of inequality and spatial segregation among urban residents. The key dimensions of Barcelona's strategic development include political commitments in core policy areas (employment, housing, energy, and mobility); the modernization of municipal governance and public services; comprehensive social inclusion across all sectors (business, culture, education, and sport) and at all territorial levels (city, districts, and neighbourhoods), implemented through diverse mechanisms such as communication, public deliberation, and social transformation; and leadership combined with international positioning, framing the city as an agent of change in addressing global challenges. Within this framework, Barcelona is conceptualized as a resilient, prosperous, and socially cohesive metropolis. The strategy also identifies a range of critical challenges, including the pursuit of equal opportunities, enhanced cooperation with other global metropolitan areas, and the application of governance instruments that strengthen democratic processes, public-private partnerships, community engagement, and civic participation.

Another illustrative model is Copenhagen and its Co-Create Copenhagen strategy (City of Copenhagen, 2025). The city's vision is articulated as that of a "liveable and responsible city with a competitive advantage", while the primary benchmarks of urban development include climate action, mobility, and waste management. Copenhagen's future is conceptualized as "a city for people and a city created by people", emphasizing collective responsibility and co-creation in shaping the urban environment. To enhance liveability, everyday life is identified as a central priority, with the overarching objective of improving the quality of daily experiences within urban spaces. The notion of a "responsible city" is defined through shared accountability for environmental protection and resource management, including the pursuit of carbon neutrality, climate change mitigation and adaptation, and the transition toward a circular economy that minimizes resource waste. Copenhagen's competitive advantages are further associated with its flexibility and creativity, a strong ecosystem of startups and innovation, and distinctive neighbourhoods that foster social diversity and provide inclusive opportunities for residents to live and thrive within the city.

In modern conditions, cities face a complex of interconnected challenges caused by climate change, limited natural resources and demographic transformations. In this context, the concept of smart cities is aimed at finding answers to key issues, in particular, regarding the formation of comfortable communities for living, improving the quality of life of the population and expanding opportunities for citizens to participate in decision-making processes. As the main tool for responding to these challenges, smart cities mainly use digital technologies that ensure more effective management of urban systems and services. In 2021, Dortmund was awarded the status of the most innovative city in Europe (European Innovation Council, 2021). The city has undergone

a comprehensive future-oriented transformation, with particular emphasis placed on education and skills development, quality of life enhancement, the promotion of democracy, equality, and social justice, as well as the strengthening of effective municipal governance. Within this framework, several key dimensions of urban sustainability were identified, including climate change mitigation and energy transition; the protection of natural resources and adaptation to climate change; sustainable mobility; lifelong learning and cultural development; social justice and societal resilience; housing and the sustainability of neighbourhoods; decent work and green economy; sustainable consumption and public health; and global responsibility within the one world approach.

In addition to the network of smart cities, the UNESCO Cities Platform presents several thematic city networks that reflect diverse dimensions of sustainable development that include creative cities, learning cities, inclusive and sustainable cities, megacities focused on water and climate, media and information literacy cities, and world heritage cities (UNESCO, 2025). An emerging area of focus, which complements these classifications, is the integration of citizen science initiatives into urban governance, enabling residents to actively participate in data collection, monitoring, and decision-making processes related to environmental, social, and infrastructural challenges. Cities that prioritize citizen science – hereafter referred to as citizen science cities – can enhance resilience, improve public safety, and strengthen evidence-based urban planning.

Like other United Nations member states, Ukraine has joined the global process of promoting sustainable development. In 2019, the President of Ukraine issued the Decree “On the Sustainable Development Goals of Ukraine for the Period up to 2030” (Verkhovna Rada of Ukraine, 2019). The Environmental Security and Climate Change Adaptation Strategy until 2030 (Verkhovna Rada of Ukraine, 2021) places significant emphasis on the prospects for achieving the SDGs in Ukraine. Sustainable development is also identified as one of the fundamental principles guiding the country’s post-war recovery (Ukraine Facility, 2024).

In the domestic context, post-war recovery must be explicitly considered in the development of a vision for modern Ukrainian cities. It is essential to plan, rehabilitate, reconstruct, and further develop critical, social, and economic infrastructure; transport systems; public facilities; and networks of essential services. A critical aspect of this process is ensuring urban resilience, strengthening environmental safety, and enhancing civil protection, particularly in response to the impacts of armed conflict, accidents at radiation- or chemically hazardous facilities, and environmental contamination of air, water, and soil. The aim of research is to explore the potential of citizen science in supporting sustainable development, environmental monitoring, and post-war recovery in Ukraine, and to develop a conceptual framework for the integration of citizen science data and participatory governance into urban planning processes. The main objectives of research are to analyze international experiences and best practices of citizen science implementation in urban planning; to examine the role of citizen science in disaster management, post-war recovery, and civil safety; to identify and categorize key stakeholders involved in citizen science projects within urban environments; to evaluate management frameworks for citizen science projects; to propose a conceptual framework for citizen science cities, integrating citizen participation, disaster preparedness and environmental monitoring.

### **Literature review**

Citizen participation in environmental monitoring represents a particularly promising approach for Ukraine’s post-war recovery and civil protection. Within the broader field of citizen science, disaster citizen science can be identified as a distinct and highly relevant area. This approach has established precedents in responding to radiation accidents, natural disasters, the assessment of consequences resulting from armed conflicts, etc. Citizen science is especially critical in situations

that require timely action, where conventional response capacities such as emergency services, local authorities, or state monitoring systems, are often limited. Local citizen researchers can provide real-time data collection, which supports evidence-based decision-making for disaster mitigation, emergency response, and the management of post-conflict recovery measures. They are able to gather valuable information about local conditions when professional scientists cannot rapidly access the affected sites or lack the resources to cover all necessary areas. Moreover, citizen researchers can leverage their intimate knowledge of local environments and communities, enhancing the reliability of collected data and fostering greater trust among residents. By integrating citizen-generated data into urban planning and disaster response strategies, municipalities can strengthen public safety, environmental security, and overall urban resilience, while simultaneously promoting community engagement in the reconstruction and sustainable development of affected cities.

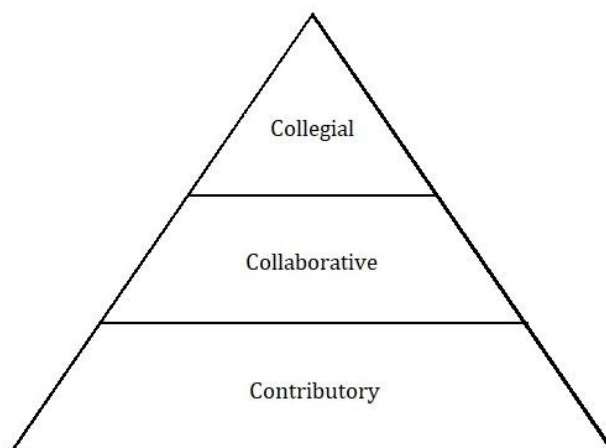
The benefits of disaster citizen science are multifaceted. They include the enhancement of education and scientific competence, the development of human capital, the creation of comprehensive data repositories, the training of future leaders, and the promotion of democratic and evidence-based decision-making (Chari, Stern, & Smith, 2021). Additionally, citizen science can play a critical role in supporting post-disaster and post-war recovery processes, encompassing the restoration of infrastructure, environmental rehabilitation, and the strengthening of community resilience. By actively involving citizens in data collection and analysis, this approach not only facilitates more timely and informed responses to emergencies but also contributes to the long-term safety, sustainability, and adaptive capacity of urban environments.

Citizen science projects employ a diverse range of data collection methods. These include the physical collection and measurement of samples, the use of sensors for quantitative monitoring, and the recording of written observations that provide descriptive information about environmental conditions. Additional methods encompass surveys and questionnaires, structured or semi-structured interviews, photographic and video documentation, and spatial mapping techniques. By integrating these approaches, citizen science initiatives can generate comprehensive and multi-dimensional datasets that support evidence-based decision-making and enhance resilience, environmental monitoring, and disaster preparedness. The versatility of these data collection methods allows citizen science initiatives to be tailored to diverse community contexts and disaster scenarios, enabling timely, context-specific responses while complementing official monitoring systems.

RAND researchers (Chari et al., 2021) argue that during periods of deep uncertainty, high-quality citizen science can significantly support communities in preparing for, responding to, and recovering from disasters. They emphasize that citizen science can take any form that is appropriate to the specific needs, capacities, and context of a given community (see Fig.). In contributory citizen science projects, research is typically initiated and designed by research institutions or government agencies, while citizen researchers primarily perform specific tasks such as data collection, image interpretation, analysis, or document transcription. In collaborative citizen science projects, research is conducted jointly by research institutions or government agencies and citizen researchers, who are actively involved not only in data collection and analysis but also in defining the research problem, designing the study, and interpreting results. In collegial citizen science projects, the initiative is controlled and conducted primarily by citizen researchers, either independently or in partnership with external institutions (e.g., government agencies or research organizations). In such projects, the public maintains primary control over the scientific methodology, research processes, and data collection.

Dickinson and Bonney (2012) examine the contribution of citizen science to community resilience within the environmental context. They argue that citizen science can play a significant role in conflict management and disaster recovery, particularly through the generation and maintenance of extensive data repositories across large geographic areas. The SHAMISEN SINGS

project is designed to apply citizen science in the aftermath of nuclear disasters. Liutsko and Cardis (2018) highlight that citizen science can complement formal environmental monitoring and provide affected populations with critical information regarding radiation levels, exposure, and health status, thereby enhancing radiological protection and supporting public safety. An illustrative example of the successful application of citizen science occurred following a train accident in Graniteville, which resulted in the release of chlorine gas. The South Carolina Department of Health and Environmental Control employed citizen science to support recovery efforts. Citizen scientists contributed by conducting environmental sampling to assess the impact of chlorine exposure on local residents and to establish a public health monitoring program (Abara, Wilson, Vena, Sanders, & McClure, 2014).



**Figure:** Levels of citizen participation in citizen science projects

*Source:* (Chari et al., 2021)

In Flint, Michigan, community members partnered with a university to collect drinking water samples, which revealed elevated levels of lead. The community-generated data prompted state officials to acknowledge the problem and initiate mitigation measures (Ruckart et al., 2019). Similarly, in Tonawanda, New York, local residents organized to collect air samples that indicated hazardous levels of pollution from a nearby industrial facility. The evidence they produced facilitated governmental monitoring, which ultimately contributed to the closure of the plant (New York State Department of Environmental Conservation, 2018).

The case of the mountain resort of Divcibare in Serbia (DivSci, n.d.) demonstrates how insufficient sewage infrastructure can create substantial environmental and public health risks. The citizen science initiative brought together local residents, environmental activists, and researchers from the University of Belgrade to collaboratively investigate and develop optimal wastewater treatment technologies in accordance with European Union recommendations, with particular attention to energy self-sufficiency and resource recovery. Anticipated outcomes of the project include the creation of innovative wastewater treatment solutions, enhanced public participation, the democratization of scientific processes, and potential influence on environmental policy in Serbia, thereby contributing to improved environmental safety and the protection of community health.

The citizen science project (Charles Sturt University, 2024) was designed to restore river ecosystems by engaging local communities in the tagging and monitoring of fish whose migratory patterns are disrupted by dams and reservoirs. By employing modern passive integrated transponder tag technologies and the FishNet cloud database, the project enables the tracking of fish movements across large spatial and temporal scales, thereby supporting evidence-based decision-making for water resources management. This initiative illustrates the significant

potential of citizen science as a tool for ecological restoration, while integrating citizens as reliable partners in governmental resource management and environmental stewardship.

In response to public demand for engagement in the aftermath of the 2019–2020 Australian bushfires, citizen science was employed as a key mechanism to involve the community in scientific research (Roger & Kinsela, 2023). Three citizen science initiatives were established to collect data and support environmental recovery efforts. Citizen researchers made substantial contributions by addressing critical gaps in both pre- and post-fire environmental data, thereby enhancing evidence-based decision-making, informing recovery strategies, and strengthening community resilience to future wildfire events.

Chari et al. (2021) developed a comprehensive toolkit designed to guide health departments in the use of disaster-focused citizen science to support public health preparedness, response, and recovery efforts. The toolkit provides methodological guidance for engaging communities, collecting and analyzing data, and integrating citizen-generated information into evidence-based decision-making processes.

Hicks et al. (2019) highlight the particular advantages of citizen science in low- and middle-income countries. They note that citizen science has the potential to foster a shared understanding of hazards, improve risk communication, and empower at-risk communities to take action to enhance resilience during and after hazardous events. Based on a review and mapping of 106 articles, the researchers identified key trends, including: major geographic clusters of projects (e.g., the United States) and underrepresented regions (e.g., Africa); a global predominance of initiatives focused on earthquakes and floods; frequent use of crowdsourcing and participatory approaches; and a tendency for projects to be implemented primarily after disasters or hazardous events.

These international examples illustrate the broad applicability and effectiveness of citizen science in disaster and environmental monitoring, providing a foundation for understanding how similar approaches can be adapted to the unique challenges faced in Ukraine. The outbreak of the war in Ukraine has underscored the profound negative impacts of the conflict on the environment. At the same time, citizen science initiatives focused on monitoring air and water quality have emerged as an effective instrument of green participatory governance. Such initiatives represent a critical mechanism for advancing sustainable development in Ukraine, promoting environmentally responsible governance, and addressing issues of discrimination and disinformation, while simultaneously strengthening community engagement and public safety.

Against the backdrop of adverse conditions, citizen-led environmental monitoring networks such as Safecast, Clean Air for Ukraine, SaveEcoBot, Ecodozor and others complement official state environmental monitoring data. An analysis of citizen environmental monitoring practices in Ukraine (Dovkola Lab et al., 2024) highlights participatory democracy strategies that have proven effective in protecting the environment and improving quality of life during the ongoing conflict. Additionally, a report (Soroka & Dovkola Lab, 2024) presents the results of an analysis of the impacts of military actions on citizen air quality monitoring networks in Ukraine. This publication provides a well-substantiated set of recommendations for the sustainable organizational development of air quality and public safety monitoring networks during wartime and in the post-conflict recovery phase. A detailed analysis of radiation monitoring results indicates that, during active military operations, the radiation levels in the air of cities within the risk zone of the Zaporizhzhia Nuclear Power Plant remained within safe limits (ranging from 10  $\mu\text{R/h}$  to 20  $\mu\text{R/h}$ ). In 2022, a missile strike targeted the Karachunivske Reservoir Dam, which provides drinking water for approximately 300,000 residents of Kryvyi Rih (Dovkola Lab et al., 2024). Following the attack, the Inhulets river turned bright red, raising public concern. Activists and experts were able to rapidly deploy citizen science tools to assess water safety, verify

environmental conditions, and prevent the spread of public panic, demonstrating the critical role of citizen engagement in ensuring environmental safety and public health during wartime.

To strengthen grassroots capacity for green recovery in Ukraine, the Erasmus+ GROMADA project (Gromada Erasmus+, 2025) was launched in 2023. GROMADA is a collaborative initiative involving the Conflict and Environment Observatory (CEOBS), the Universities of Copenhagen, Hamburg, and Lund, the Italian NGO Systasis, and the Greek educational company Web2Learn. In addition to documenting environmental damage resulting from military actions, the project investigates the potential of low-cost, community-based data collection in contexts where state monitoring capacities are limited or physical access is restricted. A further key component of GROMADA is the systematic gathering of citizen-generated evidence to support legal accountability. The project highlights that citizen science represents a significant yet underutilized resource for countering disinformation, establishing verified environmental data, and promoting public safety and environmental governance. The study (Dovkola Lab et al., 2024) highlights that, during wartime, citizen science initiatives must account for additional considerations, including the security of citizen researchers, governmental restrictions on information dissemination, the challenge of countering disinformation, and the need to restore networks of citizen researchers and academic communities in de-occupied territories following military operation.

Building on these experiences and citizen science principles, there is a rationale for developing a conceptual framework for citizen science cities in Ukraine – urban environments explicitly designed to integrate citizen-generated data, community engagement, and participatory governance into disaster preparedness, environmental monitoring, and post-war recovery strategies. It would formalize the role of citizen researchers in enhancing public safety, ensuring environmental security, and strengthening urban resilience, while providing structured channels for community participation, legal accountability, and evidence-based decision-making in both wartime and post-war recovery contexts.

### ***Materials and Methods***

In this study, a systematic, multi-level approach is employed to examine the integration of citizen science into sustainable development, environmental monitoring, and post-war recovery in Ukraine. The research methodology combines conceptual analysis, comparative case study evaluation, and stakeholder mapping, enabling both theoretical grounding and empirical applicability. The work draws on international experiences of citizen science implementation in urban and disaster contexts, including examples from the United States, Serbia, Australia, and European cities such as Barcelona, Copenhagen, and Dortmund, to identify transferable lessons for Ukraine.

Comparative analysis is used for examining strategies, policies, and frameworks of European and global cities to identify best practices in sustainable urban development and citizen science integration. Stakeholder mapping and analysis is aimed at identifying and categorizing key actors in citizen science initiatives, including citizens, NGOs, educational institutions, local authorities, research institutions, and businesses and industry. This method informs the assessment of participation modes, influence, and interest levels in project implementation. Case study synthesis was applied for analyzing specific citizen science initiatives, such as disaster-focused projects and environmental monitoring networks in Ukraine and abroad, to evaluate the effectiveness, applicability, and potential challenges of citizen engagement in disaster urban contexts. Process-based framework application was utilized for conceptualizing citizen science project management through the process (Plan-Do-Check-Act) approach to ensure systematic integration of citizen-generated data, quality assurance, participant safety, transparency, and continuous improvement. Conceptual modelling was intended for developing the framework of citizen science cities as urban environments that systematically embed citizen participation,

evidence-based decision-making, and sustainable urban governance in both routine and emergency conditions.

Methods employed include: systematic literature review of peer-reviewed articles, project reports, and policy documents; comparative analysis of strategic planning frameworks and urban development visions from international and Ukrainian contexts; qualitative stakeholder analysis using interest-influence mapping and participatory engagement typologies; synthesis of international and domestic citizen science project case studies, including disaster and environmental monitoring initiatives; conceptual development of management guidelines and operational principles for citizen science integration in Ukrainian cities, aligned with ECSA principles and ISO standards. This methodology enables the study to produce a comprehensive framework for integrating citizen science into urban governance, post-war recovery, civil protection and sustainable development, emphasizing community engagement, resilience, and evidence-based decision-making.

## **Results**

In recent years, Ukraine has been actively developing urban development visions and city-level strategic planning documents. Although these initiatives increasingly acknowledge the importance of achieving sustainable development, the issue of meaningful and active citizen participation in decision-making processes is often insufficiently addressed. In particular, the citizen science approach remains largely underrepresented, especially with regard to environmental monitoring and safety of urban environments.

One possible model for accelerating sustainable development and post-war recovery in Ukraine is the proposed concept of citizen science cities. A citizen science city is understood here as a city that actively promotes and applies citizen science for the conduct of research, and that systematically integrates citizen science into urban planning processes and decision-making related to the functioning and safety of urban systems. In such cities, citizen science is employed to support the life-supporting functions of the urban environment, both under normal conditions of everyday urban functioning and in situations requiring emergency response, including crises, disasters, conditions of hostilities, other extraordinary events as well as recovery actions. In addition, the citizen science approach is used for public environmental monitoring, serving as a mechanism of civic control and/or as a complementary source of data to existing state environmental monitoring systems. This integration enhances environmental safety, risk awareness, and evidence-based urban governance.

To ensure the effective functioning of citizen science cities, it is advisable to rely on the ten established principles of citizen science (European Citizen Science Association, 2015) developed by the European Citizen Science Association (ECSA) as a foundational framework. At the same time, these principles should be adapted to national and regional contexts, particularly with regard to volunteer safety, informed participation, risk management, and the protection of anonymity, which are especially critical in conflict-affected and post-conflict urban environments.

Understanding the roles and modes of participation of stakeholders is essential for the effective implementation of citizen science projects at the city level. Based on a systematic literature review conducted between 2023 and 2025 as part of research on citizen science, the stakeholders of citizen science in urbanized environments have been identified. These include citizens, civil society organizations, interest-based clubs, environmental associations, urban hubs, school and extracurricular groups, libraries, learners, schools, universities, professional scientists, think tanks, business and industry representatives, mass media, national government bodies, local self-government authorities, etc. Key stakeholder mapping for the implementation of citizen science projects in the urban environment within the Ukrainian context and current stage of

national citizen science practices is given in Table 1. Among the most priority stakeholders, the local authorities, educational institutions and citizens are highlighted.

It is crucial to establish local focal points for the dissemination and scaling of citizen science initiatives within cities. Such focal points may include educational institutions, libraries, hobby groups, interest-based associations, municipal centers, urban hubs, leisure clubs for older adults, etc. Educational institutions and libraries play a particularly important role in the initiation and implementation of citizen science projects, as they provide access to knowledge, infrastructure, and trusted public spaces, and facilitate intergenerational learning and community engagement. By acting as intermediaries between citizens, researchers, and decision-makers, these institutions can significantly enhance the integration of citizen science into urban planning processes, environmental monitoring, and initiatives aimed at improving the safety and quality of urban life.

**Table 1:** Stakeholder mapping for the implementation of citizen science projects in the urban environment

Level of interest	Level of influence	
	Low	High
<b>High</b>	NGOs Libraries, hubs Research and analytical centers, environmental groups	Citizens Educational institutions Local authorities
<b>Low</b>	International partners Media Students and their parents	Government Industry, businesses Politicians, activists

*Source:* developed by the author based on a synthesis of scientific literature.

Higher education institutions traditionally serve as key providers and coordinators of citizen science projects. One promising approach is the development of dedicated university-level courses on citizen science, in which students are trained in relevant methodologies, participatory approaches, and principles of collaboration with the public for the implementation of socially significant research projects. Students themselves may also act as citizen researchers, particularly those enrolled in non-environmental or non-scientific disciplines, by participating in projects related to environmental monitoring, urban sustainability, or risk assessment. Universities worldwide frequently initiate and implement citizen science projects in response to societal demands articulated by local communities or local self-government authorities. In many international contexts, universities located within the same city or metropolitan area cooperate to implement joint programs or projects. Such collaborative models are particularly conducive to the realization of citizen science initiatives, as they allow for the engagement of a broader range of partners, professional researchers, and citizen participants. This, in turn, enhances trust in project outcomes, increases public interest and visibility, and enables access to larger and more diverse funding sources, thereby strengthening the long-term sustainability and societal impact of citizen science in urban environments.

The integration of citizen science into primary and secondary education brings real-world research into the classroom, enabling students to collaborate with professional scientists on projects such as biodiversity monitoring, air quality assessment, or water quality analysis. This approach contributes to the development of scientific literacy, critical thinking skills, and a stronger connection to the local environment, while fostering civic responsibility and awareness of environmental and public safety issues. Citizen science projects could be implemented within the framework of out-of-school education, including extracurricular clubs, environmental and naturalist centers, youth tourism

centers, and similar institutions. Such settings provide flexible and practice-oriented environments that support experiential learning and early engagement in scientific activities.

Adequate financing is an essential prerequisite for the successful implementation of citizen science projects. Therefore, when adopting a city vision oriented toward the concept of a Citizen Science City, funding considerations should be treated as a high priority. This requires the explicit allocation of financial resources, for example through local or municipal budgets, to support citizen science activities, including infrastructure, equipment, coordination, capacity building, and long-term sustainability. Integrating such expenditures into urban development strategies strengthens the institutionalization of citizen science and enhances its contribution to urban planning, public safety, environmental monitoring, and post-crisis recovery processes.

The implementation of citizen science projects in citizen science cities requires particular attention to their organization and management, as such initiatives are expected to be systemic and large-scale, and the data generated will be used in urban planning and decision-making processes at the municipal level. Accordingly, citizen science projects should be conducted within a clearly defined management framework that takes into account data quality, participant safety, transparency, and accountability.

Citizen science initiatives, particularly in the fields of environmental monitoring, disaster response, and post-war recovery, can be effectively structured using a process-based management approach. The Plan-Do-Check-Act (PDCA) cycle, widely applied in international standards such as ISO 9001:2015 “Quality management systems – Requirements” and ISO 14001:2015 “Environmental management systems – Requirements with guidance for use”, provides a robust framework for organizing citizen science projects, ensuring data quality, participant safety, transparency, and continuous improvement. Within the framework of ISO 37101:2016 “Sustainable development in communities – Management system for sustainable development – Requirements with guidance for use”, ISO 37120:2018 “Sustainable cities and communities – Indicators for city services and quality of life”, and ISO 37123:2019 “Sustainable cities and communities – Indicators for resilient cities”, the PDCA cycle can be conceptualized as an effective governance mechanism for managing urban processes based on citizen science. In this context, citizen-generated data can inform the planning stage, support implementation through participatory actions, enable monitoring and evaluation via community-based indicators, and contribute to adaptive improvement of urban policies and practices, particularly in relation to public safety, resilience, and sustainable urban development. Applying PDCA enables the systematic integration of citizen science data into decision-making processes, thereby strengthening urban resilience, public safety, and sustainable recovery.

Although the ECSA principles of citizen science do not explicitly reference the PDCA cycle, they are conceptually aligned with it. Specifically, the “Plan” stage corresponds to the joint formulation of objectives and transparency; “Do” involves citizen participation in data collection; “Check” encompasses quality control and feedback; and “Act” refers to the application of results and continuous improvement. The main tenets of the PDCA processes are presented in Table 2. Thus, PDCA can be interpreted as an operationalization of citizen science principles.

At the planning stage, a clear formulation of the problem that the project aims to address should be undertaken. It is necessary to analyze what has already been done to address the problem and to identify the unique contribution of citizen science, including aspects that cannot be effectively achieved by other methods. The project objectives should be specified, along with the expected scientific, social, environmental, and governance impacts. Research methods and tools must be defined, and partnerships should be established to support the joint implementation of the project and to enhance trust in the results. Potential hazards for volunteers and the local community should be identified, and risks related to project implementation should be assessed. Required resources including equipment, technologies, funding, and materials should be evaluated, as well as the skills needed for participants and experts.

**Table 2:** Citizen science project management according to a PDCA approach

Plan	Do
Problem and objective definition	Recruitment and engagement
Selection of research methods and tools	Communication
Identification and establishment of partnerships	Training and capacity building
Assessment of required resources and potential risks	Implementation of diverse data collection techniques
Timeline and implementation plan	Data collection
Development of safety, ethical, and data quality protocols	Integration with local planning and response mechanisms
Check	Act
Data quality control	Dissemination of results, media engagement
Initial evaluation of project outcomes	Integration into decision-making
Participant feedback	Impact assessment
Review of partnerships	Documentation and archiving
Safety monitoring	Updating protocols and procedures
Adjustment and correction	Resource mobilization for future cycles

*Source:* developed by the author based on a synthesis of scientific literature.

Plans for volunteer training, timelines, and a detailed implementation plan must also be developed. Additionally, safety and ethical protocols should be prepared, alongside procedures to ensure reliability, reproducibility, and transparency of results. This includes defining protocols for data verification, quality control, and monitoring throughout the project lifecycle.

At the “Do” stage, the implementation of a citizen science project involves the recruitment and mobilization of volunteers (citizen researchers) and the broader local community, the establishment and maintenance of effective communication channels among project coordinators, professional scientists, volunteers, stakeholders, and authorities to ensure clarity, transparency, and responsiveness, the training of volunteers in research methodologies, safety protocols, ethical standards, and proper use of equipment, the systematic collection of data according to the established methodology, the application of diverse data collection techniques, including sensor-based monitoring, surveys, questionnaires, participatory mapping, photo or video documentation, and the integration of collected data to support evidence-based urban planning, environmental monitoring, and emergency response initiatives.

At the “Check” stage, the focus is on continuous monitoring and evaluation of the project’s implementation. This includes ensuring the quality and reliability of collected data through systematic review to identify errors, inconsistencies, or emerging risks. The initial assessment of project outcomes is conducted, including surveys and feedback from participants, to evaluate the effectiveness of methodologies, tools, and volunteer engagement. Observed results are analyzed, and necessary adjustments or corrections are made to improve data collection, processes, and overall project performance. Partner relationships may also be reviewed and, if necessary, expanded or restructured to enhance project implementation. Additionally, the physical safety of volunteers is continuously monitored, environmental or operational hazards are assessed in real time, and rapid response measures are implemented when required to ensure the safety of participants and the integrity of the research process.

The “Act” stage encompasses the dissemination of findings to participants, stakeholders, local authorities, and the broader community to promote transparency, trust, and engagement; the application of project outcomes to inform municipal planning, environmental monitoring, infrastructure rehabilitation, emergency preparedness, and recovery strategies; the evaluation of short-, medium-, and long-term impacts on citizen participation, data quality, urban safety, environmental protection, and community resilience; the review and refinement of safety

protocols, ethical guidelines, and data collection methods based on lessons learned and emerging risks; the planning of subsequent project phases, including expansion of volunteer networks, acquisition of additional equipment, and securing of financial resources; and the systematic documentation of all procedures, observations, incidents, and methodological decisions to ensure reproducibility, accountability, and the enduring utility of the data for future citizen science initiatives and urban governance.

The identification of key stakeholders, the structuring of citizen science projects according to the PDCA cycle, and the operationalization of ECSA principles demonstrate the feasibility and value of embedding citizen science into urban planning, environmental monitoring, and public safety initiatives. Building on this foundation, the next step involves the development of a comprehensive vision of Ukrainian cities as citizen science cities, where systematic citizen participation, evidence-based decision-making, and sustainable urban development are integrated to enhance resilience, community engagement, and long-term safety in both everyday and crisis conditions.

### **Discussion**

The findings allow the concept of a “citizen science city” to be interpreted not merely as a mechanism for engaging citizens in data collection, but as an institutional instrument for expanding the governance capacity of urban systems under conditions of uncertainty, resource constraints, and security risks. Unlike the smart city paradigm, which primarily emphasizes digital technologies and technocratic solutions, the proposed model focuses on social capital, horizontal networks of trust, and shared civic responsibility for the condition of the urban environment. In this sense, citizen science functions not only as a source of data but also as a mechanism of democratic legitimization of managerial decisions.

A comparison with international approaches demonstrates that most disaster-oriented citizen science studies concentrate on rapid information gathering and support for emergency response. In contrast, the proposed model integrates citizen science into the long-term architecture of urban governance by combining it with the PDCA process-based management framework and sustainable development standards. Such institutionalization extends the functional scope of citizen science from a reactive instrument to a systemic component of resilience-oriented governance.

At the same time, several assumptions require critical reflection. First, the assertion that citizen engagement automatically enhances resilience requires empirical verification. Urban resilience depends not only on the volume of collected data but on the institutional capacity to integrate this data into formal decision-making processes. Without appropriate regulatory and organizational mechanisms, citizen science risks remaining a parallel practice without tangible policy impact.

Second, risks related to data quality, information security, and potential manipulation must be considered, particularly in wartime conditions. In conflict-affected areas, the dissemination of open environmental or infrastructure data may create additional vulnerabilities. This necessitates the development of clear protocols for anonymization, verification, and risk management.

Third, social inequalities in access to technology and resources must be addressed. If participation in citizen science is limited to digitally literate or resource-privileged groups, existing representational imbalances may be reinforced. Inclusivity must therefore be treated as a fundamental condition for the successful implementation of the model.

From a theoretical perspective, the proposed concept contributes to the discourse on urban resilience by integrating participatory governance, process-based management, and ISO standards into a unified governance framework. From a practical standpoint, it provides a foundation for urban policies oriented toward evidence-based decision-making, transparency, and shared responsibility. However, the effectiveness of the model requires validation through pilot

projects, quantitative performance indicators, and comparative analyses of different implementation strategies.

The limitations of the study stem from its conceptual nature and the absence of empirical testing in specific Ukrainian cities. Future research should focus on developing indicators to assess the impact of citizen science on resilience, environmental security, and governance quality, as well as on examining legal and organizational barriers to integrating citizen science into local self-government systems.

## **Conclusion**

Sustainable urban development in the European context is based on the integration of social, economic, environmental, and governance dimensions, with citizen engagement recognized as a fundamental factor. For Ukraine, which is experiencing wartime challenges and preparing for post-war recovery, the formation of resilient, safe, and inclusive cities acquires strategic importance.

Citizen science can be considered an instrument for expanding institutional governance capacity by enabling rapid collection of localized data, strengthening environmental security, supporting infrastructure recovery, and enhancing trust between citizens and authorities. The proposed concept of a citizen science city envisions the systematic integration of citizen science into urban planning, environmental monitoring, civil protection, and decision-making processes.

The application of the PDCA process-based management approach, in combination with the principles of the European Citizen Science Association, provides a governance framework to ensure data quality, participant safety, procedural transparency, and continuous improvement. Such institutionalization transforms citizen science from a fragmented initiative into a structural component of urban governance.

At the same time, the effectiveness of this concept depends on the establishment of regulatory frameworks, sustainable funding mechanisms, information security protocols, and the readiness of local authorities to integrate citizen-generated data into formal decision-making procedures.

Future research should focus on empirical validation of the model in Ukrainian cities, the development of impact assessment indicators for resilience and security, and the formulation of methodological guidelines for national and local authorities regarding the institutional integration of citizen science under wartime and post-war reconstruction conditions.

## **Funding**

This study received no specific financial support.

## **Competing interests**

The authors declare that they have no competing interests.

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