University of Lille

Doctoral School of Engineering and System Sciences (EGENGSYS)

Laboratory of Civil and Geo-Environmental Engineering (LGCgE)

THESIS

Submitted to obtain the

Doctoral Degree (Ph.D.)

Specialty: **Urban Engineering**

By

Mohammed ITAIR

Defended on Monday 7th of October 2024

Leveraging Participatory Science and Smart Technology to Address Urban Challenges

Jury Composed of:

Isam SHAHROUR	Professor, University of Lille, France	Directeur
Hanbing Bian	Professor, University of Lille, France	Co- directeur
Baghdad Ouddane	Professor, University of Lille, France	President
El Khateeb Samah	Assoc. Prof., Ain Shams University	Examiner
HALWANI Jalal	Professor, Lebanese University	Reviewer
ZOUHRI Lahcen	Assoc. Prof., Polytechnic Institute, UniLasalle	Reviewer

Université de Lille

Ecole doctorale Sciences de l'Ingénierie et des Systèmes (EGENGSYS)

Laboratoire de Génie Civil et géo-Environnement (LGCgE)

THÈSE

Soumise pour l'obtention du

Grade de Docteur

Discipline : **Génie Urbain**

Par

Mohammed ITAIR

Applications de la science participative dans les systèmes urbains intelligents

Jury composé de

Isam SHAHROUR	Professeur, Université de Lille, France	Directeur
Hanbing Bian	Professeur, Université de Lille, France	Co- directeur
Baghdad Ouddane	Professeur, Université de Lille, France	Président
El Khateeb Samah	Prof. Assoc., Université Aïn Shams	Examinateur
HALWANI Jalal	Professeur, Université Libanaise	Rapporteur
ZOUHRI Lahcen	Prof. Assoc., Institut Polytechnique, UniLasalle	Rapporteur

Acknowledgement

First and foremost, I would like to express my deepest gratitude to my supervisor, Professor Isam SHAHROUR, for his unwavering support, guidance, and encouragement throughout my PhD journey. His insights and expertise have been invaluable in shaping my research and academic growth. I am also profoundly grateful to my co-supervisor, Professor Hanbing Bian, for his constant support and motivation.

To my dear parents, brothers: Qassam & Hussam, and sisters: Bisan & Rawan, I owe my deepest thanks. Their unconditional love and encouragement have been a source of strength and motivation. Their belief in me has kept me moving forward even in the most difficult moments.

A heartfelt thank you goes to my beloved wife, Safaa, for her endless love, patience, and understanding. Her constant support has been my anchor during the most challenging times of this journey.

I would also like to extend my sincere appreciation to Dr. Ammar Aljer, Dr. Sana Ounaies and Dr. Ihab Hijazi for their guidance, support, and valuable advice throughout my studies. Their mentorship has played a crucial role in my academic and professional development.

A special thank you to my friends, Khalil Lhamidi, Ayman Debis, and Josiana Hage. Their camaraderie, collaboration, and friendship have made this journey enjoyable and enriching. Their support and encouragement have been instrumental in the completion of this thesis.

I am deeply grateful to Campus France for their financial support in funding my PhD. Their assistance has been vital in enabling me to pursue and complete this research.

Lastly, I would like to thank all my friends, colleagues, and everyone who has contributed, directly or indirectly, to my research and academic endeavors. Your support and encouragement have been invaluable.

Abstract

This thesis explores using participatory science and advanced digital technologies to address urban challenges. It aims to integrate citizen participation in a comprehensive digital system that incorporates advanced technologies such as Geographic Information Systems (GIS), Building Information Modelling (BIM), and Artificial Intelligence (AI). Based on the literature review, several research gaps were identified, mainly the limited integration of participatory science in urban systems, particularly in developing countries. To address these gaps, this research developed first a flexible and scalable agile framework that facilitates the use of participatory science to address urban challenges. The framework encompasses four stages: (i) Conducting a comprehensive literature review to identify existing gaps and opportunities; (ii) Developing an agile, user-centric participatory framework; (iii) collaborating with stakeholders to refine and implement the framework; (iv) developing, implementing and testing of the participatory science platform. The research presents how the proposed frameworks could help address significant challenges in the Palestinian context.

The primary outcomes of this research are (i) a comprehensive literature review, (ii) the development of a comprehensive methodology that integrates advanced digital technology and participatory science, (iii) the design of development of a digital platform that enables digital modelling of urban systems, citizens participation and data analysis, and (iv) feedback from the implementation and use of this framework in complexes social and geopolitical contexts.

The thesis is organized into five chapters: The first two concern the state of the art and the research methodology. The last three chapters present successively the application of the participatory sciences in the following three challenging issues in Palestine: the inclusive public space, the smart campus, and the water supply system. Each chapter describes the significant challenges, the participatory science platform, data collection, and data analysis to address the identified challenges. Each chapter discusses the research limitations and suggests recommendations for policy-makers and future research.

Résumé

Cette thèse explore l'utilisation de la science participative et des technologies numériques avancées pour relever les défis urbains. Elle vise à intégrer la participation citoyenne dans un système numérique complet qui incorpore des technologies avancées telles que les Systèmes d'Information Géographique (SIG), la Modélisation de l'Information du Bâtiment (BIM) et l'Intelligence Artificielle (IA). Basée sur la revue de la littérature, plusieurs problématiques et 'Reserch Gaps' ont été identifiées, principalement la faible intégration de la science participative dans les systèmes urbains, en particulier dans les pays en développement. Pour combler ces problématiques, cette recherche a porté tout d'abord sur la mise en place d'une démarche agile et évolutif qui facilite l'utilisation de la science participative pour relever les défis urbains. La démarche est structurée suivant quatre étapes : (i) Effectuer une revue de littérature complète pour identifier les problématiques et les opportunités existantes ; (ii) Développer un cadre participatif agile et centré sur l'utilisateur ; (iii) Collaborer avec les parties prenantes pour affiner et mettre en œuvre cette démarche participative ; (iv) Développer, mettre en œuvre et tester la plateforme de science participative. Cette recherche illustre comment les démarches proposées peuvent aider à relever des défis importants dans le contexte palestinien.

Les résultats principaux de cette recherche sont : (i) une revue de littérature complète, (ii) le développement d'une méthodologie intégrée qui combine les technologies numériques avancées et la science participative, (iii) la conception et le développement d'une plateforme numérique qui permet la modélisation numérique des systèmes urbains, la participation des citoyens et l'analyse des données, et (iv) les retours d'expérience de la mise en œuvre et de l'utilisation de cette démarche dans des contextes sociaux et géopolitiques complexes.

La thèse est organisée en cinq chapitres : Les deux premiers concernent l'état de l'art et la méthodologie de recherche. Les trois chapitres suivants présentent successivement l'application des sciences participatives dans les trois enjeux suivants en Palestine : l'espace public inclusif, le campus intelligent et le système d'approvisionnement en eau. Chaque chapitre décrit les défis majeurs, la plateforme de science participative, la collecte et l'analyse des données pour relever les

défis identifiés. Ces chapitres discutent des limitations de la recherche et proposent des recommandations pour les décideurs politiques et les recherches futures.

Table of Contents

List of Figures

List of Tables

Abbreviations

Abbreviation	Definition
PS	Participatory Science
CS	Citizen Science
GIS	Geographic Information System
BIM	Building Information Modelling
DT	Digital Twin
AI	Artificial Intelligence
IoT	Internet of Things
MVP	Minimum Viable Product
WB	West Bank
MoLG	Ministry of Local Government
ANNU	An-Najah National University
PWA	Palestinian Water Authority
UN	United Nations
UNRWA	United Nations Relief and Works Agency
WHO	World Health Organization
SDGs	Sustainable Development Goals
NGOs	Non-Governmental Organization
SQ	Supply Quality

Chapter 0: General Introduction

Overview

This research deals with using participatory science to address urban challenges in developing countries. Its significance is fourfold:

First, it concerns urban challenges, which increase very quickly because of the intensive urbanization and the intensification of new challenges related to climate change **(Salimi & Al-Ghamdi, 2020; UN-Habitat, 2022)**. These challenges include providing essential services to the population, such as mobility, water, sanitation, energy, waste collection and treatment, education, health, and sport. These services require massive infrastructures with vertiginous costs for construction and management and high-capacity building for optimal and safe management **(Koop & van Leeuwen, 2017; Kurvinen & Saari, 2020)**.

Second, it concerns developing countries, which need more (i) services for the population, basic infrastructures, and financial and human resources to manage complex infrastructures and services **(Chigudu et al., 2022; Tan & Taeihagh, 2020)** . These countries also suffer from limited access to innovative technology, such as smart technology, because of the deficiency in digital infrastructures, which constitute the backbone of the deployment of smart technology, such as the smart city or the smart infrastructures **(Joia & Kuhl, 2019)**. These countries also generally suffer from governance-related issues, such as the involvement of citizens and civil society in decision-making, which could create frustration and social tensions that badly impact social peace and economic development **(Asingizwe et al., 2020)**.

Third, it concerns urban innovation through developing data-based solutions such as those used in smart technology **(Wu et al., 2022)**. These approaches raise specific and significant challenges for data collection. Generally, smart sensors are used for data collection. However, this use requires the availability of digital infrastructures for data transmission, storage, and processing, which are not available in developing countries **(Barns et al., 2017; ITU, 2021)**. In this case, citizen participation could present an excellent alternative for data collection because it is associated with citizen participation and the use of mobile devices (Paul et al., 2020a; Sauermann et al., 2020). Generally, citizens are inclined to contribute to solving their problems and assessing policies and actions that impact their lives **(Boulianne, 2020)**. In addition, mobile phones are primarily used in developing countries **(Farooq & Kustor, 2021)**.

Fourth, it concerns research development on urban issues. One of the significant difficulties in this research concerns data and user assessment of policies and strategies **(Lytras et al., 2021)**. Through citizen participation, researchers can access massive spatial and temporal data and involve the population in finding and assessing innovative solutions **(Herschan et al., 2020)**.

The following sections present a rapid literature review of the emergence of participatory science, emphasizing its social and environmental applications and the significance of this approach for urban challenges. They also discuss the gap to be filled in research, the goal and objective of this research, and finally, the manuscript organization.

Significance of Citizen Participation in Addressing Urban Challenges

Participatory science, also known as citizen science, involves the active involvement of non-professionals in scientific research, often in collaboration with scientists and institutions **(Haklay et al., 2021)**. This collaborative process offers significant benefits that enhance scientific research and societal well-being by expanding the scale and scope of data collection. It allows researchers to gather extensive datasets across diverse environments cost-effectively. It fosters public engagement and scientific literacy, empowering citizens to contribute to meaningful research **(Cross, 2022; Lewenstein, 2022)**.

The concept of involving citizens in scientific research dates back to early naturalists like Charles Darwin, who relied on observations from many enthusiasts **(Arnstein, 1969; Everett & Geoghegan, 2016)**. However, the formalization of citizen science as a recognized field began in the late 20th century **(Riesch & Potter, 2014)**. The advent of the internet and mobile technologies has exponentially increased the potential for public involvement in scientific research **(Corbari et al., 2022; Radu, 2020; Shahrour & Xie, 2021)**. Early examples include the Audubon Society's Christmas Bird Count, which started in 1900, and continues to be one of the most significant and longest-running citizen science projects **(Sullivan et al., 2014)**.

The proliferation of smartphones, GPS technology, and social media platforms has revolutionized citizen science **(Freihardt, 2020; Zheng et al., 2022)**. Mobile applications like iNaturalist **(Di Cecco et al., 2021)**, eBird **(Sullivan et al., 2014)**, and Zooniverse **(Masters & Team, 2019)** enable millions of users to contribute data, photograph species, and classify astronomical objects. Geographic Information Systems (GIS) and remote sensing technologies have further enhanced the capabilities of citizen science projects **(Corbari et al., 2021; Lee et al., 2020)**, allowing for sophisticated data collection and analysis.

Citizen participation in urban planning is increasingly recognized as a promising approach to addressing complex urban challenges **(Pocock et al., 2019)**. Traditionally, urban planning was a top-down process, with decisions made by a select few, often leading to outcomes that still needed to fully meet community needs or address their concerns **(Crompton, 2017)**. The process becomes more inclusive by involving citizens and tapping into diverse experiences and perspectives **(Gearin & Hurt, 2024)**. This inclusivity enriches the planning process and fosters a sense of ownership among residents **(Polko & Kimic, 2022)**.

Moreover, engaging citizens in urban planning acknowledges cities' complex, dynamic nature **(Horlings et al., 2021; Owuondo, 2024)**. Urban challenges like congestion, pollution, and inadequate public services require innovative, adaptive solutions. Residents experience these issues directly and can offer unique insights into their causes and potential solutions **(Filippi et al., 2020)**. Their involvement ensures that solutions are grounded in real-world experiences, enhancing their relevance and effectiveness. By leveraging the community's collective intelligence, cities can become more resilient, responsive, and vibrant.

The advancement of technology has significantly transformed the landscape of citizen participation in urban planning. Mobile applications and citizen-developed tools leverage open data and real-time information to facilitate continuous communication between residents and authorities (Borchers et al., 2023; A. J. Roche et al., 2022). This engagement allows for more informed decision-making in transportation, public utilities, and safety, ultimately improving local governance **(Aburas et al., 2024; Itair et al., 2023)**. By incorporating local knowledge and preferences, policymakers can better align their strategies with community needs, leading to innovative solutions and enhanced accountability **(Abuhasirah & Shahrour, 2021)**.

Research Gap

Despite the promise of participatory science, significant research gaps still need to be addressed. There is a need for integrated frameworks that combine citizen participation with advanced technologies to address urban challenges more effectively **(Dembski et al., 2020; Katapally, 2019; Maund et al., 2022)**. Most initiatives are concentrated in developed countries, highlighting the necessity for context-specific solutions tailored to developing nations' unique socio-political and economic conditions **(Benyei et al., 2023; Nascimento et al., 2018; Tan & Taeihagh, 2020)**. Additionally, ensuring the sustainability of these projects is crucial, as many suffer from short-term engagement **(Liñán et al., 2022)**. Technological barriers also impede broader participation, particularly in underserved areas, necessitating the design of low-tech, inclusive solutions **(Buytaert et al., 2016; Campos, 2023)**. Lastly, Governance issues, such as inadequate institutional support and fragmented policy frameworks, further complicate the implementation and scaling of participatory science initiatives **(Asingizwe et al., 2020; Head, 2023)**.

Objective and Contribution of this Research

This thesis aims to contribute to answering the questions of how to leverage participatory science and advanced digital technologies to address urban challenges in complex environments such as those in developing countries. The primary objectives of this research include (i) the design of an agile framework that fosters inclusivity and sustainability in urban spaces, ensuring a vast community share can benefit from smart urban systems services, (ii) the development of integrated solutions that combine participatory science with advanced technologies such as GIS, BIM, and AI, (iii) the development and assessment of strategies for implementing participatory science in the complex Palestinian context, (iv) providing detailed frameworks for specific applications including inclusive urban public spaces, user-centric smart campuses, and water supply management in water-scarce regions.

Thesis Organization

The thesis is organized into five chapters:

State of the Art:

This chapter provides a detailed review of the current state of participatory science and its applications in urban systems. It discusses the theoretical foundations, technological advancements, and practical implementations of participatory science in urban contexts.

Research Methodology:

This chapter outlines the research design, methods, and procedures for developing smart applications integrating participatory science into urban systems.

Creating an Inclusive Urban Public Space:

This chapter discusses the application of participatory science to address the challenges of creating inclusive public spaces. It describes the specific issues faced, the participatory platform developed, the data collection processes and the analysis conducted to identify and implement solutions.

Use of Participatory Science and Artificial Intelligence for the Creation of a User-Centric Smart Campus:

This chapter presents the development of an intelligent campus framework that leverages participatory science and advanced technologies such as BIM and AI. It explores the challenges and opportunities of creating a user-centric smart campus, detailing the participatory platform and the data-driven decision-making processes.

Leveraging Participatory Science for Tackling Water Supply Challenges in Water-Scarce Developing Regions:

This chapter addresses the challenges of water scarcity in Palestine by employing participatory science to monitor and optimize water supply management. It discusses the development and implementation of the participatory platform, data collection methods, and the analysis used to improve water supply systems.

Chapter 1: State of the Art

Urban areas worldwide face complex challenges, including population growth, environmental sustainability, water scarcity, infrastructure management, social issues, etc. Addressing these challenges requires innovative and collaborative approaches that harness the power of citizen participation and advanced technology. In recent years, the integration of citizen science and smart city systems has emerged as a promising paradigm for effectively tackling urban challenges (Dembski et al., 2020; Katapally, 2019).

This chapter provides an overview of the state of the art in leveraging participatory science and smart city systems to address urban challenges. It aims to set the stage for the subsequent chapters by highlighting the key concepts, trends, and challenges in participatory science, smart urban applications, and the unique characteristics of the Palestinian context. The chapter explores the concept of participatory science and its benefits for research, society, and the environment. The chapter establishes the connection between participatory science and urban challenges, highlighting how smart technologies can contribute to establishing innovative smart solutions. Additionally, it examines the challenges faced in implementing participatory science initiatives. The research gap, objectives, and contributions of the research are presented, underscoring the relevance of the research and its application to urban systems.

1.1 Participatory Science

Participatory Science, also known as citizen science, is a rapidly growing field that encompasses the general public's involvement in scientific research. It is a collaborative process that merges the expertise of professional researchers with the local knowledge and enthusiasm of citizens (Cross, 2022), democratizing the production of scientific knowledge and allowing for a broader scope of research (García-del-Amo et al., 2020; Lewenstein, 2022). The benefits of participatory science extend beyond scientific research, fostering a greater public understanding of science (Bonney et al., 2016), enhancing the societal relevance of research, and promoting sustainability (Sauermann et al., 2020).

The term participatory science is not exactly new; it has roots back more than 200 years (Arnstein, 1969; Silvertown, 2009). But, in the last 20 years, this term has significantly developed and become influential and widely discussed (Riesch & Potter, 2014). The definitions of this term vary based on the context where it is used and the level of engagement for citizens in the scientific work (Haklay et al., 2021). However, participatory science can be defined as “scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions.”

Day after day, the outcomes of the participatory science approach become more trusted and legitimate in research work (Prudic et al., 2019). Worldwide, there are thousands of active citizen and participatory science Initiatives directly involved in scientific research. Some of them have more than 100,000 members spread over 3000 projects with more than 2.5 million contributions (SciStarter, 2020). The Zooniverse (Zooniverse, 2024), the world’s largest platform for people-powered research, has more than 2.4 million registered volunteers so far, with more than 645 million contributions.

Figure 1-1 illustrates the significant increase in research based on a participatory approach, particularly after 2015, which aligns with the 2030 Sustainable Development Goals' global appeal to achieve sustainability and inclusivity (Fraisl et al., 2020).

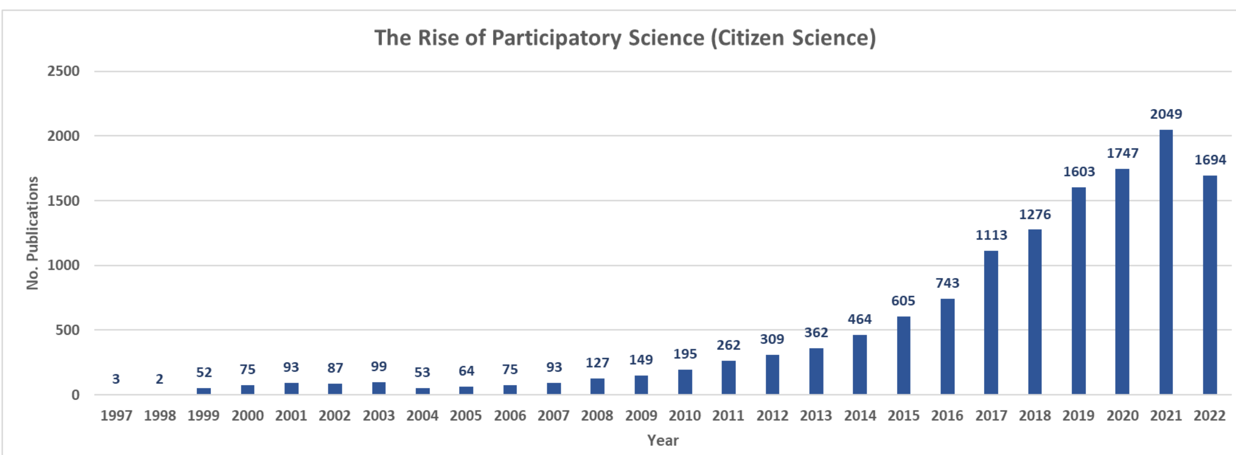

Figure 0-1 No. of Participatory Science Publications by Year. Source: Web of Science (December 2022)

Key theories in participatory science emphasize the importance of collaboration between scientists and the public. Models such as Arnstein's Ladder of Citizen Participation (Lauria & Slotterback, 2020) and Choosing and Using Citizen Science Guide (Pocock et al., 2015) provide structured approaches to involving citizens in research. These models highlight varying degrees of participation, from passive involvement to active decision-making roles.

By involving citizens in the research process, both researchers and policymakers can gain valuable insights. This can help them better understand and address the challenges and develop tailored solutions that meet the community's needs (Abuhasirah & Shahrour, 2021).

Participatory science applications span diverse fields, such as environmental monitoring (Kobori et al., 2016), astronomy (Masters & Team, 2019), public health (Murindahabi et al., 2022), archaeology (Stewart et al., 2020), education (Miller et al., 2020), and urban planning (Abusaada & Elshater, 2021). These applications have shown significant benefits in enhancing data collection and quality, increasing public awareness, and optimizing policy making. The following two subsections will respectively shed light on the benefits of citizen science in advancing research, society, and the environment, as well as the challenges facing developing countries in implementing citizen science initiatives where our context is located.

1.1.1 Benefits of Participatory Science on Research, Society, and Environment

The participatory science approach offers applications across numerous domains. It engages the public in research to address real-world issues; researchers, citizens, practitioners, and policymakers all work together to address them (Pocock et al., 2019). In our study, we categorized the benefits of citizen science into 3 general categories: Research, Society, and Environment.

We developed these three categories after studying a large number of the most successful participatory science projects and publications. **Table 1-1** illustrates the benefits and impacts of participatory science on research, society, and the environment, supported by references.

Table 0-1 The Benefits of Participatory Science on Research, Society, and Environment

Category	Benefit	How? || Impact	Example || Project/s	Reference/s
Research	1. Enhancing Data Collection	1.1 Expand Geographic Coverage	The **"eBird" project**, a popular citizen science initiative for bird monitoring, has collected over 880 million bird observations since 2002. This extensive dataset provides valuable information on bird distributions, migration patterns, and population trends, aiding ecological research and conservation efforts.	(Sullivan et al., 2014)

		1.2 Accelerate Research Progress	the **"Galaxy Zoo" project** engaged hundreds of thousands of volunteers who collectively classified millions of galaxies. Their contributions led to the discovery of new galaxy types and advanced the understanding of galaxy formation and evolution.	(Masters & Team, 2019)
		1.3 Collect Difficult or Expensive Data	Citizens play a crucial role in achieving SDGs 6 and 10 by conducting **Sanitary inspections (SIs) through citizen science.** This study demonstrates the potential for non-expert citizens, aided by experts, to collect SI data using on-site visits and remote photographic images.	(Herschan et al., 2020)
	2. Improving Scientific Innovation	2.1 New Avenues for Scientific Exploration	In the Netherlands, the **"iSPEX" project** engaged over 9,000 citizen scientists who used a smartphone accessory to measure aerosol concentrations in the atmosphere. This large-scale participation provided valuable data on air quality and particulate matter, helping to map pollution levels in different regions	(Land-Zandstra et al., 2016)
		2.2 Enhance Collaboration and Interdisciplinary	The **"Ocean Sampling Day" project** engaged over 150 marine research stations worldwide, resulting in the collection of 6,799 samples in just 24 hours. This citizen science effort significantly expanded the data coverage of microbial communities in the global ocean.	(Schnetzer et al., 2016)
Society	1. Empowering Community	1.1 Improve Collective Responsibility and Advance Democracy	The **"Community-Based Monitoring and Information System" (CBMIS)** in Nepal engages local communities in monitoring natural resources and addressing environmental challenges. Through training and capacity-building efforts, the project enhances the ability of communities to understand and manage their natural resources, fostering a sense of ownership and empowerment	(Paul et al., 2020b)
	2. Promoting Education	2.1 Raise Individuals' Knowledge	The citizen science **project "Foldit"** invites players to solve protein folding puzzles through online gaming. Foldit players successfully deciphered the crystal structure of a protein related to AIDS in just ten days, which had eluded scientists for over a decade. This achievement highlighted the problem-solving capabilities and innovative contributions of citizen scientists.	(Miller et al., 2020)
	3. Promoting Public Health	3.1 Raise Health Awareness and Resilience	Citizen science proves impactful in promoting public health by developing effective mosquito surveillance methods. A study in rural Rwanda demonstrates that **handmade plastic bottle traps, designed and tested by citizen scientists,** utilizing attractive cues such as carbon dioxide and light, successfully capture malaria vectors. This cost-effective approach shows promise for integrating citizen science into mosquito surveillance activities.	(Murindahabi et al., 2022)

Environment	1. Preserving Biodiversity	1.1 support Environmental Monitoring	The **"Snapshot Serengeti" project** in Tanzania engaged citizen scientists in classifying millions of camera trap images from the Serengeti National Park. This effort covered a vast area and provided insights into animal behavior, population dynamics, and species interactions	(Swanson et al., 2016)
	2. Advancing Sustainability	2.1 Contribute to Sustainability Goals Measurement and Achievement	**A comprehensive set of indicators**, comprising over 200 questions, is developed to measure the influence of citizen science across various sustainability domains. These indicators will contribute to an interactive **platform, MICS**, facilitating citizen science impact assessment and ensuring alignment with SDG targets.	(Parkinson et al., 2022)

As we can deduct from the table 1, the participatory science approach has benefits across various domains. In the research context, participatory science has proven to be instrumental in enhancing data collection. Firstly, it expands geographic coverage, allowing data to be collected from a broader range of locations, contributing to a more comprehensive understanding of phenomena. Secondly, participatory science accelerates research progress by leveraging the collective power of many participants, enabling the collection of vast amounts of data in a relatively short period. Furthermore, participatory science enables the collection of difficult or expensive data that would otherwise be challenging for researchers to obtain.

In terms of society, involving citizens in research fosters a sense of collective responsibility and advances democracy. Citizens become engaged in real-world issues, working alongside researchers, practitioners, and policymakers. This collaborative approach promotes inclusivity, transparency, and engagement. Moreover, participatory science projects contribute to promoting education by raising awareness. Participation in citizen science initiatives provides opportunities for learning, skill development, and exposure to scientific methods and concepts. This engagement enhances scientific literacy and empowers individuals' knowledge. Additionally, participatory science promotes public health by raising health awareness and resilience. By involving citizens in monitoring environmental factors or disease vectors, participatory science projects help identify potential health risks, inform public health interventions, and empower communities to take proactive measures for their well-being.

In the environment, participatory science plays a crucial role in preserving biodiversity. participatory scientists contribute to environmental monitoring efforts, helping to track species distributions, population dynamics, and habitat changes. This data is invaluable for understanding ecological patterns, identifying conservation priorities, and informing management strategies (Riyaz, 2022). Moreover, participatory science advances sustainability by contributing to measuring and achieving sustainability goals. By involving citizens in data collection related to energy consumption, waste management, or pollution levels, participatory science projects generate data that can be used to assess progress toward sustainability targets.

1.1.2 Participatory Science in Developing Countries

Participatory science holds big potential for both developed and developing countries. Nevertheless, notable differences and challenges arise due to differences in resources, technological capabilities, socio-cultural factors, institutional frameworks, and policy environment. This section presents a comparison that aims to explore and contrast citizen science projects in developing and developed countries, highlighting key similarities, differences, and lessons learned from each context.

When going over the countries that lead participatory science initiatives, the developed countries dominate the list. Countries such as the United States, the United Kingdom, Australia, and Germany have invested heavily in participatory science initiatives, developing platforms and networks that enable the public to contribute to research. Meanwhile, such initiatives are rare in developing countries. **Figure 1-2** shows the top 10 countries in participatory science projects, and **Figure 1-3** shows the geographic distribution for these projects.

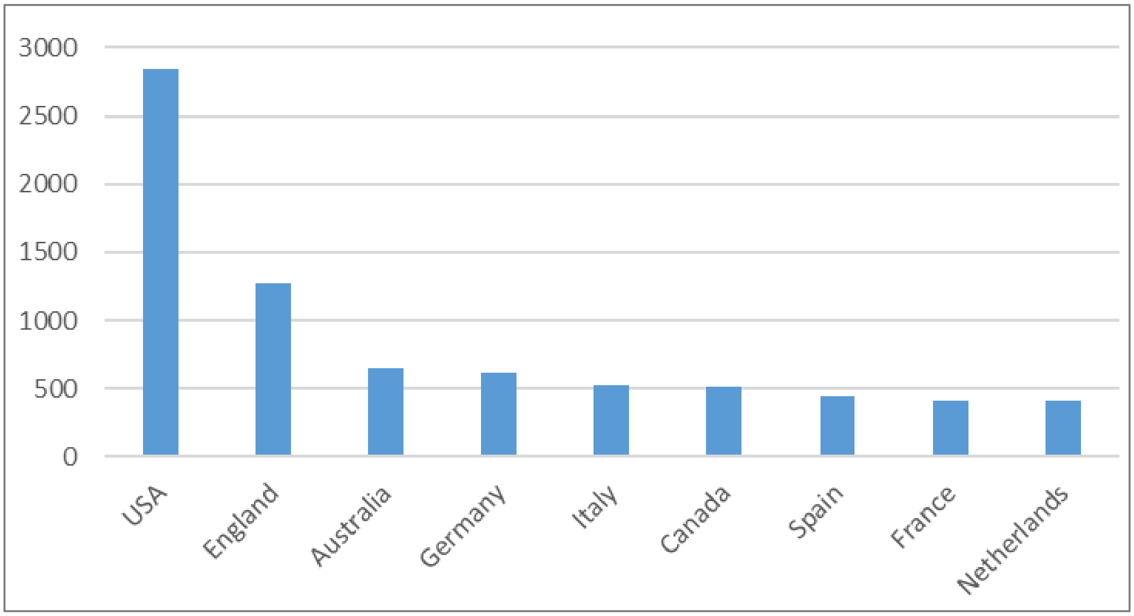

Figure 0-2 Top 10 Countries in Participatory Science Projects. Source: Web of Science (January 2023)

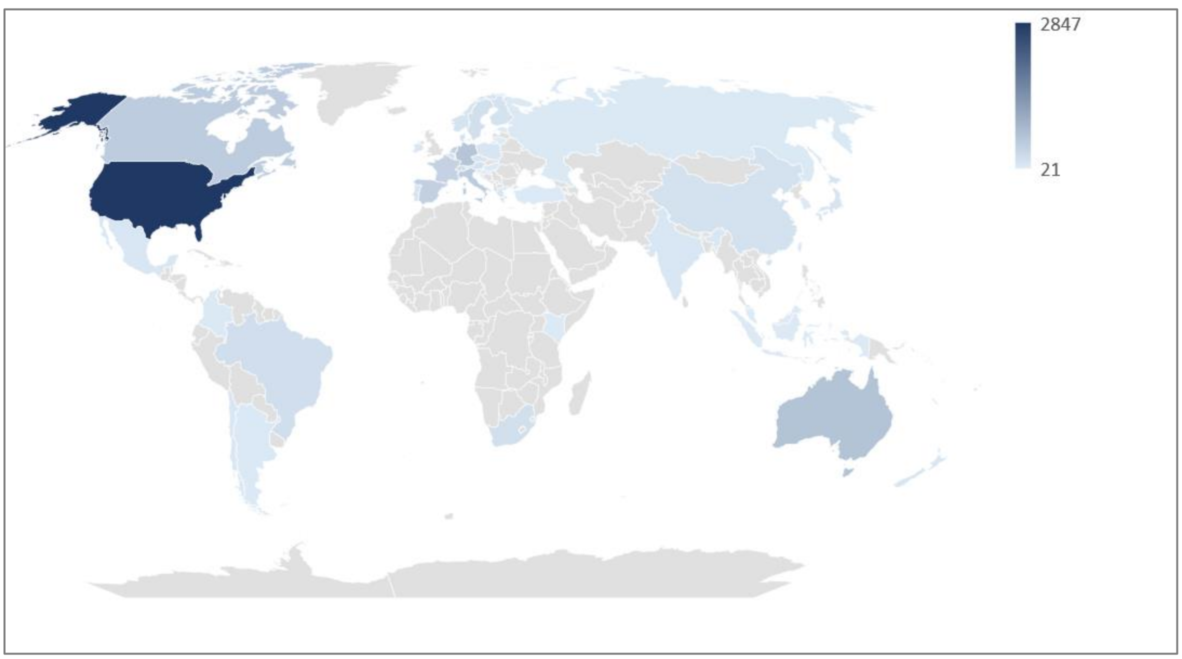

Figure 0-3 The Geographic Distribution of Participatory Science Projects by Country 1995 -2023. Source: Web of Science (January 2023)

Even though participatory science holds great promise for addressing urban and environmental challenges, adopting and successfully implementing its initiatives in developing countries are more challenging than in developed countries. Therefore, it is important to identify these challenges in the pursuit of building successful, long-term initiatives to achieve their objectives. Here, we explore the key challenges faced by developing countries in adopting and making successful citizen science projects:

- **Technological Capabilities and Infrastructure**

The technological gap is a fundamental challenge in implementing participatory science in developing countries (Weyer et al., 2019). Developed countries generally have robust technological infrastructures, including widespread internet access, high smartphone penetration, and advanced data processing capabilities. These resources facilitate collecting, analyzing, and disseminating knowledge in participatory science initiatives.

In contrast, many developing countries face significant technological limitations. According to the International Telecommunication Union (ITU), as of 2021, internet penetration in the Least Developed Countries (LDCs) was around 47% and 34% in developing countries rural areas compared to 89% in developed countries (ITU, 2021). Limited access to the internet and digital devices can hinder the ability of citizens to participate in science projects that rely on digital tools for data collection and communication.

For example, a study on participatory water quality monitoring in rural India found that limited internet connectivity and a lack of smartphones among participants were significant barriers to effective data collection and reporting (Buytaert et al., 2014). These technological constraints necessitate the adaptation of citizen science methodologies to local contexts, often requiring low-tech or offline solutions to ensure broader participation.

- **Resource Availability and Support**

Resource constraints are another major challenge for participatory science in developing countries (Ferreira et al., 2019). Participatory science projects in developed countries often benefit from substantial financial and logistical support from academic institutions, government agencies, and non-profit organizations. This support can cover costs for training, equipment, data management, and outreach activities.

In developing countries, however, financial resources for such projects are often limited. Governments and institutions may prioritize other pressing needs such as healthcare, education, and infrastructure development, leaving little funding for citizen science initiatives. Additionally, local organizations may need more expertise or capacity to support large-scale participatory projects.

These challenges necessitate building solutions that harmonize with the available resources and integrate with existing systems, ensuring they are feasible and sustainable over the long term. This requires innovative thinking that adapts cutting-edge knowledge to practical applications within existing resources and capabilities (Campos, 2023; Ferreira et al., 2019; Muchunguzi, 2022), such as employing low-cost technologies, building strong relations between research and society, facilitating stakeholder involvement, and fostering cooperation.

- **Socio-Cultural Factors**

Socio-cultural factors play a significant role in the success of participatory science projects. In developed countries, there is often a high public awareness and interest in scientific issues driven by education systems and media coverage. This can facilitate the recruitment and retention of citizens (San Llorente Capdevila et al., 2020).

However, in many developing countries, socio-cultural barriers, such as low levels of democracy, mistrust of local institutions, including scientific ones, and differing cultural attitudes towards science and technology, can obstruct participation. **Benyei et al. (2023)** shed light on these obstacles and explain that projects have adopted various strategies to address these challenges. These include promoting decentralized and low-tech solutions and engaging in bottom-up actions from a human-rights perspective. They also observed that these projects might have a more significant impact on participants than on science.

- **Institutional Frameworks and Policy Environment**

Institutional support and favorable policy environments are crucial for the success of participatory science initiatives. In developed countries, well-established institutions such as universities, research centers, and government agencies often provide the necessary infrastructure, funding, and expertise (Nascimento et al., 2018). Moreover, policies that promote open data, public engagement in science, and environmental monitoring can create an enabling environment for participatory science.

In developing countries, institutional frameworks may be weaker, and policies supporting participatory science may be lacking or poorly implemented. Corruption, interest conflicts, political instability, and bureaucratic inefficiencies can further hinder the development and sustainability of participatory science projects (Head, 2023; Tan & Taeihagh, 2020).

To address these challenges, participatory science projects have to adopt agile governance models that can overcome or go along the barriers. In their study, **Asingizwe et al. (2020)** present an exemplary model that addresses the complexities of engaging participants in citizen science at malaria control in Rwanda. This agile model stands out for its clear understanding of the limitations and barriers inherent in the context and its effective management of participation steps. By recognizing and navigating socio-cultural, economic, and logistical challenges, the program demonstrates how well-structured citizen science initiatives can thrive even in challenging environments. This model's thoughtful design and implementation fostered meaningful community involvement and showcased the potential for scalable and adaptable citizen science projects that can operate within various constraints. This approach is commendable for its ability to harmonize with local conditions while achieving its scientific and community engagement goals.

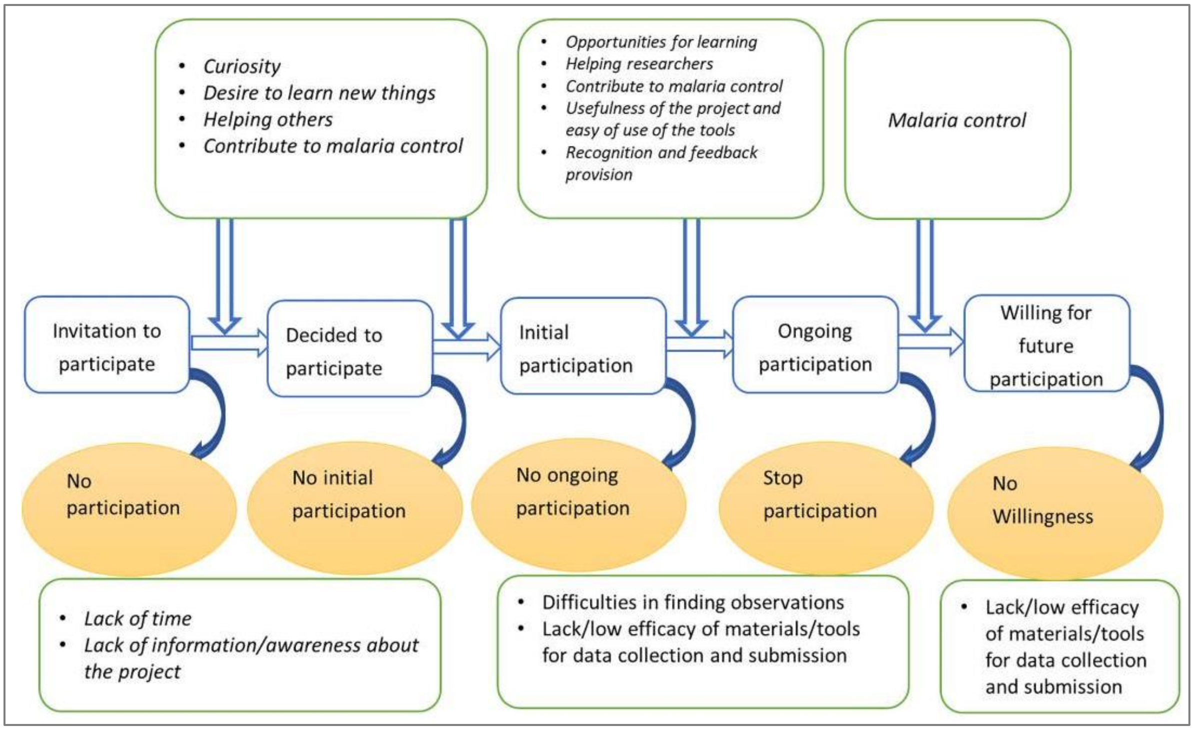

Figure 0-4 Motivations and barriers to engaging in different participation stages in a citizen science program (Asingizwe et al., 2020).

Figure 1-4 shows the model presented by **Asingizwe et al. (2020)**. This model illustrates the journey from the invitation to participate to a future willingness to participate again. Motivational factors such as curiosity, learning new things, and helping others drive initial participation. Ongoing participation is encouraged by opportunities for learning, contribution to malaria control, and recognition. However, barriers such as lack of time and information, difficulties in finding observations, and inefficacy of tools can impede participation at various stages. This model underscores the importance of understanding and addressing these barriers to maintain participant engagement and ensure the program's success.

1.1.3 Insights for Successful Participatory Science Projects in Developing Countries

Comparing participatory science initiatives in developed and developing countries reveals several key lessons. First, technological and resource constraints in developing countries necessitate innovative, low-cost, and adaptable approaches to citizen science. Projects that succeed often leverage local knowledge and simple technologies to overcome these challenges.

Second, socio-cultural factors must be carefully considered and addressed. Successful initiatives typically involve extensive community engagement, respect for local knowledge, and efforts to build trust and scientific literacy among participants.

Third, strong institutional support and favorable policies are essential for the sustainability and scalability of participatory science projects. Developing countries can benefit from creating or strengthening institutional frameworks and policies that promote public engagement in science and support community-based monitoring initiatives.

Looking ahead, the future of participatory science in developing countries will likely involve greater integration of digital technologies as access improves. Mobile applications, low-cost sensors, and platforms for data sharing and collaboration will play an increasingly important role. Additionally, international collaborations and knowledge exchanges can help developing countries build capacity and learn from successful projects in other regions.

Investing in education and awareness programs to improve scientific literacy and public interest in science is also crucial. Empowering citizens with the knowledge and tools to participate in scientific research can drive social and environmental change, ultimately contributing to sustainable development goals.

1.2 Application to Palestine

The Palestinian context presents a unique set of challenges and opportunities for developing and implementing participatory and community-based projects. The region's socio-political landscape, characterized by ongoing conflict, poor governance, and limited resources, significantly impacts urban planning and development (Al-Omari, 2023; Hamad et al., 2022; Itair & Armoush, 2024). Despite these challenges, there is a growing recognition of the potential for innovative, community-driven solutions to improve urban resilience and sustainability (Itair et al., 2022a; Soliman et al., 2022; State of Palestine, 2021).

Public participation is not new in the Palestinian context and has been discussed across various contexts for years (Ibaid, 2021; MoLG, 2018; Saleh et al., 2011). Officially emphasized since the first edition of the Planning Guide in 2013 (MoLG, 2013b), which promoted community participation as fundamental to strategic planning for cities and towns, this emphasis persisted through its latest edition in 2018 (MoLG, 2018). However, the momentum of these initiatives has waned, and new tools for their sustainability have not been developed despite the rise of smart governance initiatives that ostensibly advocate for citizen participation. The primary issue remains: "What is the purpose of the involvement?" Most community participation projects today lack continuity, primarily serving as propaganda and confidence-building measures for public institutions. While they generate initial enthusiasm, their impact and citizen involvement diminish during implementation, preventing the full benefits of participatory science.

Despite the familiarity with participatory projects and the robust technological foundation in Palestine, developing necessary tools and applications still needs improvement. This research aims to address this gap by exploring solutions based on participatory science, supported by various technological tools, to enhance the use of participatory science in developing smart urban systems.

1.3 Research gaps, objectives, and contribution

According to the literature, despite the significant progress in participatory science, several research gaps persist, particularly in developing regions. This section presents the research gap, and highlights the objectives of this research and its contribution to the society.

1.3.1 Research Gaps

Based on the literature review, the following research gaps were identified:

- **Limited Integration of Participatory Science and Urban Systems:**

While participatory science has shown potential in various fields, its integration with urban systems still needs to be explored. There is a need for comprehensive frameworks that combine citizen participation with advanced technologies to address urban challenges more effectively and develop smart urban services.

- **Context-Specific Solutions for Developing Countries:**

Most participatory science initiatives are concentrated in developed countries. Developing countries' unique socio-political and economic conditions, especially those experiencing conflict, necessitate tailored approaches that consider local constraints and opportunities.

- **Sustainability of Participatory Initiatives:**

Many participatory projects need more continuity and long-term impact. Research is needed to develop sustainable models that ensure continuous citizen engagement and effective implementation of participatory science initiatives.

- **Technological Accessibility and Inclusivity:**

Technological barriers, such as limited internet access and digital literacy, hinder citizens' participation in scientific projects. There is a gap in designing low-tech and inclusive solutions that enable broader participation, particularly in rural and underserved areas.

- **Measurement and Impact Assessment:**

More robust methodologies are needed to measure the impact of participatory science on urban development and sustainability. Developing comprehensive indicators and assessment tools is crucial for understanding the real-world benefits and informing policy decisions.

1.3.2 Research Objectives

To address these gaps, this research aims to achieve the following objectives:

- **Develop Integrated Solutions:**

Create and implement integrated solutions that combine participatory science with advanced technologies (GIS, Digital Twin, BIM, AI) to tackle urban challenges.

- **Promote Inclusivity and Sustainability:**

Design frameworks and applications that foster inclusivity and sustainability in urban spaces, ensuring that all community members can benefit from smart urban systems and services.

- **Context-Specific Strategies:**

Develop and test strategies for implementing participatory science in the Palestinian context, considering local socio-political and economic factors.

- **Application-Specific Frameworks:**

Provide detailed frameworks for three specific applications: inclusive urban public spaces, user-centric smart campuses, and water supply management in water-scarce regions (Section 1.3.3).

1.3.3 Contributions

This study contributes to the field of participatory science and smart urban systems through:

- **Use of Smart Technology for Creating an Inclusive Urban Public Space:**

This application addresses the need for inclusive urban spaces by integrating participatory science. The key contributions include establishing a comprehensive framework for assessing public space inclusivity incorporating GIS, low-cost technologies, and sustainability indicators.

- **A Framework for a User-Centric Smart Campus:**

This application focuses on developing a smart campus framework that leverages participatory science and incorporates advanced technologies such as Digital Twin, and AI. The primary contributions include developing a comprehensive data collection and analysis framework through a participatory platform at An-Najah National University's Faculty of Engineering. This framework emphasizes experiential knowledge from campus users over traditional sensor-based approaches, enhancing the understanding of campus dynamics and user needs.

- **Leveraging Citizen Science for Tackling Water Supply Challenges:**

Addressing water scarcity, particularly in water-scarce regions like Palestine, this application employs participatory science to monitor and optimize water supply management. The key contributions include developing an innovative system based on participatory science to involve end-users in collecting water supply system performance data. This system evaluates the performance of water authority strategies, addressing issues such as operating deficiencies, illegal connections, and discrepancies between scheduled and actual operations.

While these research gaps, challenges, and contributions are particularly relevant to developing countries, the methodologies used and developed in this study, along with the insights and results gained, are also highly valuable in the context of developed countries. They address similar gaps in integrating advanced technologies with participatory science to foster inclusive, sustainable urban development. The frameworks and strategies proposed can thus be adapted and applied globally, contributing to advancing smart urban systems across diverse socio-economic landscapes.

1.4 Conclusion

This chapter provided an overview of the state of the art in leveraging participatory science to address urban and environmental challenges. It highlighted the key concepts, trends, and challenges in participatory science, emphasizing the unique characteristics and opportunities in developing regions like Palestine. The benefits of participatory science for research, society, and the environment were discussed, alongside the challenges faced in implementing these initiatives in developing countries. The chapter also identified critical research gaps, outlined the objectives of this study, and the contributions made through integrating advanced technologies with participatory science.

Considering the great benefits and potential of participatory science in addressing urban and environmental challenges and considering the significance and specificity of these challenges in Palestine, this research will focus on (i) establishing a general framework for the application of participatory science to urban challenges (ii) combining the participatory science with smart digital tools, and (iii) the application of the developed framework to three relevant areas in Palestine: inclusive urban public space, user-centric smart campus, and smart water supply system.

Chapter 2: Methodology

2.1 Introduction

This chapter presents the research design, methods, and procedures employed in this research to develop smart applications that integrate participatory science into urban systems. By combining participatory science with advanced technologies and institutional frameworks, these applications offer a high capacity to (i) promote public engagement in addressing urban issues, (ii) overcome the technological and institutional barriers of public participation by providing low-tech and inclusive solutions, (iii) propose user-centric tools for data collections and analysis, and (iv) enhance decision-making in building society-tailored solutions.

Moreover, these applications present context-specific strategies in Palestine, considering its socioeconomic factors in advancing urban systems.

The research addresses the following questions:

I. How can participatory science be effectively integrated into smart urban systems?

II. What are the key challenges and opportunities in implementing participatory science initiatives in urban contexts?

The chapter presents the methodology used in this research, including the insights gained from the literature review, the agile framework for organizing participatory projects within the urban context, the system architecture of the participatory platform to help realize and integrate smart participatory approaches into urban systems, and the implementation of this platform in addressing various urban issues in the Palestinian context.

2.2 Research Methodology

2.2.1 Overview

This research aims to develop smart and integrated applications of participatory science within urban systems to enhance citizen engagement, increase community awareness, and improve decision-making in addressing the growing urban challenges.

Figure 2-1 illustrates the methodology followed in this research, which comprises four steps:

Step 1: Conducting a Literature Review of Participatory Science:

This step involves a comprehensive review of participatory science applications across various fields, emphasizing urban contexts. It Investigates the recent technical and institutional strategies, frameworks, and tools and identifies strengths, limitations, and gaps in existing applications.

Step 2: Developing an Agile Framework for Organizing Participatory Science Projects Within Urban Systems

This flexible and scalable framework comprehends the desired outcomes and fundamental components of various urban systems to identify the potential roles participatory science can play within these components. It aids in determining the necessary level of citizen participation, the conceptualization and design of the framework, including the required tools and the smart services to be offered. Consequently, this facilitates effective communication with stakeholders, encouraging the adoption of participatory applications and managing their interactions.

Step 3: Cooperation with the Stakeholders

This step focuses on transforming the system architecture outlined in Step 2 into practical applications by collaborating with governmental and non-governmental institutions interested in adopting participatory science. This involves defining the target groups, customizing the services, and outlining the ethical considerations. Developing a minimum viable product (MVP) starts in this phase and serves as a prototype showing how the application is presented and how tools are integrated.

Step 4: Application Deployment

This final step involves launching the application with partners through training workshops and continued support for stakeholders. This step comprises the deployed product that integrates the tools developed for data collection, analysis, and sharing. Testing and evaluation are ongoing and essential steps for guaranteeing the participatory framework's usability, performance, and impact through feedback consideration and tool refinement.

Providing an agile architecture enables the system to function with minimal requirements while allowing for continuous development and expansion. This adaptability ensures various short-term and long-term benefits. It also aligns with the project's timeframe and the relatively limited financial resources available to researchers and partners.

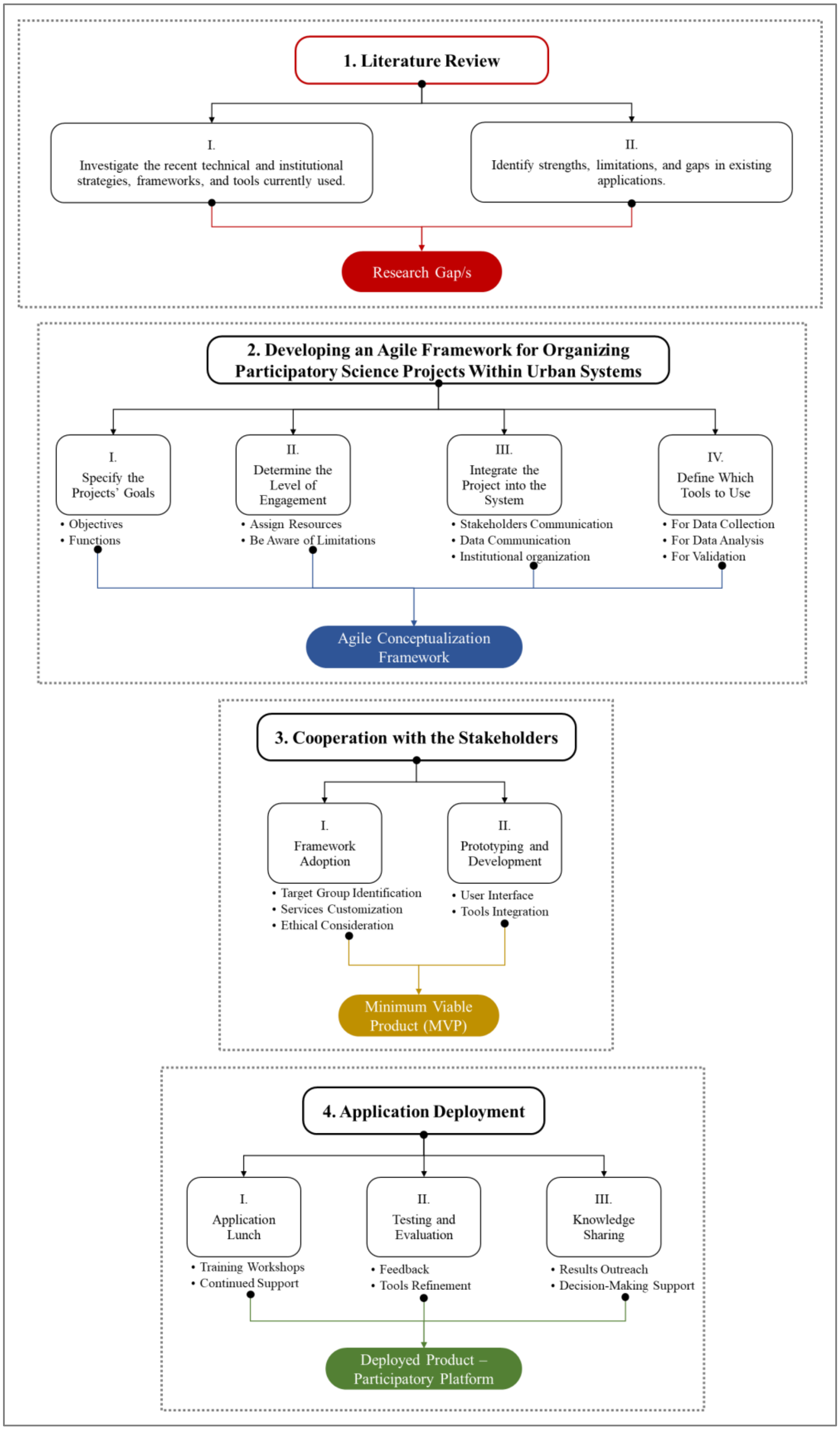

Figure 0-1 Research Methodology

2.2.2 Literature Review: Examination and Outcomes

The literature review involves a systematic examination of articles, case studies, reports, and relevant literature, focusing on the following key areas:

- Identification of Relevant Sources: We utilized academic databases such as Google Scholar, DOAJ, IEEE Xplore, and ScienceDirect to search for peer-reviewed articles. Keywords included "participatory science," "smart urban systems," "public engagement," " citizen science," "Participatory Framework," "Participatory research," " community-based participatory research," "User-centric Decision," and "Urban governance." Additional sources were identified through citation tracking and expert consultations.

- Inclusion Criteria: The inclusion criteria were set to filter studies published mainly within the last five years, focusing on urban contexts and participatory science applications.

- Data Extraction and Analysis: Around 700 references were collected, ensuring a comprehensive understanding of the field. Of these, around 250 were utilized directly in conducting the study. Relevant studies were reviewed and categorized based on their contributions to participatory science, technological frameworks, public engagement strategies, and their relevance to urban contexts. Key themes, methodologies, outcomes, strengths, and limitations were extracted and analyzed to identify research gaps and opportunities.

The literature review has highlighted several critical areas that inform the research methodology of this study. Firstly, there is a significant need for integrating participatory science with urban systems through comprehensive frameworks that leverage advanced technologies and citizen engagement (Dembski et al., 2020; Katapally, 2019; Yeager, 2021). Additionally, the unique socio-political and economic conditions of developing countries necessitate tailored approaches, particularly in conflict-affected regions like Palestine (Benyei et al., 2023; Ibaid, 2021; Itair et al., 2022a; Itair & Armoush, 2024; Nascimento et al., 2018; Tan & Taeihagh, 2020). Sustainability remains a challenge, with many initiatives lacking long-term impact, underscoring the importance of developing models that ensure ongoing citizen participation (Asingizwe et al., 2020; Head, 2023; Liñán et al., 2022).Technological barriers, such as limited internet access and digital literacy, must be addressed by designing low-tech, inclusive solutions to broaden participation (Benyei et al., 2023; Buytaert et al., 2016; Campos, 2023). Finally, robust methodologies for measuring the impact of participatory science on urban development are essential to inform policy decisions and validate the benefits of these initiatives. These insights guide the research objectives and methodology, emphasizing the need for integrated, inclusive, and sustainable participatory science applications in urban systems (R. Biswas et al., 2019; Geekiyanage et al., 2021; Karvonen et al., 2021).

2.2.3 Developing an Agile Framework for Organizing Participatory Science Projects Within Urban Systems

This step highlights the synergy between technologies, institutional frameworks, and participatory science. It presents a fixable and scalable system architecture that guides implementing a participatory approach in various urban applications.

As shown in **Figure 2-2**, the conceptualization framework development includes four stages: Specifying the Project's Goals, Determining the Level of Engagement, Integrating the Project into the System, and Defining Which Tools to Use. These four stages constitute an agile conceptualization framework that provides a general and adaptable approach to developing participatory science applications within urban systems.

Following this framework, each new application can be systematically developed and tailored to specific urban challenges, ensuring consistency and adaptability.

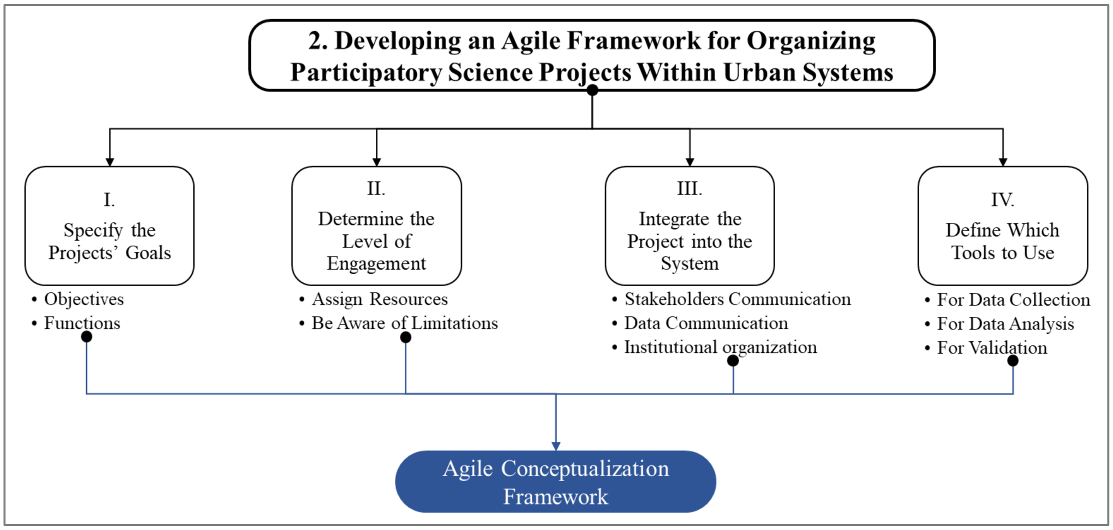

Figure 0-2 Agile Framework for Organizing Participatory Science Projects Within Urban Systems

I. Specifying the Project's Goals:

This initial stage focuses on clearly defining the project's objectives and outcomes. This stage sets a focused direction for the participatory science initiative by identifying the specific urban challenges and the intended impact. Clearly defined goals help align the project with broader urban development plans and ensure that all stakeholders have a shared understanding of the desired outcomes (Cornish et al., 2023). The project must have a clear purpose, with specific goals and objectives (Pocock et al., 2015, 2019; Shirk et al., 2012).

II. Determining the Level of Engagement:

In this stage, the extent and nature of citizen participation are studied. This involves deciding the degree of involvement required from the public, ranging from simple data collection to active decision-making roles. Determining the engagement level helps design participation methods appropriate for the project's goals and the community's capabilities (Herman Assumpção et al., 2018; A. J. Roche et al., 2022).

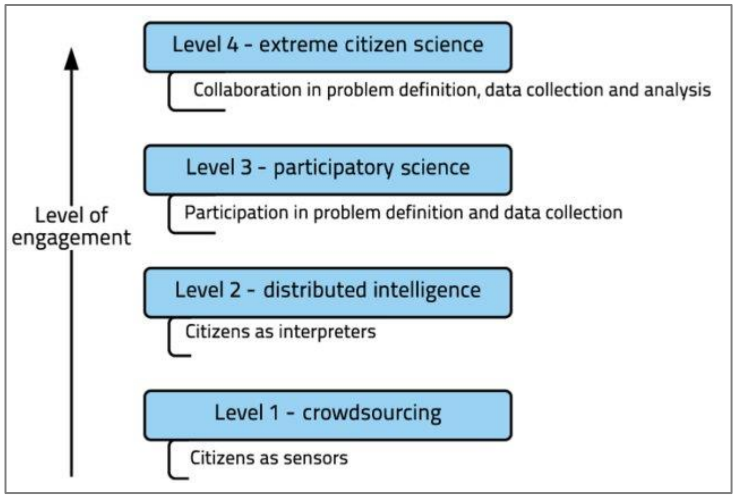

Figure 0-3 Level of Engagement in Citizen Science Projects as presented by (Haklay, 2013)

Determining the level of Engagement requires understanding what each level of resources requires and the consequent limitations, whether financial, logistical, or administrative (Pejovic & Skarlatidou, 2020). Moreover, the science capital introduced by (Essex & Haxton, 2018) contributes to determining engagement levels. (Hecker et al., 2019)

Deciding the level of engagement is typically made by a combination of stakeholders, which can include project leaders and researchers, funding bodies, and policymakers. Project leaders and researchers are usually responsible for the initial design and implementation of the project. They assess the project's goals, resources, and logistical constraints to determine appropriate levels of public involvement (Geekiyanage et al., 2021; Vaughn & Jacquez, 2020). Funding bodies, policymakers, and organizations that provide funding or set policies for citizen science projects, can influence engagement levels by stipulating requirements or limitations based on available resources and desired outcomes (Hecker et al., 2019; Turbé et al., 2019).

Normal users or citizens can also play a role in determining and shaping the level of engagement. While they may not independently decide on the engagement level, their input and participation can affect this process. Public consultations, surveys, and feedback mechanisms allow citizens to express their preferences, concerns, and ideas about their involvement in the project. This input can be invaluable in tailoring engagement strategies (Pereira & Völker, 2020).

III. Integrating the Project into the System

This stage focuses on embedding the participatory project within the existing urban systems and institutional frameworks. It involves coordinating with relevant stakeholders, aligning the project with existing policies, and ensuring compatibility with current technologies and processes. Integration into the system ensures the project is sustainable and can leverage existing resources and support structures (Katapally, 2019; Rambonnet et al., 2019; Shahrour & Xie, 2021).

Participatory science is more than a low-cost data collection method; it goes beyond that to make science more accessible and wider-reaching, which advocates for change. So, it is necessary to find a reason for citizens to encourage them to participate actively and sustainably (Kaplan Mintz et al., 2023). This happens when researchers and policymakers consider the benefit to society through the participation of its citizens (Hecker et al., 2019).

IV. Tools Development

The final stage involves selecting and developing the appropriate technological and methodological tools to support the participatory project. This includes tools for data collection (Maund et al., 2022), analysis (Santos-Tapia et al., 2024), and validation (Moor et al., 2019). Defining which tools to use ensures the project has the resources to facilitate effective participation and achieve its goals.

This research supports the idea that web services effectively support participatory science initiatives, as these services can include different tools for collecting and analysing data and disseminating knowledge (Batsaikhan et al., 2020; Schmuderer et al., 2019). **Figure 2-4** shows the general architecture for a participatory science platform adopted in this research. This platform is based on exchanging data and services between the research team and the stakeholders of participatory projects. This architecture is customized and refined according to the different projects' technical specifications to be outlined with the stakeholders in step 3 (Cooperation with Stakeholders).

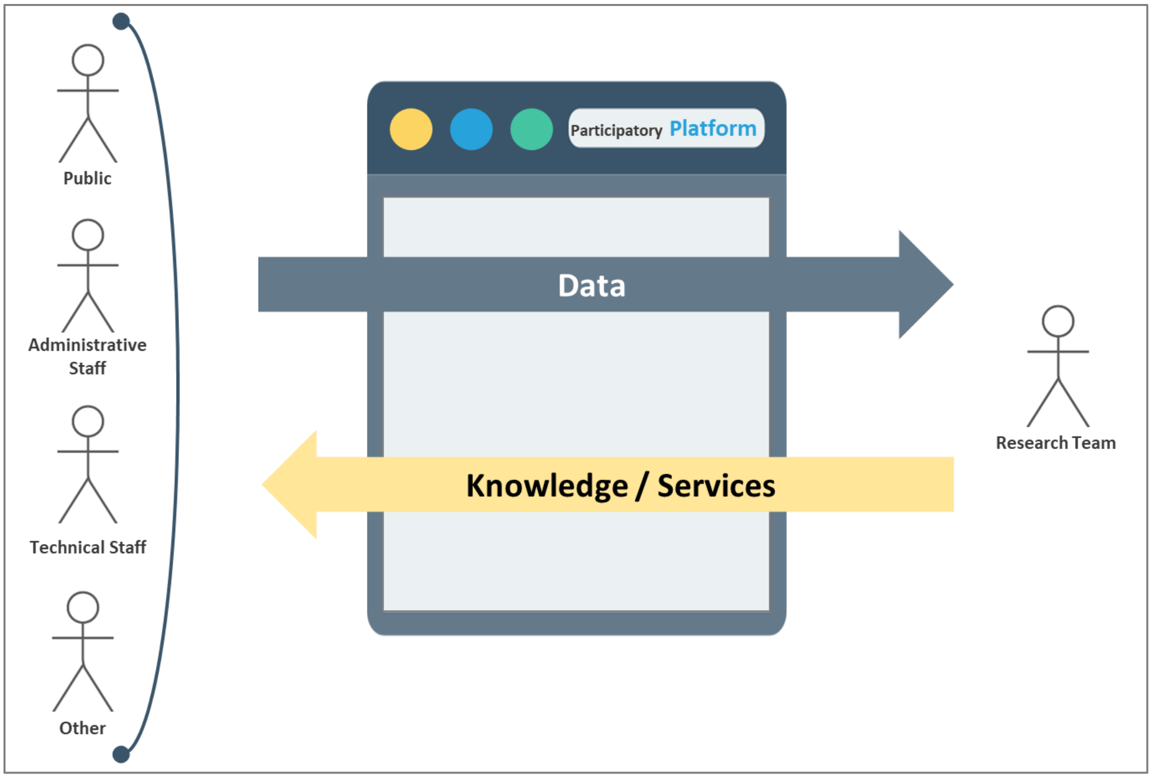

Figure 0-4 The General Architecture for the Participatory Science Platform

2.2.4 Cooperation with Stakeholders

This phase seeks to translate the conceptual framework into practical applications by engaging with relevant stakeholders, including governmental and non-governmental organizations, community groups, and academic institutions. The cooperation with stakeholders involves two main key activities:

I. Framework Adoption:

It is crucial to identify stakeholders who have a vested interest in participatory science projects. These include governmental bodies responsible for urban development, local NGOs, community organizations, educational institutions, and private sector partners.

This research collaborated with three different entities: An-Najah National University (Via Al-Maqdisi Research Project), the Municipality of Kharas (via the Palestinian Water Authority), and the Municipality of Nablus (via the Ministry of Local Governance). Together, they adopted the framework in three distinct contexts:

- Use of Smart Technology for Creating an Inclusive Urban Public Space (Municipality of Nablus).
- A Framework for a User-Centric Smart Campus (An-Najah University)
- Leveraging Citizen Science for Tackling Water Supply Challenges (Municipality of Kharas)

The collaboration and framework adoption included target group identification, service customization, and ethical consideration. By identifying and engaging specific target groups, the project ensured that the solutions were tailored to the needs and contexts of the different communities involved. Services customization allowed the framework's adaptation to meet each application's unique requirements, enhancing its effectiveness and relevance. Ethical considerations were integral throughout the process, ensuring that the methodologies and technologies employed were respectful of local contexts, sensitive to the participants' privacy, and aligned with ethical research and community engagement standards.

Figure 2-5 illustrates an example of how the general architecture from **Figure 2-4** has been tailored to meet the specific objectives of a particular system. It depicts the architecture adapted to the goals of the Water Authority and the Municipality of Kharas for participatory science, identifying the involved parties, levels of participation, and types of services. Additionally, **Figure 2-6** outlines the levels of interaction within the project. These levels were determined in collaboration with the municipality and the water authority to ensure their specific needs and considerations were addressed.

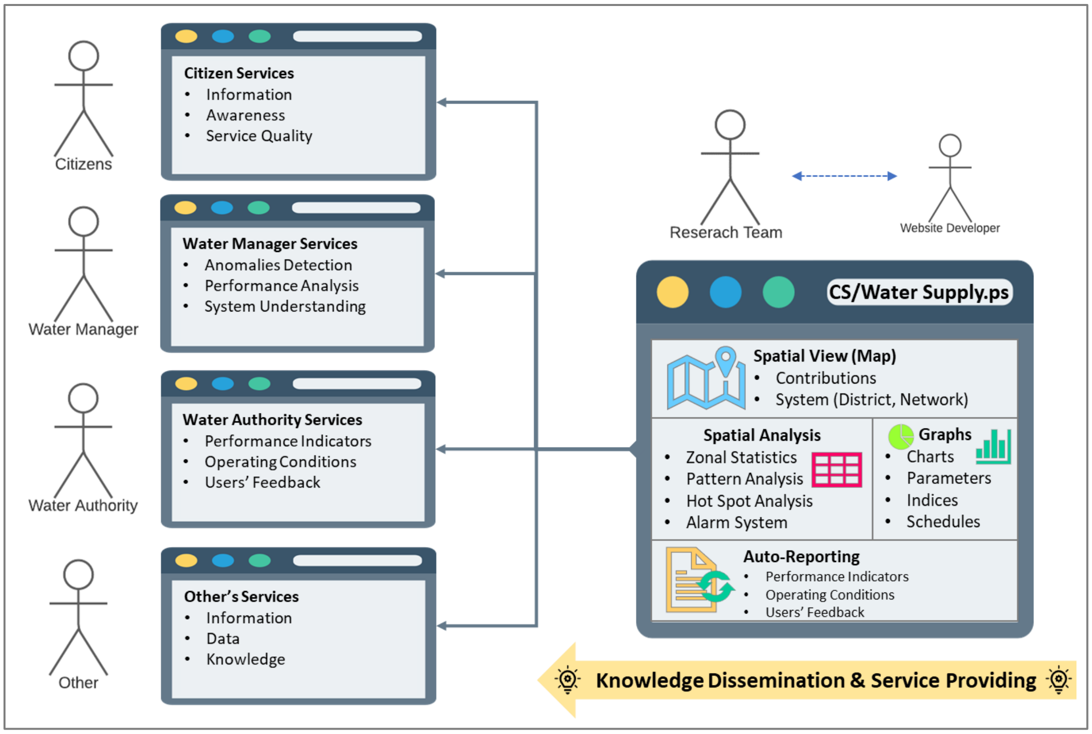

Figure 0-5 Adapted Architecture for the Participatory Water Supply Optimization Project.

Access Level / System Feature	Browse The Platform	Get Notifications	Access to Data	Make a Contribution	Upload Data to the Platform	Download Data	Edit Project Platform
Visitor Level (L0)	✔						
Contributor Level (L1)	✔	✔				✔	
Water Department Staff Level (L2)	✔	✔	✔	✔		✔	
Researcher Level (L3)	✔	✔	✔	✔	✔	✔	
Project's Manager Level (L4)	✔	✔	✔	✔	✔	✔	✔

Figure 0-6 Stakeholders Level of Interaction with the Water Supply Optimization Participatory Project

The same adoption process was followed with An-Najah National University Project (**Figure 2-7**). At An-Najah, the methodology for implementing the participatory science approach to optimize facilities management at the Engineering Faculty involves a systematic process of student engagement and data collection. Specific facilities requiring improvement are identified based on student concerns, faculty perceptions, and the research team's experience. Parameters such as comfort, safety, and accessibility are defined for each facility, including temperature, lighting, and cleanliness. Active student participation is encouraged through surveys and feedback sessions, and their insights are collected via a dedicated platform. The gathered data is analysed to identify patterns and areas for improvement using qualitative techniques. This data is then mapped onto architectural diagrams for clear visualization. Decision-making and action planning involve collaboration between faculty staff, administrators, and student representatives to develop action plans addressing the identified issues. This approach aims to leverage student feedback for evidence-based decision-making in facilities management.

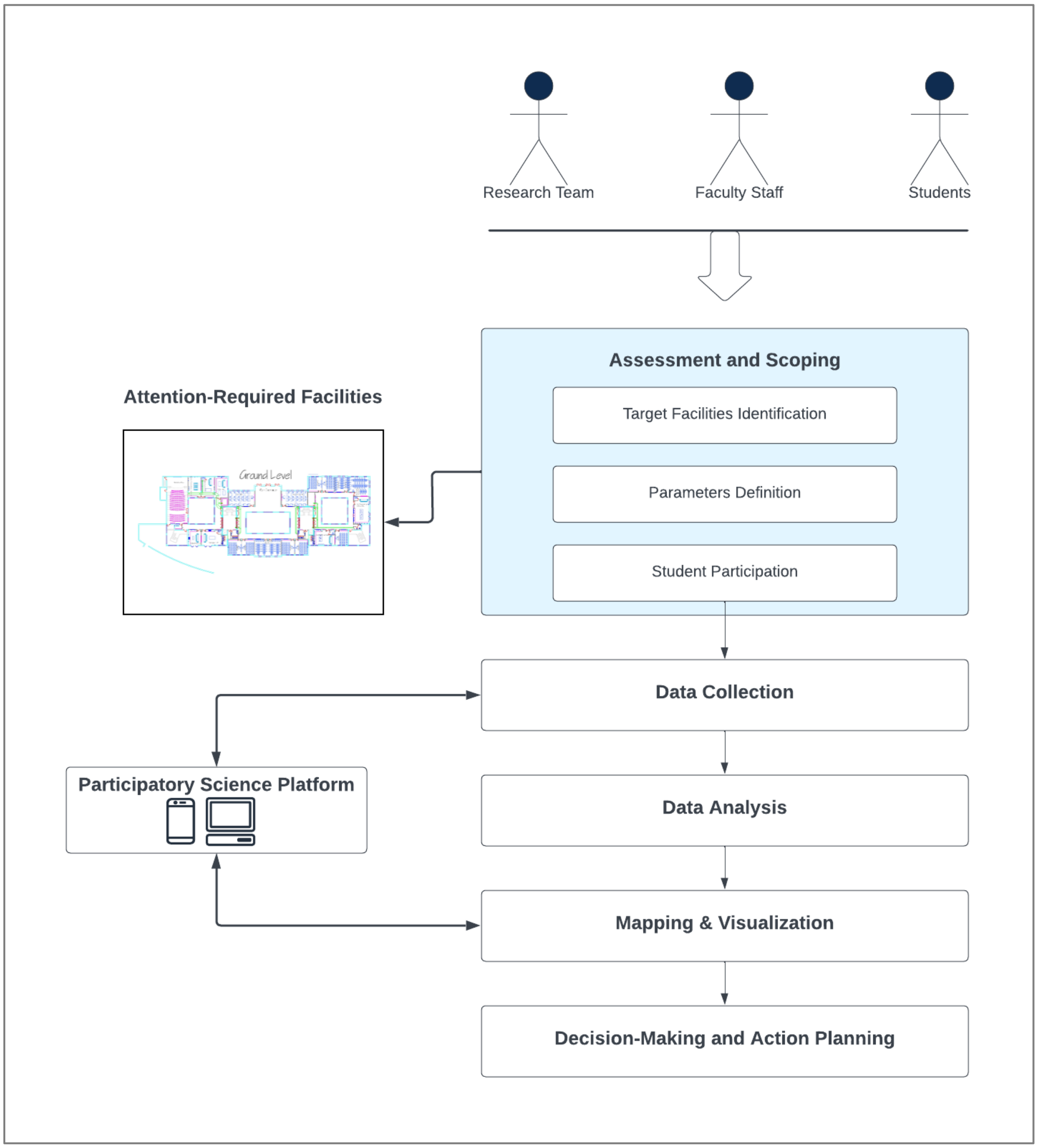

Figure 0-7 Adapted Architecture for the Campus Facilities Optimization Participatory Project.

For the inclusive public spaces project, collaboration with the Municipality of Nablus focused on adopting a participatory approach to achieve Sustainability Goal 11.7, which aims to create inclusive, safe, and attractive public spaces. This initiative aligns with the Municipality of Nablus' strategic vision for advancing sustainable development goals and addresses the community's need for accessible and appealing public areas.

II. Prototyping and Development

This This step is important to demonstrate the participatory science application's feasibility and functionality and develop a Minimum Viable Product (MVP). This step incorporates the application's core functionalities, such as data collection, analysis, and visualization tools. The MVP should be a simplified version that effectively demonstrates the application's potential.

Figure 2-8 illustrates the development of a participatory platform for water science as an MVP in partnership with the Water Authority. This platform performs essential functions such as data collection and result sharing, as agreed upon. **Figures 2-9** and **2-10** depict the MVP developed with An-Najah University for the Campus Facilities Optimization Participatory Project. For the inclusive public spaces project with the Nablus Municipality, the Kobo Toolbox website was utilized (KoboToolbox, 2023). This is a free and open-source tool that offers robust features for information exchange and dissemination.

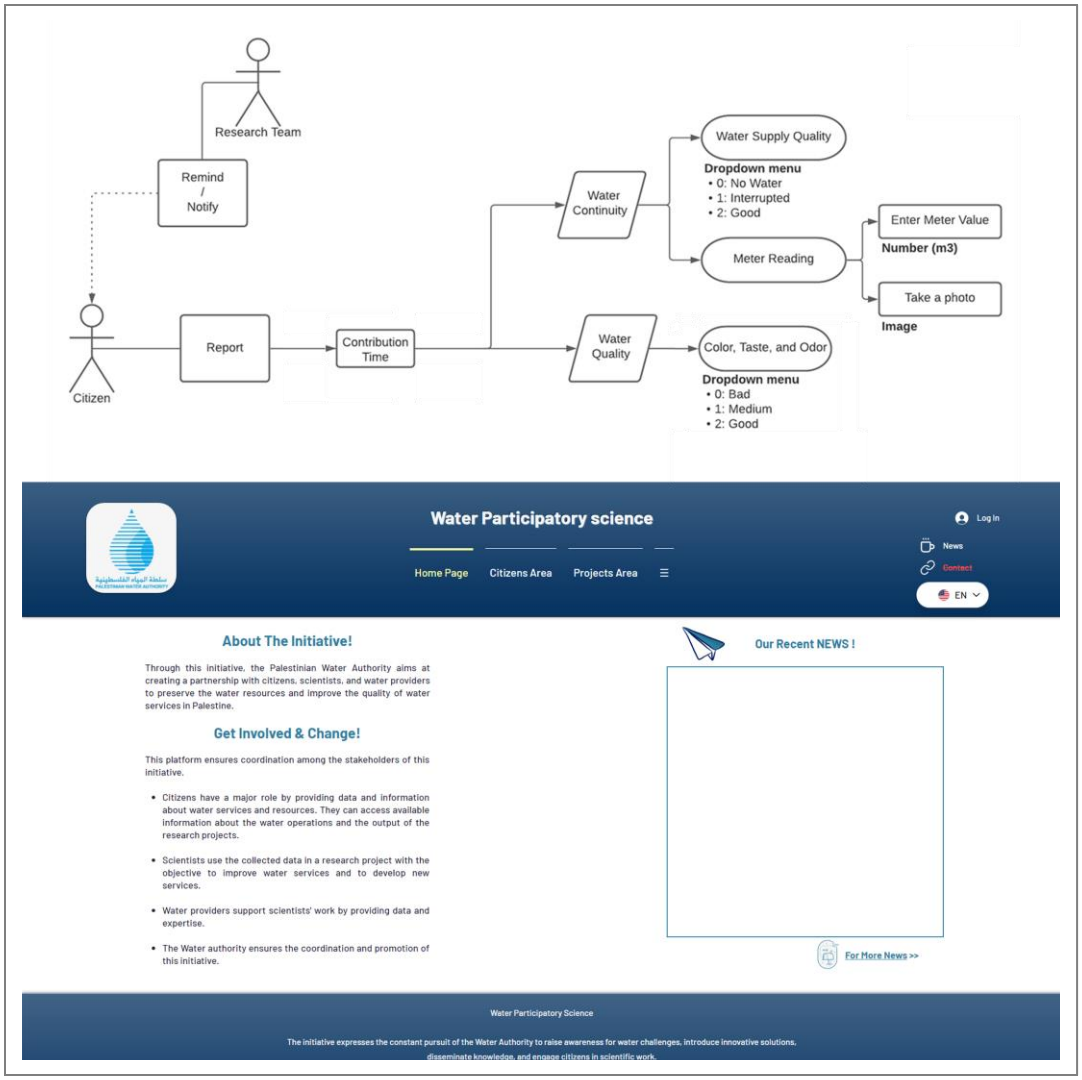

Figure 0-8 MVP Development for the Participatory Water Supply Optimization Project.

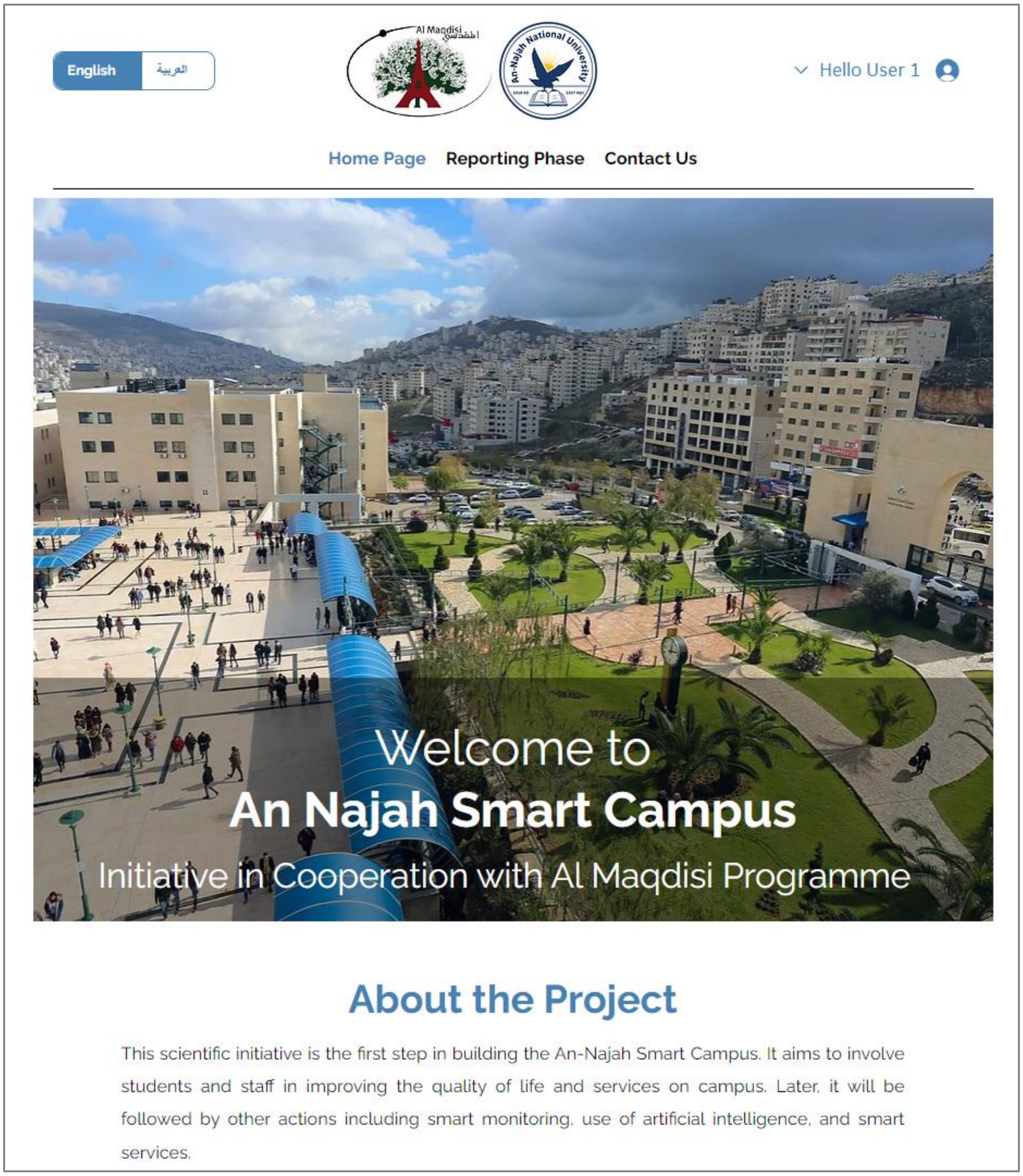

Figure 0-9 The landing page of the Campus Facilities Optimization Participatory Project

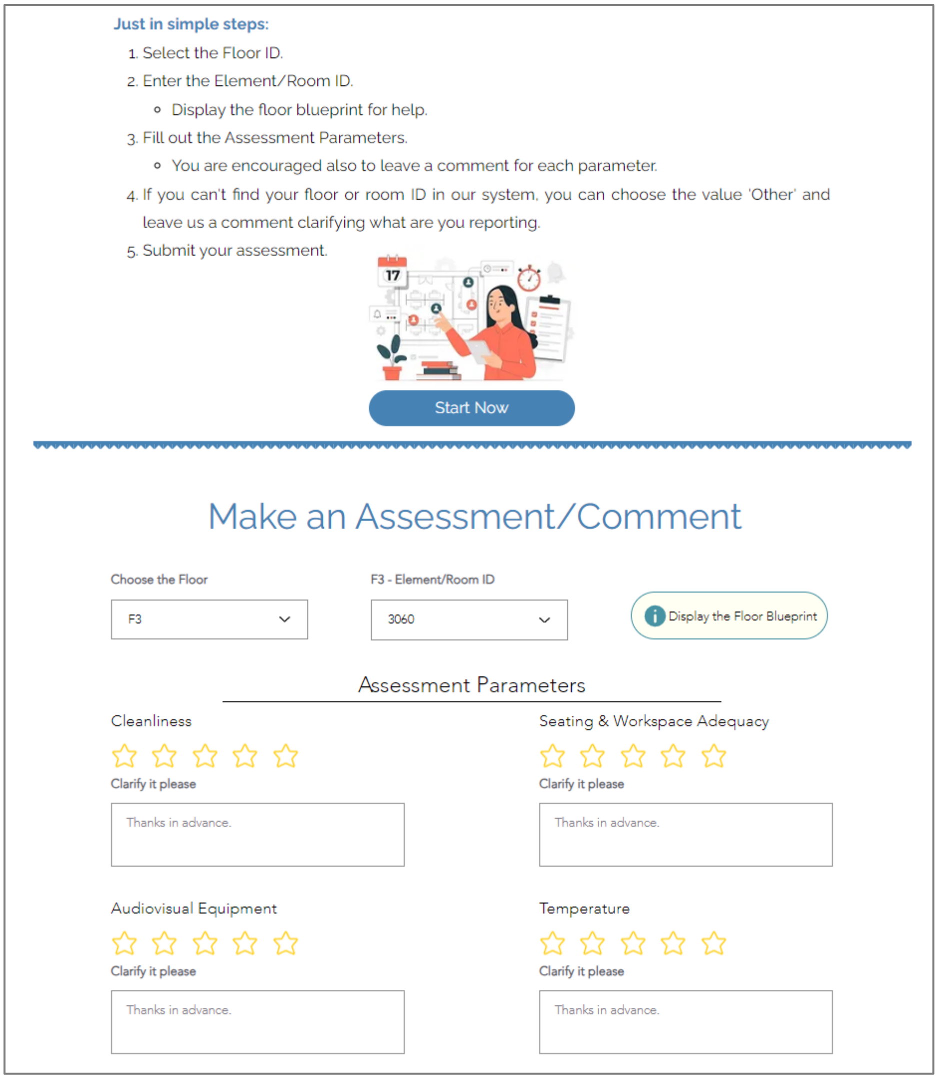

Figure 0-10 MVP: The reporting mechanism of the Campus Facilities Optimization Participatory Project

2.2.5 Application Deployment

The final step involves the full-scale deployment of the participatory science application, ensuring that it is integrated into urban systems and supported by stakeholders. This step includes three activities:

- ***Activity 1: Launch and Training:***

The application's official launch introduces it to the broader community and stakeholders through a dedicated event highlighting its features, benefits, and potential impact on urban challenges. This is followed by training workshops designed to equip stakeholders with the necessary skills to use the application effectively. These workshops cover all aspects of the application, including data collection, analysis, and decision-making processes, ensuring that users are well-prepared to utilize the tools provided.

- ***Activity 2 Testing and Evaluation:***

This step continuously assesses the application's usability, performance, and overall impact. This includes collecting user satisfaction surveys, performance metrics, and impact assessments. A feedback loop is established to gather insights from stakeholders and users, enabling data-driven decisions and continuous refinements to the tools and features based on real-world usage and feedback.

- ***Activity 3. Knowledge Sharing:***

One essential part of the deployment process is knowledge sharing. Lessons learned, best practices and insights gained from the application deployment are disseminated to a wider audience through reporting, publications, and workshops. This helps reach the results and supports decision-making processes by providing valuable information and evidence to policymakers and other stakeholders. Additionally, fostering a community of practice among users and stakeholders encourages ongoing collaboration, knowledge exchange, and innovation, ensuring that the benefits of the participatory science application extend beyond the initial deployment.

The following chapters will detail and demonstrate how the application is implemented in three urban contexts. They will provide a detailed overview of the deployment process, the challenges encountered, and the outcomes achieved in each context, offering valuable insights for future implementations.

2.3 Conclusion

This chapter outlined the research methodology for developing smart participatory science applications within urban systems. This methodology integrates a literature review, developing an agile framework, active stakeholder collaboration, and systematic application deployment.

The literature review identified the gaps, strengths, and limitations of existing participatory science applications. It highlighted the necessity of integrating advanced technologies and citizen engagement to address urban challenges effectively. The review also underscored the need for context-specific solutions, especially in conflict-affected regions like Palestine, emphasizing the importance of sustainable and inclusive participatory models.

The agile framework provides a scalable and flexible approach to organizing participatory science projects. It guides the specification of project goals, determination of engagement levels, system integration, and tool development. This framework ensures that participatory science applications are systematically tailored to specific urban challenges, promoting consistency and adaptability.

Stakeholder collaboration is pivotal in translating the conceptual framework into practical applications. The research successfully demonstrated the framework's applicability in diverse contexts by partnering with academic institutions, municipalities, and governmental bodies. This collaboration facilitated target group identification, service customization, and adherence to ethical considerations, ensuring that the solutions were contextually relevant and ethically sound.

The deployment phase encompassed launching the applications, conducting training workshops, and implementing continuous testing and evaluation. These steps ensured that the applications were effectively integrated into urban systems, supported by stakeholders, and continuously refined based on real-world feedback. Knowledge sharing was integral to this phase, promoting the dissemination of best practices and fostering a community of practice among users and stakeholders.

The methodologies and frameworks developed in this research offer a robust foundation for future implementations of participatory science applications in urban systems. By promoting public engagement, addressing technological and institutional barriers, and enhancing decision-making processes, these applications can significantly contribute to sustainable urban development. The following chapters will detail the deployment process and outcomes in three distinct urban contexts, providing further insights and validating the efficacy of the proposed methodology.

Chapter 3: Creating an Inclusive Urban Public Space

3.1 Introduction

Based on the foundational theories and methodologies discussed in the first two chapters, this chapter discusses the implementation of UN target 11.7 concerning inclusive urban public space and proposes a user-centric smart public space concept to help achieve this goal. The significance of this research is related to the crucial role of the public space in community building, inclusivity, democracy, physical and mental health, social interaction, civic engagement, citizens' participation, and economic vitality (UN General Assembly, 2015; World Health Organization. Regional Office for Europe, 2016). In addition, this space has a vital role in improving the urban environment, particularly the air quality and biodiversity (Yang et al., 2022). The UN 2030 Agenda for Sustainable Development highlighted through target 11.7 the necessity of providing a safe and inclusive public space for all, particularly for women, children, and people with disabilities (OHCHR, 2020; UN DESA, 2015).

Based on data from 1072 cities, the 2023 UN Sustainable Development Goals Report (UNITED NATIONS DEPARTMENT FOR ECONOMIC AND SOCIAL AFFAIRS, 2023) alerts that access to open public spaces remains low globally, particularly in developing countries. This report reveals that over 75% of the participating cities have less than 20 % of their area dedicated to public spaces and streets. This ratio is much lower than the UN goal, which targets a 45-50% ratio to the public space and streets. The situation for the public space is yet more critical because this space accounts for only 3.2% of the urban land in 2020, about four times less than that occupied by streets. Scholars highlighted significant disparities in the accessibility to public space (Ahmimed, 2018). For example, women, children, and people with disabilities face substantial difficulties accessing public space due to safety concerns and inadequate infrastructure. According to the World Health Organization (WHO), women face a higher risk of experiencing violence in public spaces than men, with an estimated one in three women experiencing physical or sexual violence in their lifetime (WHO, 2021). Furthermore, women are more likely to be excluded from the public space due to gender norms. Similarly, children and persons with disabilities face challenges accessing and utilizing public spaces due to a lack of appropriate infrastructure and facilities, especially in developing countries (Wellenstein & García Mora, 2021).

Various approaches have been proposed to improve the accessibility to the public space. Esfandfard et al. (Esfandfard et al., 2018) proposed the “universal design” approach that facilitates access of all to the public space, regardless of people's abilities or disabilities. Kent (Kent, 2019) proposed the "placemaking" concept to involve the community in designing and developing public spaces. Ellery & Ellery (Ellery & Ellery, 2019) used this concept to create a public space that is not only functional but also meaningful and enjoyable for all citizens. Community-led initiatives have also been proposed as a practical approach to creating inclusive public spaces. These initiatives engage community members in designing and implementing public spaces, promoting ownership, and ensuring that the public spaces meet the needs of the diverse groups of the community (Ni & Cattaneo, 2019). These initiatives also foster a sense of community and encourage responsible use of public spaces. Zhou (Zhou, 2019) highlighted the role of citizens’ participation in creating an inclusive urban public space.

However, initiatives proposed to improve the public space are still fragmented and have not yet allowed to achieve the target of creating an inclusive public space, as stated by the last UN Sustainable Development Goals Reports (Ahvenniemi et al., 2017; Angelidou et al., 2017). Considering the crucial role of this space in improving the quality of life for all, there is a pressing need for an innovative concept for inclusive public space that guarantees accessibility for all and improves services to the community. This chapter contributes to this objective by (i) establishing a comprehensive framework for the inclusive public space, which is based on both social and environmental indicators, (ii) the application of this framework for the assessment of the public space and the city of Nablus in Palestine to understand the challenges of this space and the expectations of citizens, and (iii) the elaboration of the smart public space concept to address the challenges of the inclusive public space. This concept is inspired by the smart city concept, which offers several opportunities, particularly citizens’ engagement (Bastos et al., 2022; Cardullo & Kitchin, 2019; Granier & Kudo, 2016; Mansour et al., 2024; Prandi et al., 2023) and the use of digital technologies such as IoT, crowdsourcing, and artificial intelligence for real-time monitoring of the public space and assessment of the public space services. It also provides tools to improve citizens’ safety and accessibility. This concept integrates recent developments in mobile applications and online platforms that offer valuable information on accessibility features, empowering individuals to navigate urban environments (Chiu & Lee, 2018; Lau et al., 2018).Additionally, immersive technologies like virtual and augmented reality offer innovative ways to simulate and design inclusive spaces (Dick, 2021; McKenna, 2017).

The smart governance has also a crucial role in the smart public space concept as confirmed by Glebova & Desbordes (Glebova & Desbordes, 2022) who used this concept to improve the accessibility and usability of sports facilities and to promote tourism.

As highlighted by Dudek et al. (Dudek et al., 2023), a smart intelligent urban system should go beyond simply incorporating advanced technology; it should also play a central role in promoting social responsibility by nurturing a strong sense of community and shared responsibility.

This research aims to establish a framework for the construction of inclusive public spaces, which have a major role in building a socio- and eco-friendly city. The framework incudes a set of social and environmental indicators for the assessment of the inclusivity of the public space. It is used for evaluating the public spaces in a complex urban context that of the City of Nablus in Palestine to understand the functioning of this pace and the expectorations of citizens. Based on this evaluation, the research establishes the concept of the smart public space that improve the functioning and services of this space to meet citizens expectations.

The chapter is structured as follows. First, it presents the research methodology and material and emphasizes the indicators for inclusive public space. Then, it discusses applying this concept for assessing the public space in the city of Nablus in Palestine. The assessment includes data collection through site visits and users' opinions and data analysis to determine the public space's main challenges and the users' expectations. Finally, the chapter presents the smart public space and how it could help address the public space challenges.

3.2 Methodology and Materials

3.2.1 Overview

This research focuses on developing an inclusive public space that enables equal access for citizens, regardless of gender, ethnicity, age, and ability. This research is based on a comprehensive literature review and analysis of collected data. The research starts with an extensive literature review about the inclusive public space to explore previous works about the inclusivity of the public space and the indicators used for constructing this space and its assessment. The indicators are then used to assess the public space in Nablus, a major city in Palestine. The evaluation includes collecting data about the spatial distribution of the public space and its significant features. It also includes interviews with the users of public space about their perception of and expectations of this space. Data analysis resulted in identifying the social and environmental challenges of the public space. The smart public space is proposed to address the challenges of the public space. This concept ensures citizens' effective participation in public space governance to make it more inclusive. It also uses the capacity of smart technology to enhance the public space's safety and provide a set of digital services to users.

The following sections provide an extensive description of the research methodology's first stages, including establishing indicators for the inclusive public space and data collection for assessing the public space in Nablus.

Sections 3 and 4 will present the analysis of collected data to understand the challenges of the public space and the concept of the smart public space, which was established to address these challenges.

3.2.2 Indicators of the Inclusive Public Space

An inclusive public space should ensure accessibility to all citizens regardless of their home location, gender, ethnicity, age, and abilities (Landman, 2020; Pineda, 2022). It also should provide adequate facilities and services to citizens. Both public authorities and communities need indicators to establish and assess strategies for inclusive public spaces. These indicators could be classified into the following categories (**Table 3-1**): (i) spatial distribution, (ii) typology, (iii) facilities and services, (iv) green and humid areas, (v) governance and management, (vi) safety, (vii) users' category, and (viii) user's satisfaction.

The spatial distribution measures the proximity of the public space to citizens regardless of their residence or working location. The typology informs about public spaces, such as plazas, linear markets, community yards, sidewalks, recreation areas and parks, and playgrounds. The facilities and services indicators concern the public space equipment such as public toilets, seat shading, water taps, garbage bins, lights, baby services, parking areas, and catering. The green and humid area indicators indicate the ratio and distribution of green and humid areas in the public space. The management of the public space concerns decision-making, citizens' participation, and maintenance of resources. The safety indicators concern safety equipment, vandalism, and security measurements. Finally, the category of public space users indicates the classifying of the population using the public space according to their gender, age, and abilities, while the users' satisfaction informs about their degree of satisfaction with the public space.

Table 0-1 Indicators for the inclusive public space.

No.	Indicator Category	Description
1	Spatial distribution	Proximity of the public space to citizens regardless of their residence or working location.
2	Typology	Type of public spaces: plazas, linear markets, community yards, sidewalks, recreation areas and parks, and playgrounds
3	Facilities and services	Public space equipment and services: public toilets, seat shading, water taps, garbage bins, public lights, baby services, parking areas, and catering.
4	Green and humid areas	Ratio and distribution of green and humid areas in the public space
5	Governance and management	decision-making, citizens' participation, and maintenance of resources.
6	Safety	Safety equipment, vandalism, and security measurements.
7	Users' category	Category of the population using the public space (gender, age, disabilities)
8	Users' satisfaction	The user's degree of satisfaction with the public space services.

3.2.3 Presentation of the Case Study, Nablus City, Palestine

The set of indicators presented in the previous section were used for the assessment of the public space in the city of Nablus in Palestine. This city constitutes a regional urban center in the northern part of the West Bank (The World Bank, 2021). This city is recognized as a vibrant commercial and cultural center, housing An-Najah National University and the Palestinian Stock Exchange. With a population of approximately 200,000 residents (Palestinian Central Bureau of Statistics, 2018), it plays a crucial role as an administrative, educational, commercial, and industrial hub in the region. Its historical development reflects the influences of the Ottoman and British mandate periods, visible in the old and modern neighborhoods that emerged around the city (Ghadban, 2008).

The city of Nablus is experiencing significant population growth and density (The World Bank, 2021), experiencing significant population growth and density. According to the Palestinian Central Bureau of Statistics (Palestinian Central Bureau of Statistics, 2018), Nablus has an annual population growth rate of 2.5% and an average family size of 4.8. This rapid population increase has resulted in high population density, surpassing other regional cities. The expansion of urban areas has been limited, leading to a notable difference in built-up density, which reaches 733 inhabitants/km^2 in some neighborhoods (Hadba et al., 2014).

3.2.4 Data Collection

Based on discussions with the municipality and the community, 63 spaces were selected for this study. **Figure 3-1** illustrates the location of these spaces in the city.

Ten field surveyors collected data using the open-source Kobo Toolbox App (KoboToolbox, 2023). The use of the Kobo Toolbox streamlined the data collection process by facilitating efficient and accurate data entry. This toolbox allowed the collection of various data types, including images and videos. For a comprehensive understanding of the public spaces' inclusivity, interviews were conducted with different categories of individuals during both daytime and nighttime. This approach enables capturing the perspectives of diverse citizens, including individuals from different age groups, genders, and people with disabilities.

The collected data concerned the indicators presented in **Table 3-1**. Data concerning the first two indicators (spatial distribution and typology) were collected by the survey team and confirmed by the municipality. Data concerning other indicators were collected from the users of the public spaces. Around 630 users participated in this survey. The participants encompassed a diverse cross-section of the community, representative of the broader population's characteristics.

The survey protocol dictated that five individuals be interviewed in each public space: 2 males, 2 females, and 1 individual with a disability or a child. This approach aimed to capture a well-rounded understanding of users' experiences across different demographics. Notably, the female respondents exhibited greater responsiveness in completing the survey forms, which can be attributed to factors such as the form's length and the women's engagement with the subject matter.

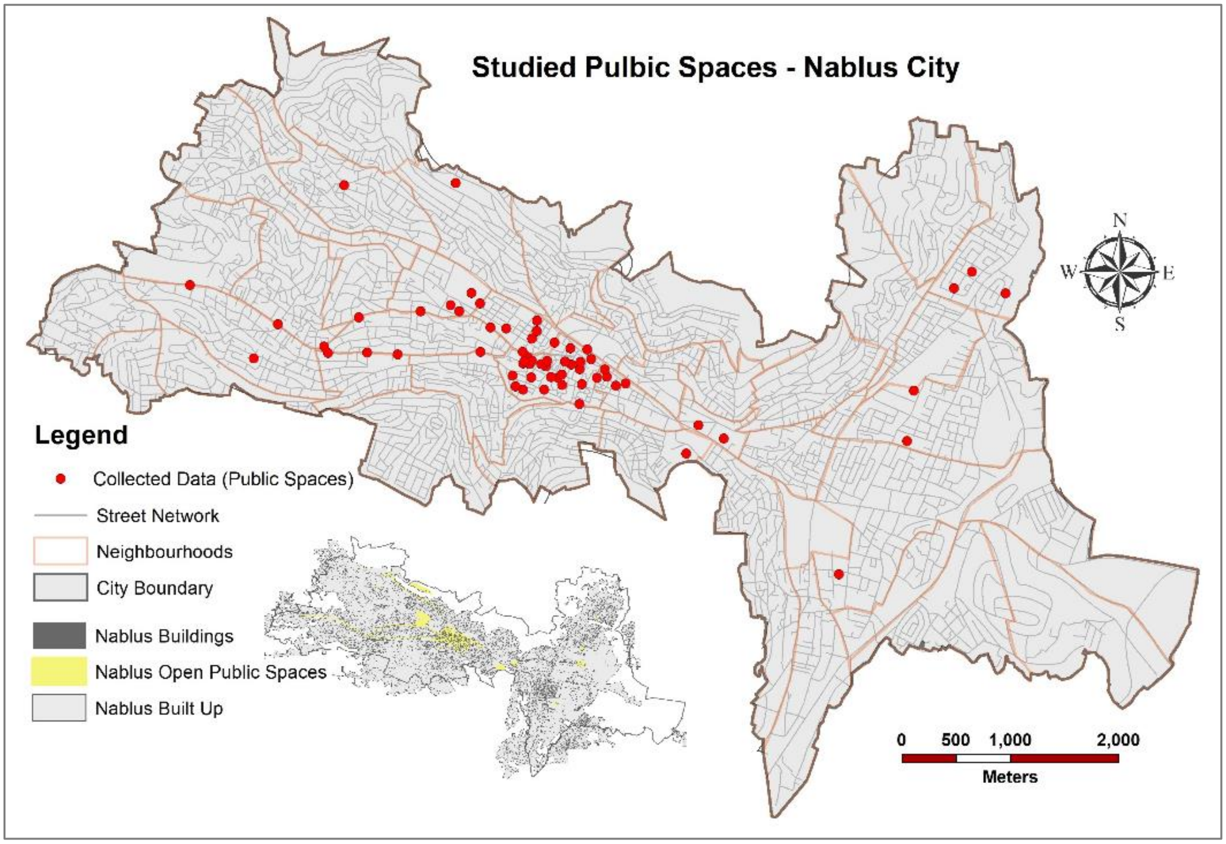

Figure 0-1 Localization of the surveyed public spaces in the city of Nablus.

3.3 Results

3.3.1 Spatial Distribution of the Public Space

The total area of the public spaces within the city was found to be 496,359 m^2, which includes market areas, community yards, and streets -Linear market streets. The per capita ratio of public spaces is 2.6 m^2/inhabitant, which falls below local and international standards and varies between five m^2 and nine m^2 per person (European Commission, 2019; Ministry of Municipal

Rural Affairs and Housing, 2015). The allocation of public spaces in the master plan is below the standards; at least an additional one km^2 of new public spaces is required to meet the standards.

Figure 3-2 illustrates the distribution of the public space in the city. It shows that the public space is concentrated in the city center and the old city. The Eastern part has reduced public spaces, including two camps and a low-income population. Results show that only 30% of the city's neighborhoods have access to public space within five min walking distance, while over 41% need more than ten minutes walking to access public space. The open spaces better serve the western part than the Eastern part. Results also show that 41% of the public spaces' entrances are unclear, posing difficulty in accessing these spaces.

When explicitly considering parks and playgrounds, a more nuanced perspective emerges regarding walking distances. In this context, merely 7% of these recreational facilities are conveniently accessible within a 5-minute walking radius. Conversely, 73% of parks and playgrounds demand traversing distances exceeding ten minutes on foot. This differentiation highlights a more pronounced challenge in accessing recreational spaces designed for leisure and outdoor activities. The disparities between accessibility to public spaces at large and specifically to parks and playgrounds underscore the complex spatial distribution within the city.

Moreover, the survey revealed that most public spaces operate on a neighborhood scale, typically ranging from 500 to 2000 square meters in size. Pocket parks spanning fewer than 500 square meters are conspicuously limited in number despite their noteworthy impact on urban aesthetics. These small green areas contain a distinctive capacity to increase the aesthetic attractiveness of the urban landscape. Regrettably, their limited presence could curtail small-scale relaxation, leisure, and visual delight opportunities.

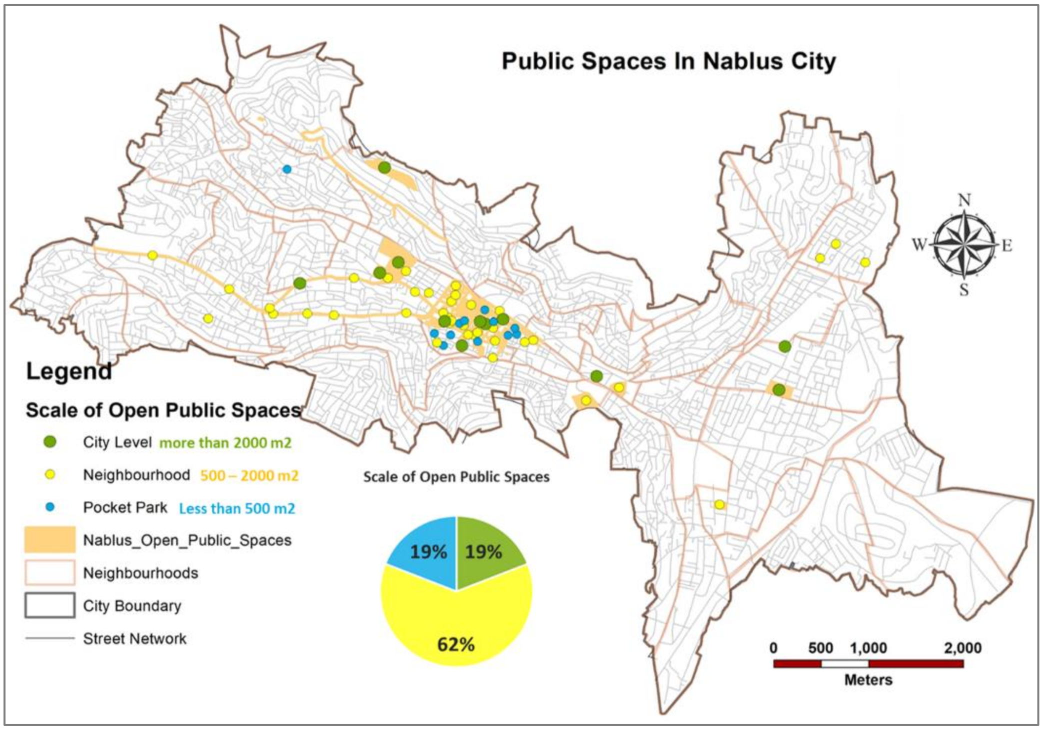

Figure 0-2 The scale of open public spaces in the city of Nablus.

3.3.2 Public Space Typologies

Figures 3-3 and **3-4** show the public space typology, including plazas, linear markets, community yards, sidewalks, transportation stations, parking lots -informal playgrounds-recreation areas and parks, playgrounds, and empty spaces. The linear market dominates the public space. Rafidia Street, a famous street in the city, was identified as the most vital public space. Furthermore, the old city has a significant concentration of community yards, which exhibit a semi-public character. However, there was a shortage of plazas, parking, and playgrounds.

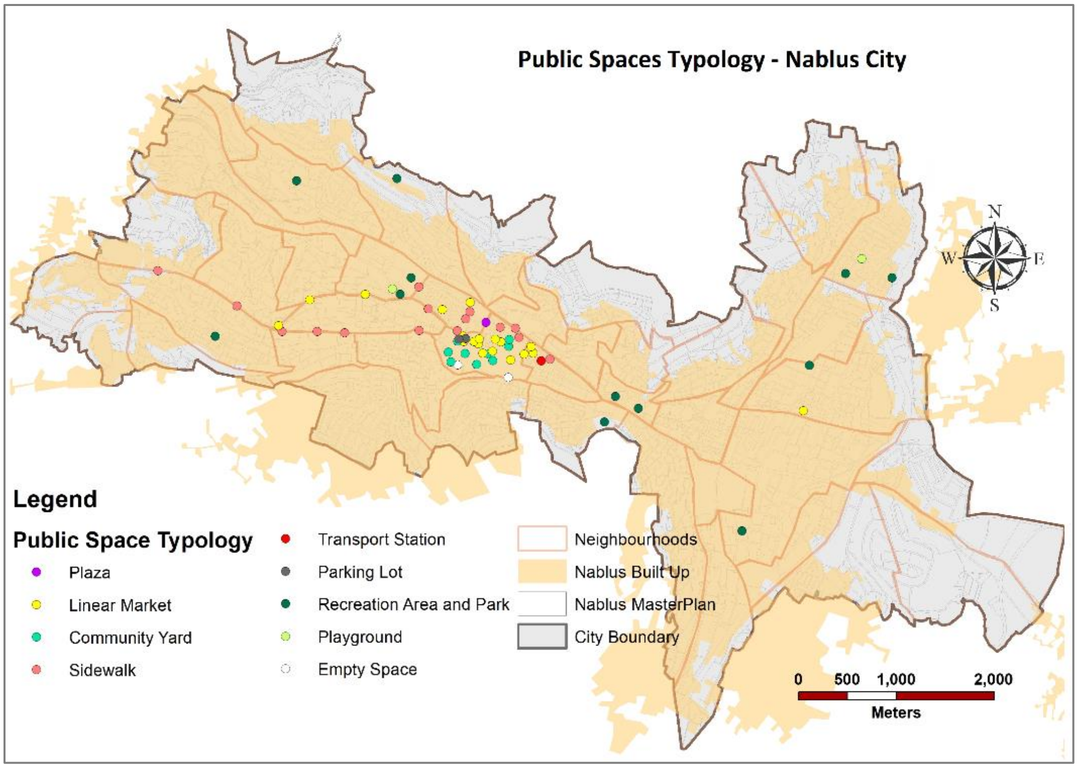

Figure 0-3 Spatial distribution of the public spaces according to their typology.

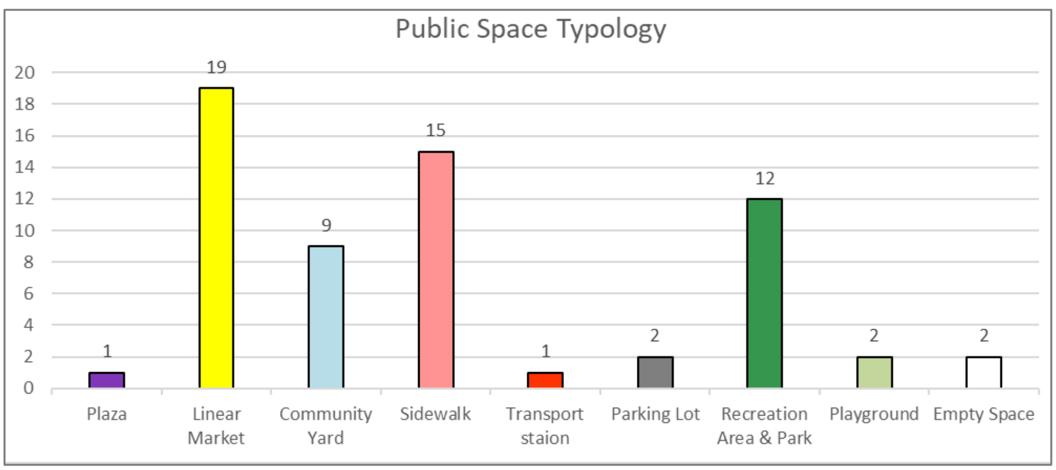

Figure 0-4 Repartition of the public spaces' typology.

3.3.3 Facilities

Figure 3-5 shows the facilities of the public space. It indicates an excellent equipment by public lighting (87%), but no significant facilities such as public toilets, assistance for blind people, bike parking, direction signature, and body facilities. Only 32 % of the public spaces are equipped with seating facilities, 19% by water tap, 28% by artificial shade, 56% by garbage facilities, and 32% by vehicle parking. We observe also that only 41 % of the public space provides access to people with disabilities.

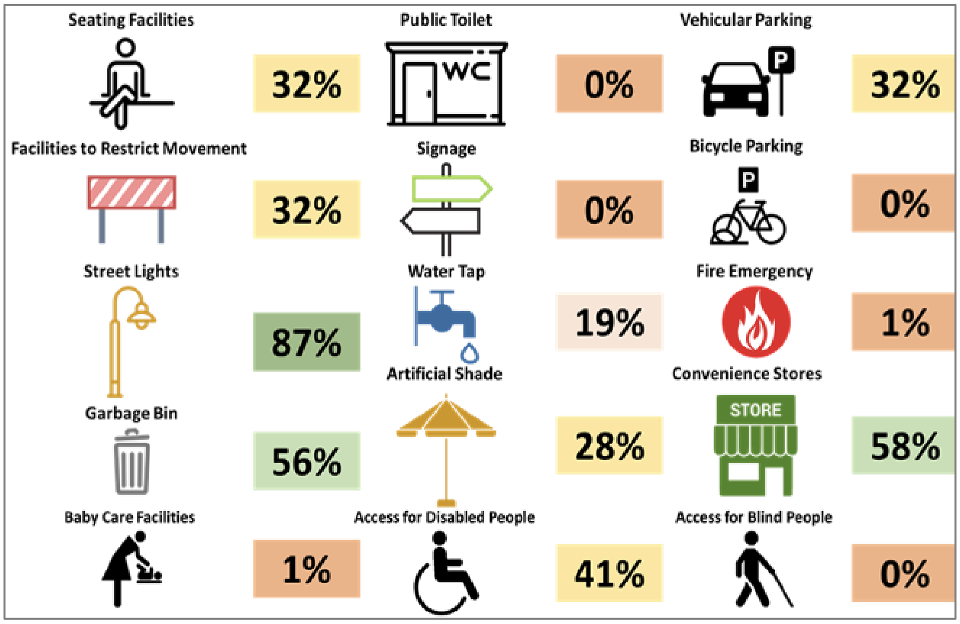

Figure 0-5 Facilities of the public space in Nablus.

3.3.4 Green and Humid Areas

The survey indicates a deficit in green areas. Less than 30% of the public spaces include green areas. **Figure 3-6** illustrates the distribution of the green area in the city. It indicates a high concentration of the green area in the park Jamal Abdul-Nasser and the quasi-absence of this area of the old town. The lack of green areas in public spaces negatively impacts these spaces' attractiveness and environmental function.

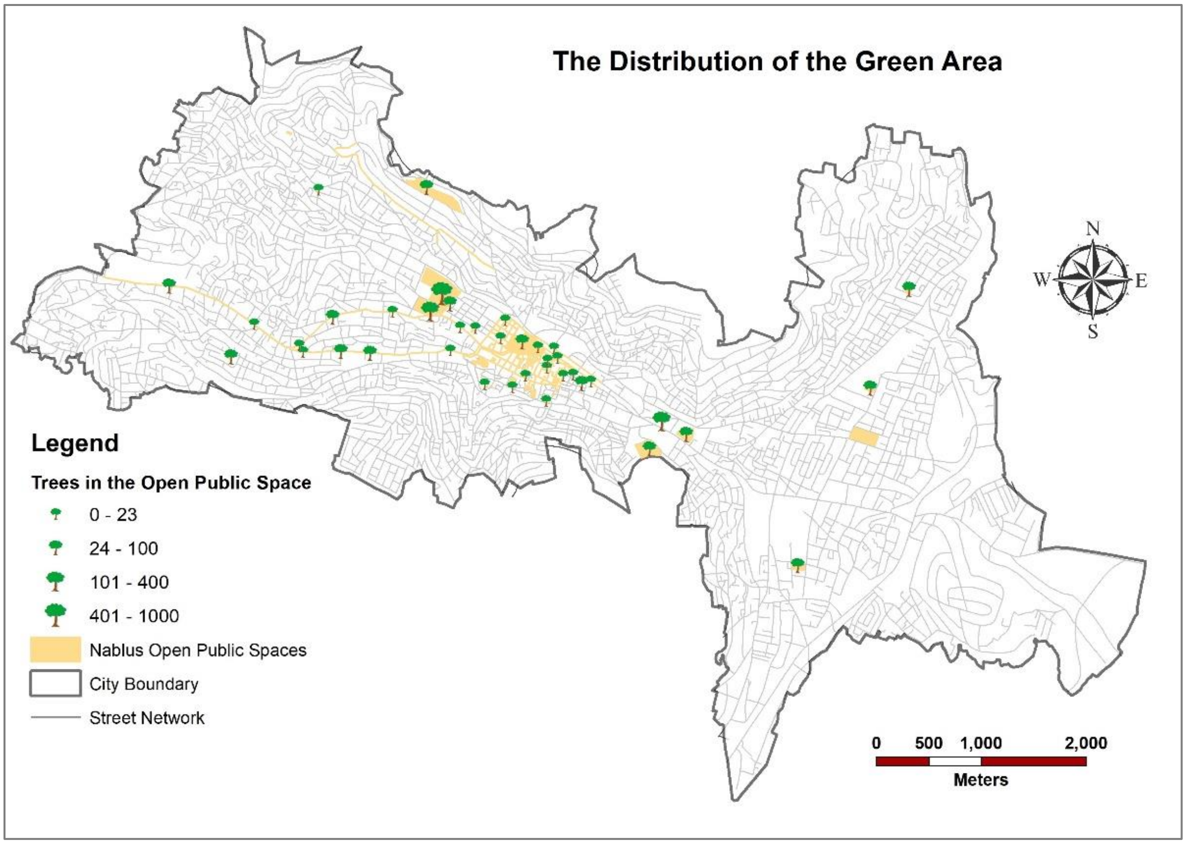

Figure 0-6 Distribution of the green area in the city.

3.2.5 Governance and Management

The public spaces in Nablus are mainly governed and managed by the municipality. Only two of the 63 public spaces are owned by UNRWA (United Nations Relief and Works Agency for Palestine Refugees) within the camps and managed jointly with the municipality. Citizens are not yet involved formally in the governance and management of these spaces.

Regarding formality, 52 designated public spaces and 11 informal spaces have organically evolved in response to community needs. This interplay between formal and informal spatial designations exemplifies the complexity of urban management and the multifaceted nature of public space utilization.

3.2.6 Safety

Figure 3-7 shows that during the daytime, 66% of the interviewed women reported feeling safe in public spaces, 32% felt partially safe, and only 2% did not feel safe, while 84% of men reported being safe, 15% somewhat safe, and only 1% unsafe. The situation changes significantly during nighttime. Only 19% of women reported feeling safe, 43% partially safe, and 38% unsafe. In comparison, 66% of men reported feeling safe, 27% partially safe, and 7% unsafe. This result indicates safety presents a strong obstacle for women to access public spaces, in particular during nighttime.

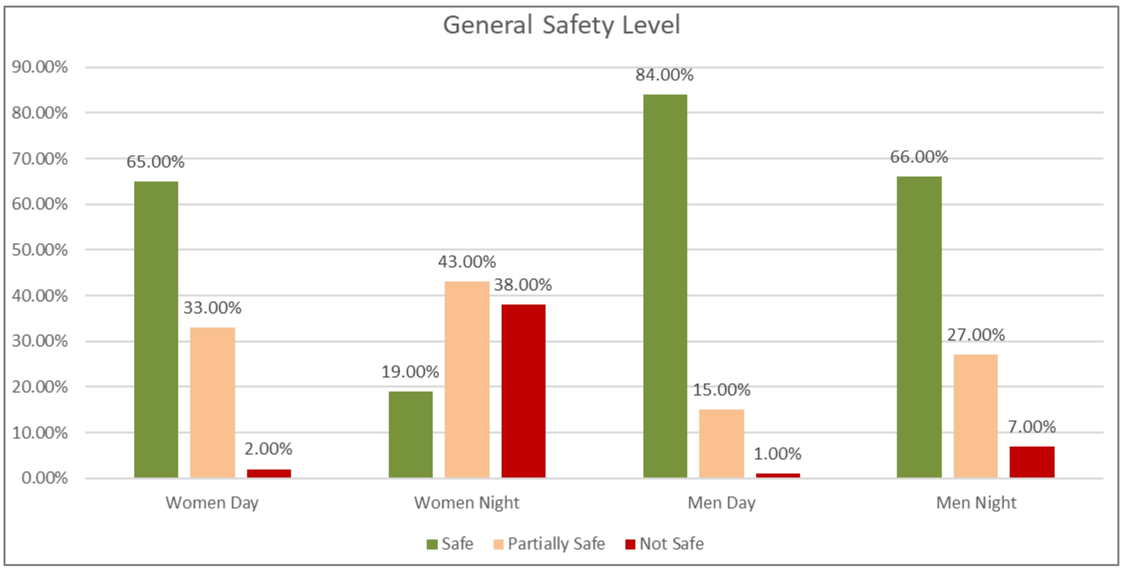

Figure 0-7 General safety level by gender and time of day.

3.2.7 Category of the Public Space Users

Figure 3-8 shows the number of day users of the public spaces is three times that of night users. Moreover, it shows that young males dominate the use of the public space, while people with disabilities have reduced use of it during the day and night.

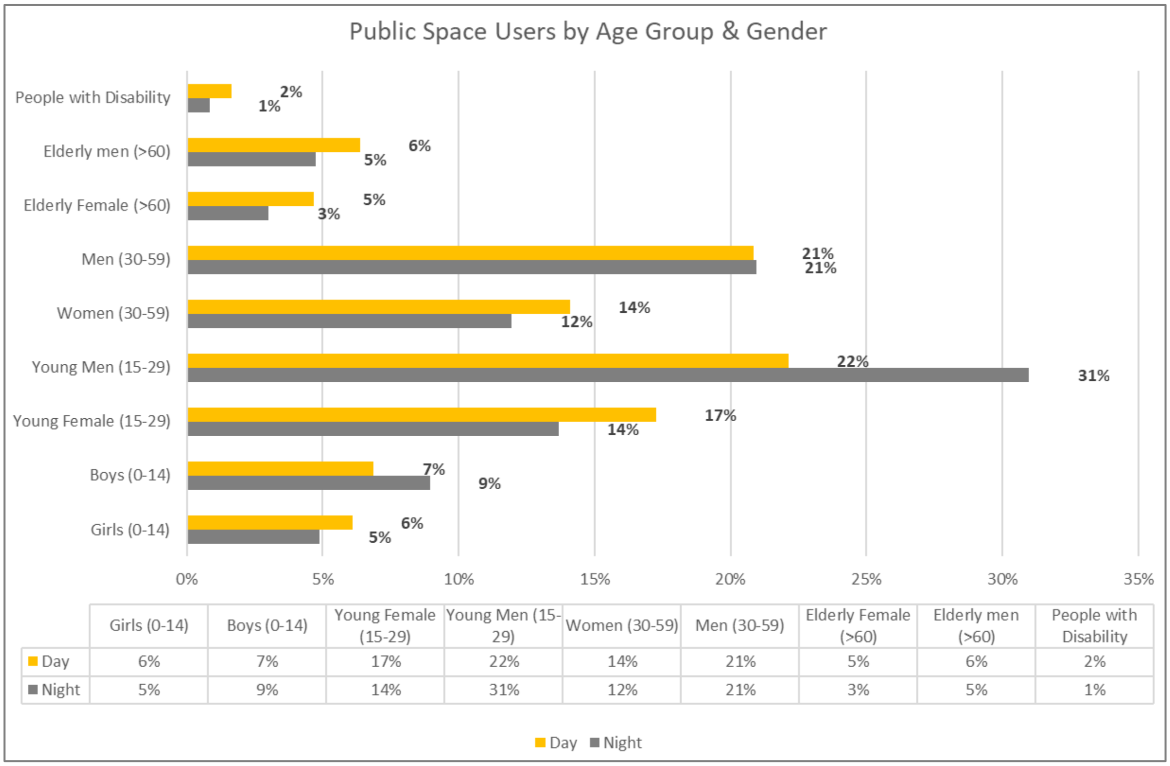

Figure 0-8 Day/Night users of open public spaces in the city by age group and gender.

3.2.8 Users' Satisfaction

Figure 3-9 shows the users' satisfaction with facilities and services in the public spaces. Seating facilities garnered 35% satisfaction, with 15% expressing partial satisfaction and 50% reporting dissatisfaction. Lighting received 36% satisfaction, 46% partial satisfaction, and 18% dissatisfaction. For garbage bins, 29% were satisfied, 54% partially satisfied, and 17% dissatisfied. Water taps garnered 36% satisfaction 64% partial satisfaction. Artificial shading satisfied 47%, partially satisfied 47%, but left 6% unsatisfied: vehicular parking generated 17% satisfaction, 56% partial satisfaction, and 27% dissatisfaction. Regarding accessibility for disabled individuals, 34% found it satisfying, 17% partially satisfying, and 49% unsatisfying.

These results highlight a high level of users' dissatisfaction, particularly with seating facilities, waste disposal, and facilities for individuals with disabilities. In turn, this significantly affects the aesthetic value of the public spaces. Specifically, around 40% of the public spaces are regarded as uncomfortable, while over 60% of the reviewed open public spaces have garbage management issues.

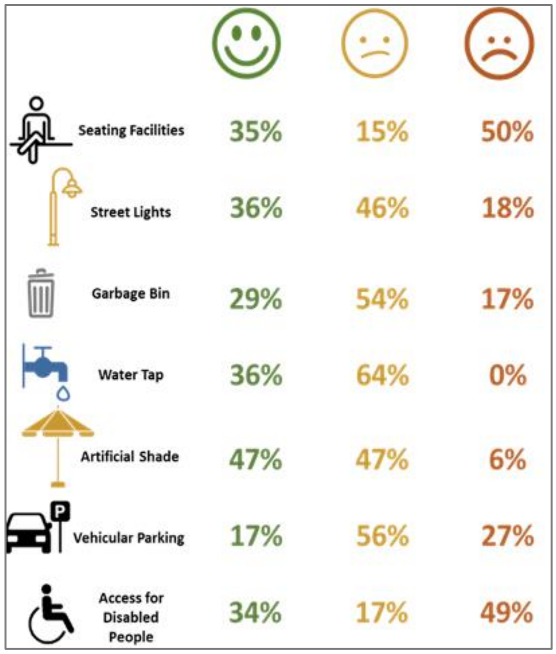

Figure 0-9 Satisfaction levels with physical features in public spaces.

3.4 Discussion

The analysis conducted in the preceding section reveals a significant shortfall in the quality of public spaces within the city of Nablus, highlighting a clear lack of inclusivity. This assessment has exposed a multitude of shortcomings, including but not limited to: inadequate spatial coverage, inequitable distribution, notable absences in key areas of the city, security concerns, particularly affecting women, low levels of civic engagement, and a dearth of essential facilities such as public toilets, access to clean tap water, seating, artificial shade, clear navigation signage, and facilities catering to individuals with disabilities. These collective deficiencies severely restrict citizens' accessibility to public spaces, underscoring the urgent need for comprehensive improvement measures.

The following sections provide an extensive discussion of a significant issue of the inclusive public space, that of its accessibility and the smart public space as a solution to improve the inclusivity of the public space.

3.4.1 Accessibility of the public space

The distribution and accessibility of public spaces emerge as a significant concern, with the total area falling below recommended standards. The spatial concentration of the public space in certain areas exacerbates the disparities between neighborhoods. This is particularly evident in the city's east, where reduced public spaces are available for low-income populations and two refugee camps. Consequently, urban planning efforts should prioritize the equitable distribution of public spaces across the city, considering the diverse needs of neighborhoods and population groups (UN Habitat, 2015; Wolch et al., 2014). Engaging the community stakeholders, including residents from marginalized groups, can provide valuable insights and ensure that public spaces reflect the needs and expectations of the entire community (Abusaada & Elshater, 2021; Waddington et al., 2019).

Furthermore, urban planning should focus on improving the accessibility and visibility of the public space through clear entrances and wayfinding signage (Project for Public Spaces, 2018). This will enhance the overall user experience and encourage more people, including those with disabilities, to utilize the city's public spaces.

Results also indicate a gender disparity in the use of public space, particularly during nighttime. Women reported feeling less safe than men, likely influenced by insufficient lighting and social problems occurring in these spaces. Moreover, people with disabilities have a reduced presence in the public space, reflecting the lack of inclusive design and facilities that address their needs.

Strategies should be implemented to encourage the understanding and diverse participation of different age groups, genders, and abilities in public spaces. This should inform the design and management of the public space to ensure their inclusivity, particularly safety for all community members (Wojnowska-Heciak et al., 2022). Integrating the voices and perspectives of women, people with disabilities, and other marginalized groups in decision-making will foster a sense of ownership and belonging among users (Polko & Kimic, 2022).

The physical features of the public spaces are generally unsatisfactory, in particular seating, lighting, garbage disposal, green coverage, and facilities for women and people with disabilities. Seating was identified as a critical area for improvement. Moreover, the lack of necessary features for specific users' groups, such as women's needs and accessibility considerations for people with disabilities, highlights a significant gap in the design and construction of these spaces. Enhancing the quality and diversity of physical features, along with ensuring the provision of inclusive amenities, can contribute to creating more attractive and user-friendly public spaces that meet the diverse needs and preferences of the community.

3.4.2 Smart Public Space

Analysis of the data collected regarding the public space in Nablus highlights the imperative for proactive measures to enhance its inclusivity and ensure alignment with users' expectations. More precisely, the analysis showed a high users' dissatisfaction with public space safety, facilities, services, and accessibility. It also highlighted a lack of citizens' participation in the governance and management of the public space.

Considering the vital role of the public space in cities and the Palestinian regulations concerning the crucial role of the public space (Itair et al., 2022b; MoLG, 2013a, 2013b, 2018), a new strategy is required in Palestine for building a smart space that involves citizens in its government and uses the latest technology to improve the quality of services to citizens and the environment.

The smart public space should involve citizens in the public space governance because they are the main ones concerned with this space. Also, they can provide users with valuable information about the public space location, design, facilities, services, and social environment. This space should also be monitored by the latest technology to improve services to users, in particular accessibility, safety, navigation, access to tap water, toilets, seating, shading areas, and green and humid spaces. It should also provide specific services for people with disabilities. This space should also be eco-friendly, using advanced technology for water saving, irrigation, renewable energy, smart public lighting, and biodiversity survey and protection.

The smart public space is inspired by the smart city concept (Albrecht et al., 2013; Gracias et al., 2023; Szczepańska et al., 2023), which aims at improving the quality of life in cities by involving citizens in city affairs and improving the efficiency of urban systems and functions.

Figure 3-10 depicts the architecture of the innovative smart public space concept, as outlined by Shahrour and Xie (Shahrour & Xie, 2021). This architectural framework comprises six layers, each vital in shaping the concept's functionality and efficacy. These layers encompass governance, physical infrastructure, data collection mechanisms, communication protocols, server infrastructure, and smart services.

The governance layer, positioned horizontally, serves as the linchpin for orchestrating the organizational dynamics and decision-making processes inherent to the design, amenities, services, and overall operation of the public space. Central to its role is ensuring a robust and inclusive engagement of critical stakeholders—from citizens who utilize the space to policy-makers who shape its policies and the administrative entities overseeing its execution.

The physical layer constitutes the tangible foundation of the concept, encompassing the spatial elements, equipment installations, facilities, and the diverse services offered within the public space. It also extends its scope to encompass citizens, who not only act as end-users of the space but also serve as a wellspring of valuable data and critical evaluations that contribute to the enhancement of the public space experience.

The data collection layer includes tools and resources meticulously orchestrated to amass comprehensive data about the public space. This layer encompasses an array of Internet-of-Things (IoT) components, such as intelligent sensors endowed with the capability to meticulously monitor a spectrum of vital parameters within the public space ecosystem. These parameters encompass aspects ranging from spatial occupancy, ambient air quality, and accessibility metrics to the intricate functionality of lighting installations, facilities' operational status, and overall safety benchmarks. The data layer also includes interactive tools like mobile Apps that transmit users' observations and suggestions. The data collection process must adhere to a stringent commitment to transparency while dutifully respecting the overarching regulations concerning data privacy.

The communication layer connects the physical layer to the server infrastructure. Employing both wired and wireless communication protocols, this layer orchestrates the seamless transmission and exchange of data. Advanced communication mechanisms, such as the 5G technology and the innovative LoRaWan protocols, are at the forefront of its capabilities, which contribute to the swift and robust transmission of data across the interconnected network. Through these sophisticated communication avenues, the public space concept attains an elevated level of cohesion, ensuring that the insights gleaned from the data-rich physical layer are channeled effectively to and from the central server hub.

The server layer is pivotal in executing multiple functions, including data storage, processing, and analysis. The latter employs various mathematical and Information Technology tools, including statistics and artificial intelligence, to metamorphose collected data into valuable insights, actions, and services. It can furnish statistical insights regarding public space usage and operational efficacy. These insights, in turn, contribute to enhancing service quality, optimizing equipment efficiency, and rationalizing resource allocation. Additionally, the system excels in real-time anomaly detection, swiftly implementing corrective measures when necessary. Furthermore, its contributions extend to fortifying safety through enhancing lighting systems, utilizing security cameras, and deploying a mobile app alert system.

The smart services layer encompasses a broad spectrum of actions that elevate citizen experiences and environmental conditions. Services include real-time updates on public space dynamics, facility operations, service availability, navigation aids, social connections, WIFI accessibility, efficient irrigation practices, intelligent public lighting, and streamlined parking management.

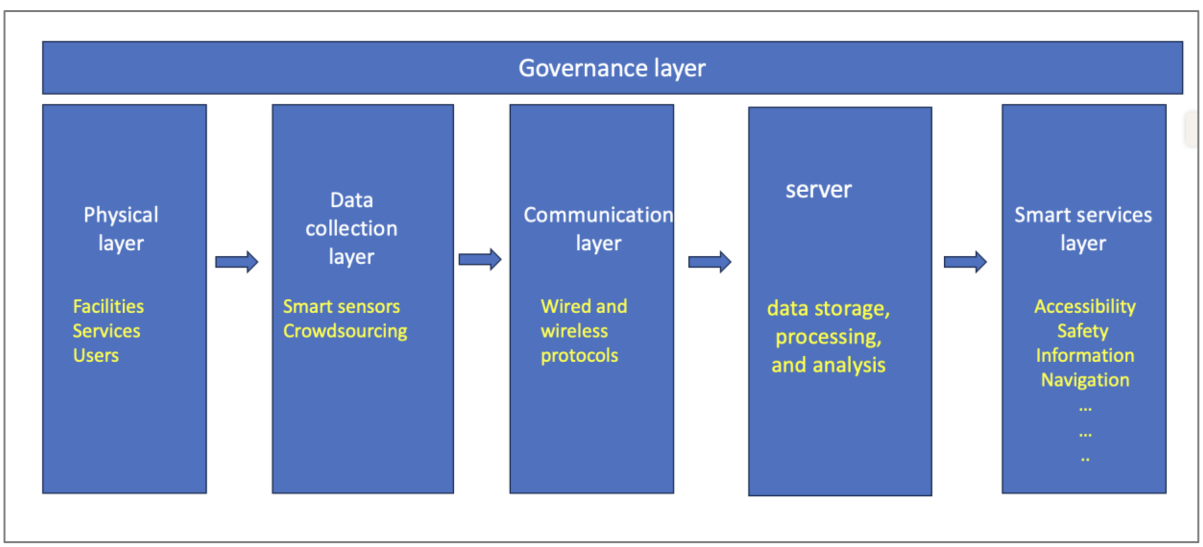

Figure 0-10 The smart public space layers.

3.5 Conclusion

This chapter examined the improvement of implementing the UN Target 11.7 concerning inclusive urban public spaces. It contributes to this goal by elaborating the concept of the inclusive public space. The significance of this concept lies in recognizing the crucial role that public spaces play in community building, physical and mental well-being, social interaction, civic engagement, citizen participation, and economic vitality. However, the 2023 UN Sustainable Development Goals Report and scholars have raised concerns about the limited access to public spaces, particularly for low-income individuals, women, children, and people with disabilities.

Considering the significance of the inclusive public space, this chapter proposed a comprehensive framework for assessing this inclusivity. The framework employs eight indicators: spatial distribution, typology, facilities, green areas, governance, safety, user categories, and user satisfaction. These indicators were employed to evaluate the inclusivity of the public space in Nablus, a major Palestinian city. The assessment validated the observations made by the UN and scholars, highlighting the low inclusivity of the public space in Nablus, particularly due to inadequate availability and poor spatial distribution. Additionally, the assessment revealed significant citizens' dissatisfaction with safety conditions and services. It underscores the significance of involving citizens in the governance of the public spaces as they are the primary stakeholders who can provide valuable data and insights to enhance the quality and performance of these spaces.

Enhancing the inclusivity of the public space necessitates a comprehensive approach that engages citizens in their governance and leverages the latest technology, particularly smart technology. By employing such technology, real-time information and services can be provided to citizens, enabling the monitoring of the public space, improving facility efficiency, and creating an eco-friendly environment that preserves resources and biodiversity. The chapter outlines how the smart public space contributes to achieving this inclusivity and proposes an architectural framework for its implementation.

This chapter suffered from some limitations. The main limitation concerned data collection because authorities were not able to provide basic data about the public space' policy strategy, planning, facilities and functioning. Field visits and Interviews were then used to collect data. In the future data could be collected more frequently and by involving more people through mobile applications and smart monitoring. The interviews focused on the citizens' perception of the public space facilities, safety and governance. In the future, interviews should be extended to the use of digital to tools to understand citizens' expectations and fears about these tools, which will help in the development of smart tools for the public space.

Chapter 4: Use of Participatory Science and Artificial Intelligence for the Creation of a User-Centric Smart Campus

4.1 Introduction

This chapter presents the development and implementation of a user-centric smart campus. The latter aims to involve campus users, including students, faculty members, and technical and administrative staff, in the smart transformation of the campus. It completes the technical approach that focuses on using the Internet of Things (IoT), artificial intelligence (AI), and big data analytics to construct smart systems (Radu, 2020; Rieder et al., 2023; Shahrour & Xie, 2021; Wang et al., 2021).

Integrating human sensing through crowdsourcing into smart urban systems emerged as a groundbreaking approach. It leverages urban dwellers' collective intelligence and experiential knowledge, offering a rich real-time data source and insights that traditional sensor-based systems may overlook (Corbari et al., 2022; Pallavi et al., 2021). By tapping into the lived experiences of individuals, smart urban systems help a deeper understanding of urban dynamics, from traffic patterns (Aburas et al., 2024) to public space utilization (Itair et al., 2023), thereby enhancing the adaptability and resilience of cities to meet population needs. Scholars highlighted the emergent discourse on participatory approaches and human-centric methodologies in urban design and management (Cardamone & Lobel, 2016; Pocock et al., 2019; J. Roche et al., 2020; Sagers, 2020). They underscore the value of engaging users in data collection and decision-making, enhancing the adaptability and relevance of smart urban solutions (Paul et al., 2020b; Rymarzak et al., 2020; Sanabria-Z et al., 2022).

The concept of a smart campus presents challenges and opportunities to encompass the complexities of higher education environment (Omotayo et al., 2021). This concept has gained considerable attention (Ahmed et al., 2023). The Internet of Things (IoT) has been the cornerstone of enhancing the efficiency and sustainability of campus facilities (Nachandiya et al., 2018; Valks, Arkesteijn, Koutamanis, & Den Heijer, 2021; Valks, Arkesteijn, Koutamanis, & den Heijer, 2021).

The literature on smart campuses covers a range of subtopics, such as energy management, security systems, infrastructure optimization, and data analytics (Ali et al., 2020; Eltamaly et al., 2021; Jabbar et al., 2021).

Acknowledging the human element as a fundamental aspect of the smart campus was widely recognized (Min-Allah & Alrashed, 2020; Polin et al., 2023; Prandi et al., 2020). Many studies have underscored the importance of considering the experiences, preferences, and contributions of individuals who inhabit and interact with the campus environment (Alrashed, 2020; Yip et al., 2022). However, amidst the rapid proliferation of technology-driven initiatives, a significant disparity and inadvertent sidelining of the human element has emerged. While the discourse on smart campuses may reference the human component, the focus has been on the technological facets of smart campus development (Fortes et al., 2019; Villegas-Ch et al., 2019). It is worth recognizing that while sensors provide essential data, they fall short in capturing the interactions between users and their environment (Tuzcuoğlu et al., 2022). This oversight underscores a gap in the smart campus narrative, a gap in the application and incorporation of user-driven contributions into the operational fabric of smart campuses. Moreover, the user-centric approach constitutes an excellent alternative in areas facing difficulties or restrictions in implementing smart sensors. This approach enables capturing personal aspects of the user experience and enhances users' engagement in building the smart campus.

This chapter addresses this gap in the development of smart campuses by integrating a user-centric framework with advanced technologies such as AI, BIM, and web services. Unlike existing studies focusing on technological solutions like IoT and big data analytics, this research emphasizes the importance of incorporating user feedback and participatory approaches to enhance campus services and infrastructure. Previous studies have demonstrated the effectiveness of sensor-based systems in data collection but often overlook the qualitative aspects of user experiences and interactions. The high potential of this framework will be illustrated through its application to the campus of the Faculty of Engineering at An-Najah National University. This application will investigate the transformational potential of users' involvement in developing smart campus services. In addition, the chapter introduces the use of artificial intelligence to generate data to prove the proposed framework.

The chapter is structured as follows: It presents the research methodology and the framework of the human-centered smart campus. Then, it describes the case study, including a description of the campus of the Faculty of Engineering at An-Najah National University, the construction of the digital model of the faculty environment, the construction of the participatory platform, and the analysis of the performances of the proposed framework using the AI-generated data. Finally, the last sections present a discussion of the results of applying the framework on the AI-generated data and the major outcomes and recommendations of this research.

4.2 Methodology

Incorporating user feedback and participation is crucial for the successful development and operation of smart campuses. This approach ensures that the services and infrastructure are aligned with campus users' actual needs and experiences. Specific mechanisms for collecting user feedback include online participatory platforms, surveys, and interactive mobile applications that allow users to report issues and suggest improvements. Establishing clear communication channels between users and campus administrators is essential for ensuring that feedback is heard and acted upon. Implementing iterative processes, where user feedback is continuously collected, analyzed, and used to make informed decisions, will help in the continuous improvement of campus services. This approach not only enhances user satisfaction but also promotes a more responsive and adaptable campus environment.

The research methodology is based on the analysis of papers dealing with (i) the construction of a framework for the smart systems (Aljer et al., 2024; Corbari et al., 2022; Pallavi et al., 2021; Radu, 2020; Rieder et al., 2023; Shahrour & Xie, 2021; Wang et al., 2021), (ii) the participatory science (Aburas et al., 2024; Cardamone & Lobel, 2016; Itair et al., 2024; Paul et al., 2020b; Pocock et al., 2019; J. Roche et al., 2020; Rymarzak et al., 2020; Sagers, 2020; Sanabria-Z et al., 2022), and (iii) the research of the smart campus (Ahmed et al., 2023; Ali et al., 2020; Eltamaly et al., 2021; Jabbar et al., 2021; Nachandiya et al., 2018; Valks, Arkesteijn, Koutamanis, & Den Heijer, 2021; Valks, Arkesteijn, Koutamanis, & den Heijer, 2021). These studies show that creating a user-centered smart campus starts with a definition of the project goal and a comprehensive identification of the components of the campus, including the built environment, the expected services, and the campus stakeholders, including their roles and expectations. This phase identifies the data to be collected and the sources of these data, particularly from the campus users. The methodology also includes establishing protocols and tools for data collection. Finally, the methodology discusses how the collected data will be analyzed and transformed into services.

The subsequent paragraphs describe the components of the phases of the methodology followed by the construction of the smart campus framework.

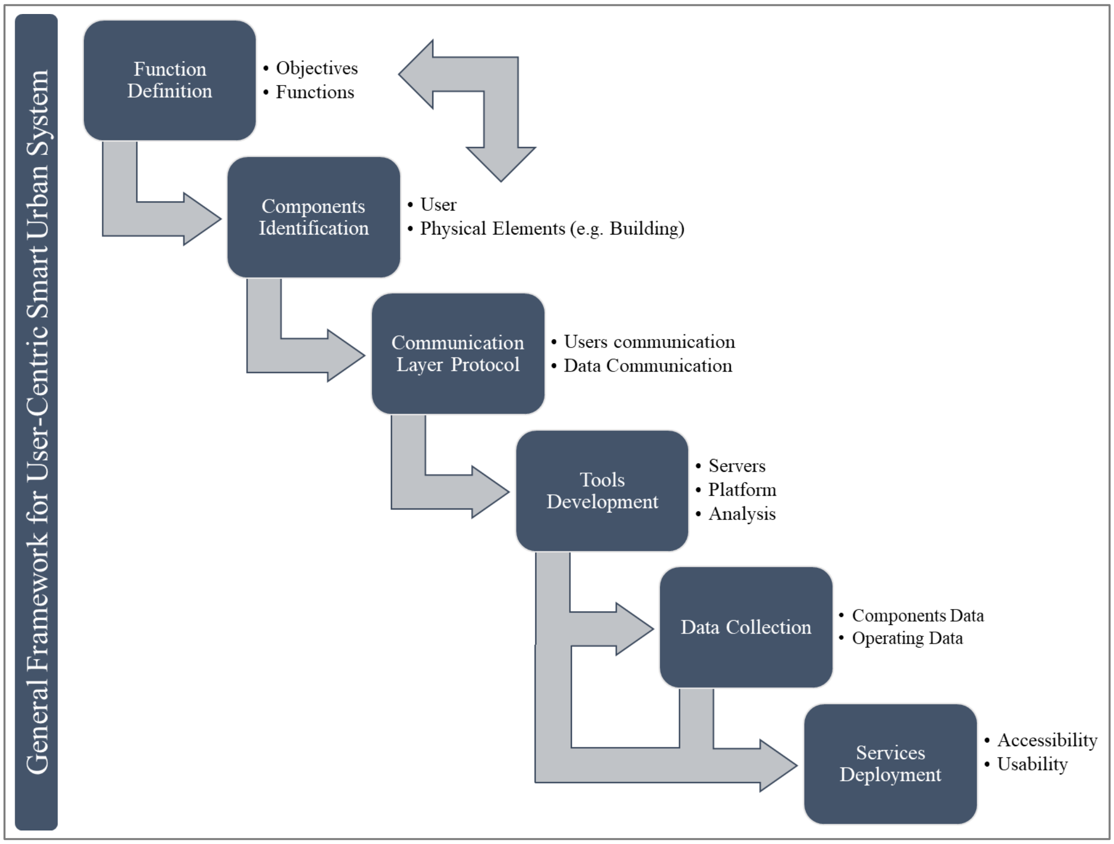

Figure 0-1 Framework for the user-centric smart urban system.

- **Phase 1: Function Definition**

The initial phase involves establishing the smart urban system's objectives and desired outcomes. In this phase, we determine the specific functions the system is expected to perform, which could range from traffic management on the city scale to energy conservation on the building scale. This involves a detailed analysis of the urban context, its current challenges, and the opportunities for technological intervention. We align these functions with user needs and system sustainability to ensure the system is practical and forward-thinking.

- **Phase 2: Components Identification**

After defining the system's functions, it proceeds to the components identification phase to identify the essential components to perform the defined functions. This includes physical elements such as roads, buildings, or hardware. We also consider human components, such as stakeholders and end-users, whose needs and interactions with the system are critical for its success.

- **Phase 3: Communication Layer Protocol**

In the Communication Layer Protocol phase, we establish the necessary protocols for interaction between the identified components. This is crucial for ensuring the system operates seamlessly and data flows efficiently between different parts. Protocols must ensure interoperability, scalability, and security, thereby facilitating the robust performance of the smart urban system.

- **Phase 4: Tools Development**

Tools Development is the phase where we create or adapt the tools needed for the smart system. These tools handle data analysis, user engagement, and system management tasks. The previously identified functions and components inform the development of these tools, and they are built to interface effectively with the established communication protocols.

- **Phase 5: Data Collection**

Data Collection is an ongoing phase that commences alongside tool development. This phase gathers data from various sources, including sensors, user input, and existing databases. The collected data is quantitative and qualitative, encompassing various indicators relevant to the system's functions. Effective data collection is pivotal for understanding the urban environment's real-time status and making informed decisions.

- **Phase 6: Services Deployment**

The final phase, Services Deployment, is where the system goes live. Services conceptualized in the Function Definition phase are deployed using the tools and protocols developed. Deployment is not the end but the beginning of a continuous improvement process where services evolve based on user interaction and data insights.

Each of these phases is interconnected. While presented linearly, they often occur in iterative cycles that allow for continuous refinement and adaptation. The methodology is designed to be flexible and adaptable for the case study and any urban environment seeking to implement a smart urban system with a strong user-centric focus.

4.3 Application to University Campus

This section presents the implementation of the proposed user-centric framework at An-Najah University's Faculty of Engineering. It shows how the proposed framework can be implemented and discusses its limitations and future improvements. It also illustrates how the AI-based approach could generate data for the proposed framework's proof of concept.

4.3.1 Overview

An-Najah National University, situated in Nablus City, Palestine, is the city's preeminent institution of higher education and the largest in the country. The university is located on the city's western side, occupying a prominent position at one of the main entrances to Nablus. The engineering faculty at the university holds the distinction of being the largest in Palestine, both in terms of physical area and academic community. The faculty represents a crowded educational environment with more than 5,000 users and an area of about 4,000 square meters (ANU-FEIT, 2023).

The general structure of the work is based on creating a digital environment that enables users to access friendly campus services. This structure entails digitizing the campus environment, including modeling buildings, defining users, and designing the communication channel between them. **Figure 4-2** presents the framework architecture based on that presented in the methodology section.

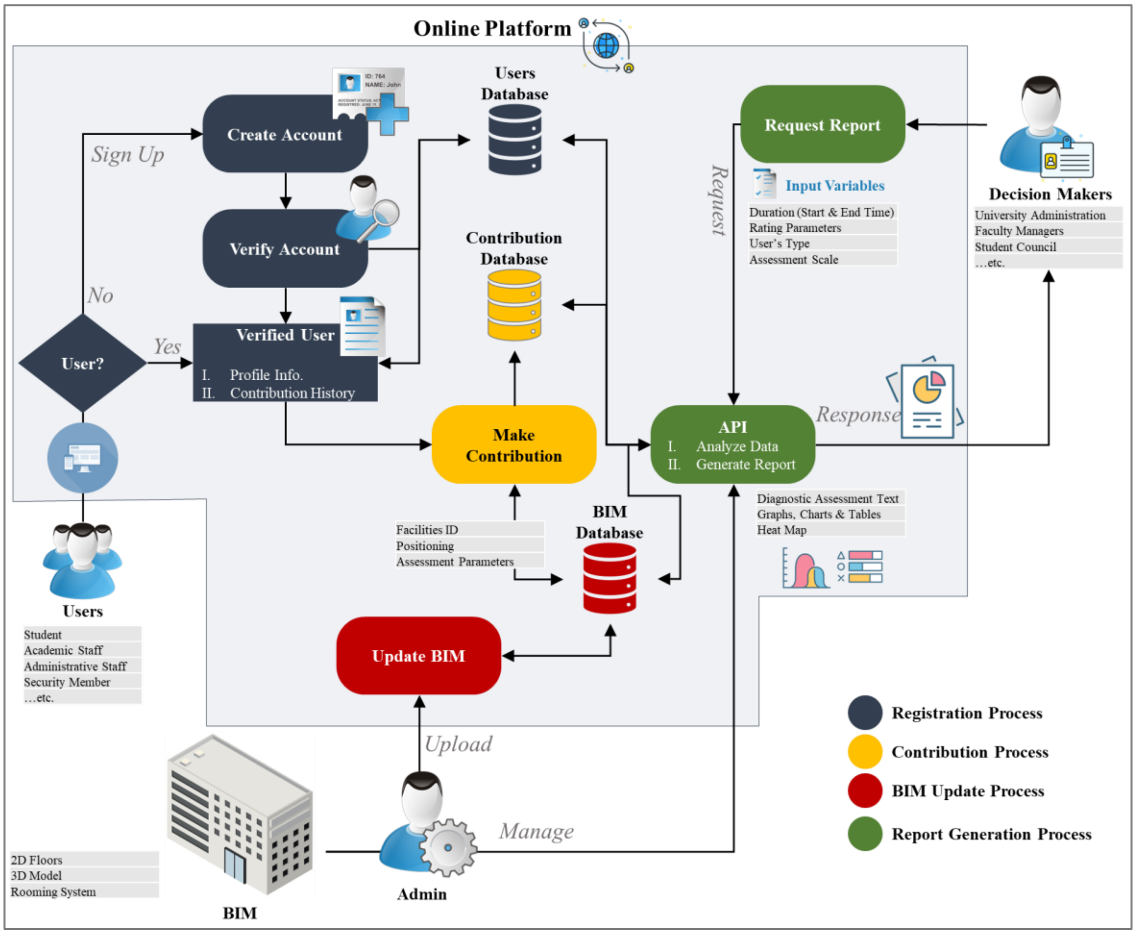

Figure 0-2 System architecture of the user-centric framework applied to the case study.

It uses an online platform as the primary interface for users' interaction and data exchange. This platform is conceptualized as the digital environment that encapsulates the diverse processes of the proposed framework, symbolized by the encompassing boundary observed in the system architecture visualization. The platform's intuitive and user-friendly design allows seamless navigation and engagement for users of varying technical proficiencies. It is the bridge between the user's data and the framework's analytical capabilities, facilitating data entry and retrieval of processed information. The following points describe the key main functionalities, features, and mechanisms on the platform:

I. User Registration

User registration is the starting point for interacting with the platform. Students, academic staff, administrative personnel, and security members engage with the system via a sign-up process. Upon creating an account, the user's identity is authenticated, ensuring the system's input is secured and validated. Verified users can then contribute to the system by providing feedback or data regarding their interaction with the campus environment.

II. Contribution Mechanism

The contribution mechanism within our framework is a streamlined process that enables users to inform campus facility assessments directly. Initiated through a user-friendly interface on the online platform, users select relevant identifiers for the floor and room, engage with an interactive blueprint for accuracy, and fill out a series of structured assessment parameters. They are also prompted to offer qualitative feedback, providing a rich narrative to accompany quantitative data. This input is subsequently submitted and integrated into the system's databases, ensuring that each user's experience contributes to the evolving digital representation of the campus. This mechanism captures the dynamic interplay between users and their environment, fostering a continuously adaptive smart campus model.

III. Data Integration and Management

User-generated data is stored in two central repositories: the Users and Contribution databases. The Users Database maintains essential profile information and a history of the user's contributions, whereas the Contribution Database archives the specific input related to the campus facilities and environment.

IV. Building Information Modeling (BIM) Database

Concurrently, the system utilizes a BIM Database that contains detailed information about campus facilities, including identification numbers, spatial positioning, and various assessment parameters. This database is continuously updated to reflect any changes or modifications within the campus infrastructure, ensuring an up-to-date digital model of the physical campus.

V. API Functionality

An API is an intermediary that analyzes the collated data and generates comprehensive reports. These reports are synthesized by analyzing user-contributed data and BIM data, producing diagnostic assessments in text, graphs, charts, tables, and heat maps. This allows for a multidimensional view of the user-environment interactions, contributing valuable insights into the daily operations and user experiences on campus.

VI. System Interaction, Reporting, and Output

The system architecture facilitates interaction with various stakeholders, such as university administration and faculty managers. The system can initiate report requests; input variables such as duration, rating parameters, and assessment scales are specified. The generated reports are dispatched to the respective stakeholders, providing actionable insights that can influence policymaking and campus management strategies.

4.3.2 Facilities Mapping and Parameters Assessment

The research included creating a BIM detailing the faculty's existing facilities; thirteen assessment parameters, ranging from cleanliness to safety, were identified to quantify user experiences precisely. Facilities were divided according to their use into five categories. The subsequent graphs describe the distribution of these parameters among the facilities (**Figure 4-3**).

Assessment Parameter	**Facilites' Category**				
	Academic Use	Toilets	Open Area	Emergency	Vertical Circulation
Cleanliness	✓	✓	✓	✓	✓
Seating & Workspace Adequacy	✓		✓		
Audiovisual Equipment	✓				
Temperature	✓	✓	✓	✓	✓
Ventilation	✓	✓	✓	✓	✓
Lighting	✓	✓	✓	✓	✓
Acoustics & Noise Levels	✓		✓	✓	✓
Accessibility	✓	✓	✓	✓	✓
Disabled Accessibility	✓	✓	✓	✓	✓
Power Outlets Availability	✓		✓		
Hygiene Stuff		✓			
Plumbing Functionality		✓			
Safety	✓	✓	✓	✓	✓

Figure 0-3 The distribution of the assessment parameters among the facilities' categories.

We followed the object-based modeling and rooming system approaches (Abreu et al., 2023; Beck et al., 2021; Raza et al., 2023) to digitize the faculty environment and build the BIM. Utilizing Autodesk Revit, we accurately digitized the faculty's environment into a comprehensive BIM model. The building has 7 floors distributed over 3 basic blocks on a lot area of 4,000 m^2 and a floor area of around 20,000 m^2. As shown in **Figure 4-4**, this model stands for digital documentation of the physical layout and is an essential asset for future enhancements, including integrating smart services.

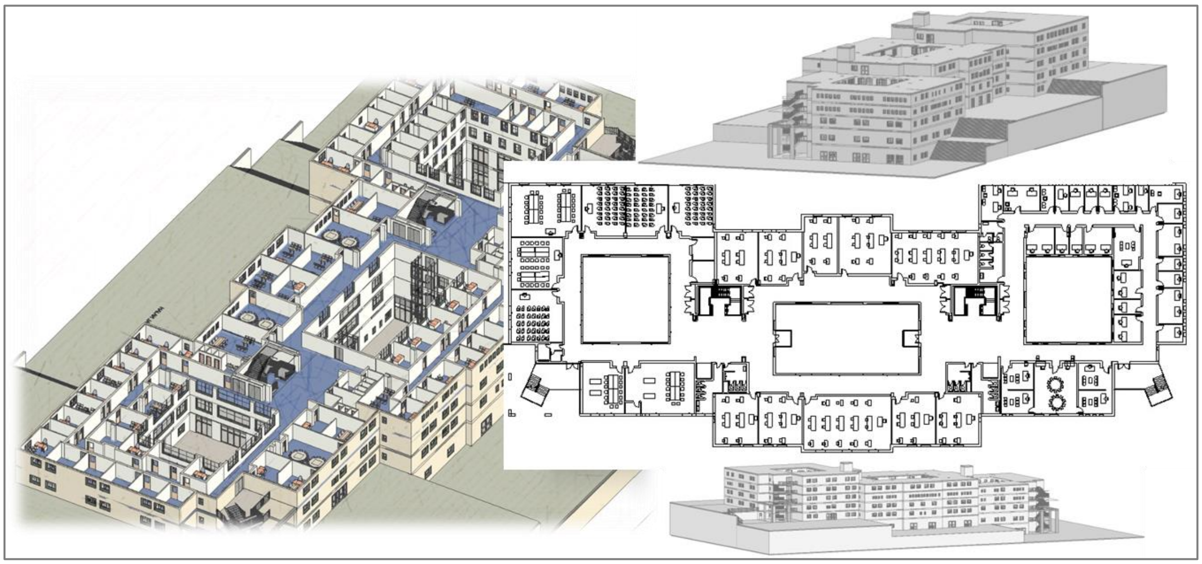

Figure 0-4 Faculty digitalization – Creating the BIM.

The digitization process involved assigning identifiers to facilities using the university's rooming system. The approach followed in this step is crucial to raise the maturity of the BIM to move from a Digital Model to a Digital Twin (Bosch et al., 2015; Deng et al., 2021; Hijazi et al., 2020; Mansour et al., 2024). The BIM model includes 214 objects corresponding to a facility, a classroom, a corridor, an office, etc. (**Figure 4-5**).

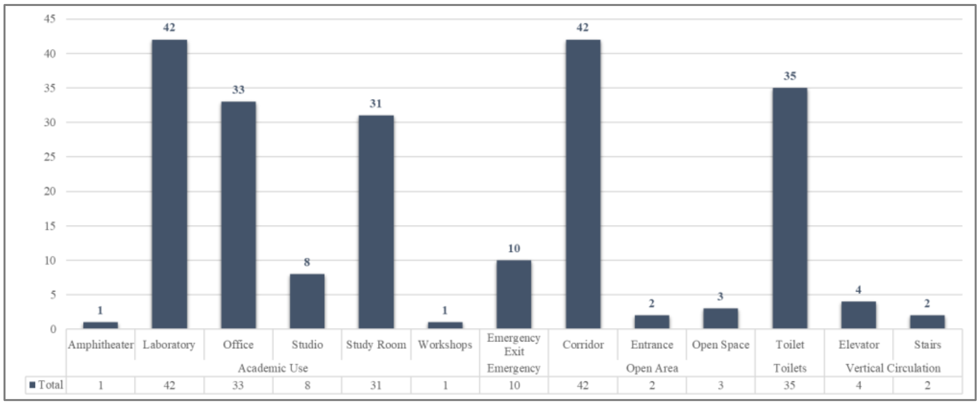

Figure 0-5 The distribution of facilities based on category and function.

4.3.3 Online Participatory Platform

The online participatory platform was created as a gateway for users' contributions and evaluations. It offers a welcome page that outlines the initiative and the project's aims, enhancing user engagement through clear language and a welcoming layout. Users are guided through a structured process to submit their assessments. This process is facilitated by an intuitive interface that prompts users to select specific locations via drop-down lists and provide ratings for the predetermined assessment parameters. Additionally, the platform features an interactive aid where users can view floor blueprints to identify and assess facilities precisely, ensuring accuracy in their contributions. Each parameter provides a rating system and a comment section for users to elaborate on their experience or clarify their ratings, allowing for detailed qualitative feedback.

Moreover, the platform offers a formal and streamlined service for decision-makers. It includes a function to request reports automatically generated based on user input within a chosen timeframe. The automated report generation function compiles user ratings and comments into a cohesive report and harnesses real-time and historical data, presenting decision-makers with insights into facility performance across various parameters such as cleanliness, space adequacy, and equipment functionality. The algorithmic synthesis of quantitative ratings enables a multidimensional understanding of user experiences, thereby informing strategic improvements and optimization of campus facilities and services. This functionality epitomizes the framework's commitment to a user-centric approach, ensuring that the assessments reflect the campus community's experiences and needs and translating these assessments and feedback into actionable intelligence for campus administration.

4.3.3 AI-Generated Data for the Framework's Proof of Concept

The AI was used to generate data to prove the concept of the proposed system. It is based on research about using AI, like ChatGPT (Lingo, 2023), to generate synthetic data to validate concepts (Hittmeir et al., 2019; Korakakis et al., 2018; Lu et al., 2023; Reiner Benaim et al., 2020). **Figure 4-6** illustrates the approach used in this research.

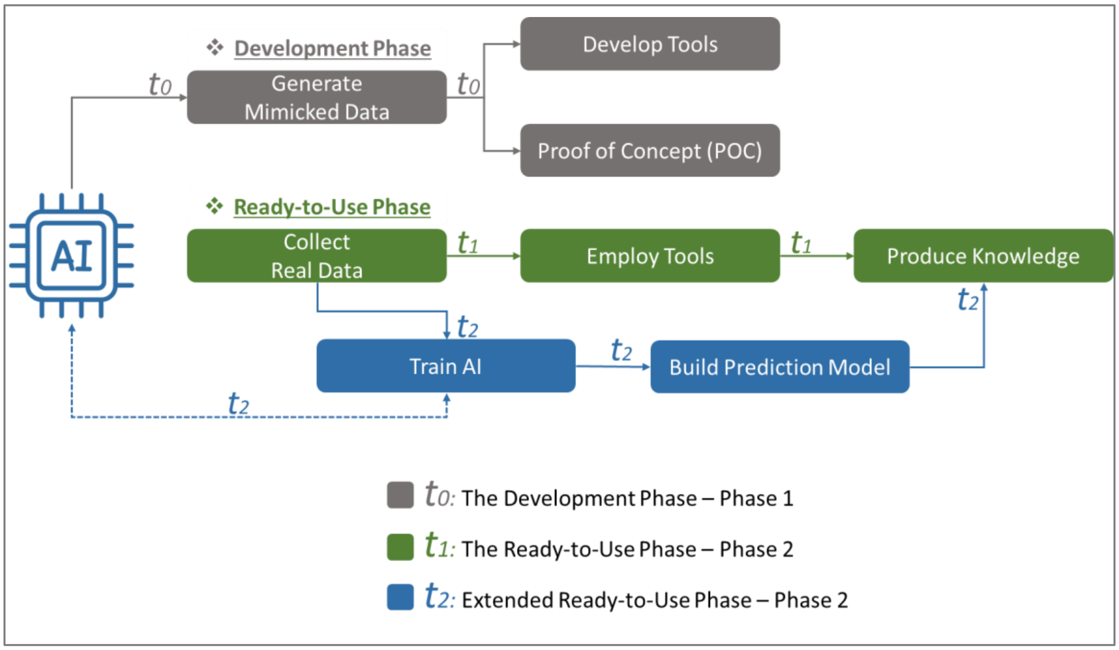

Figure 0-6 AI-Based approach for building a user-centric framework.

Generating mimicked data involves creating artificial datasets replicating real data characteristics for various purposes, such as compromising privacy (Braddon et al., 2023) and accelerating research (D'Amico et al., 2023). Various methods, such as generative artificial intelligence and conditional generative adversarial networks, generate synthetic data in health sciences, economy, and software development (D'Amico et al., 2023; Koenecke & Varian, 2020, 2020). This research used AI to generate datasets representing the campus users and their assessment contributions. **Figure 4-7** shows the work process used to generate the mimicked data. The process includes four steps.

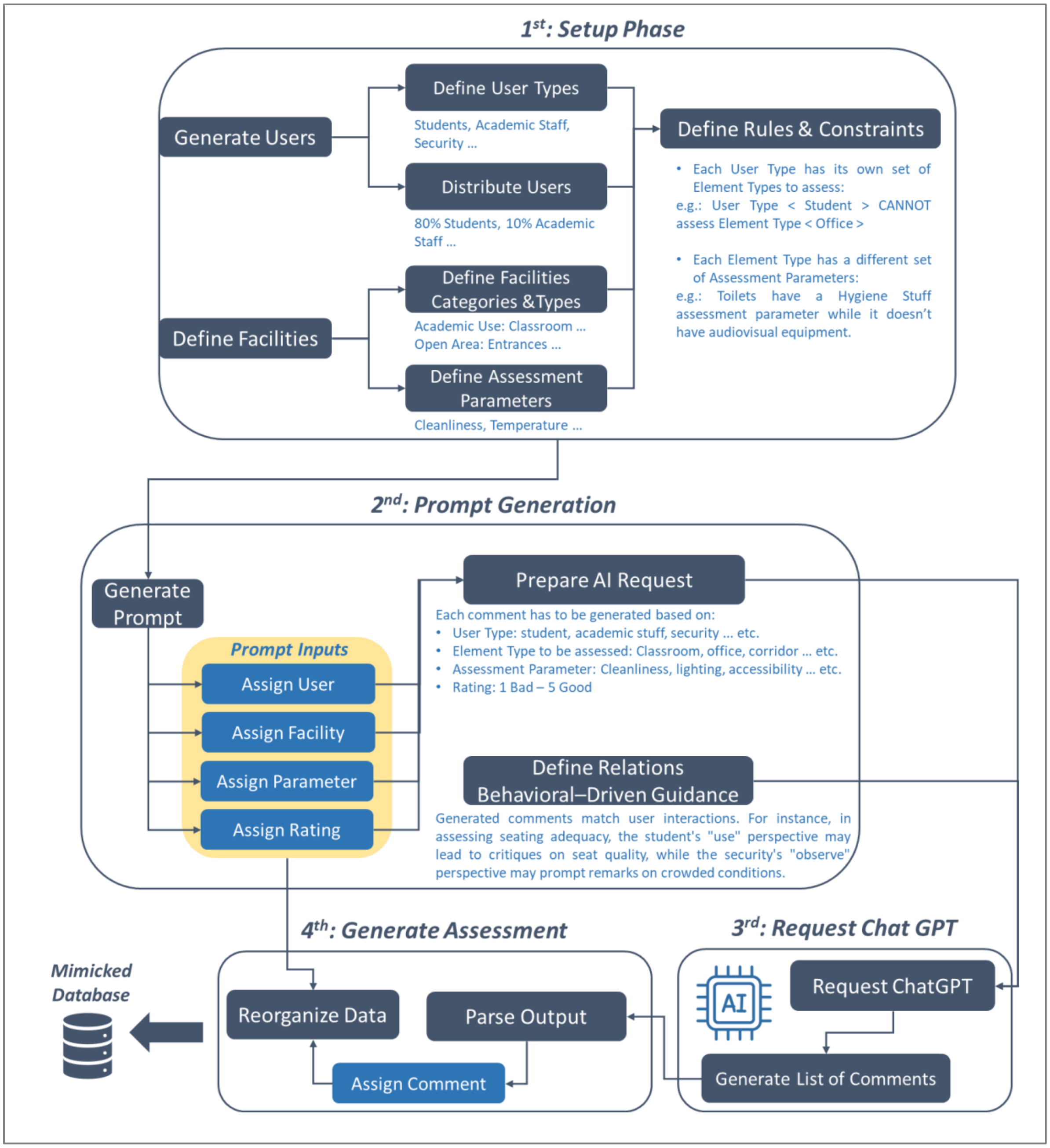

Figure 0-7 AI-Driven process for generating mimicked user assessments in a campus environment.

The first step, 'Setup Phase,' defines user types such as students, academic staff, and security. It then distributes these users according to predefined ratios (e.g., 80% students and 10% academic staff). This step also includes defining facilities with specified types (e.g., academic use, open areas) and setting up assessment parameters (like cleanliness temperature) that reflect the data points to be collected. Rules and constraints are established to ensure the validity of the generated data. For example, user types have associated element types they can assess—students may not evaluate faculty offices, and each element type may have unique assessment parameters.

The second step, 'Prompt Generation', takes inputs from the setup step to generate prompts. It involves assigning a user, facility, and parameter and then a rating to simulate the assessment process. The AI request preparation involves tailoring comments based on user type, facility type, and assessment parameters. Behavioral-driven guidance is also introduced, ensuring the generated comments are congruent with expected user interactions. For example, when evaluating seating adequacy in a studio, the comment will differ based on the perspective: the student's interaction is described as "use," while the security's interaction is described as "observe." Hence, the student might comment on the poor quality of the seats, while the security personnel might remark on the crowded conditions. The third step, 'Request ChatGPT' utilizes ChatGPT to process the prompts and generate a list of comments that mimic real user feedback. Figure 10 shows some code snippets used in the 3rd step. The fourth step, 'Generate Assessment', involves reorganizing the data obtained from the AI, parsing the outputs, and assigning comments to create the mimicked dataset.

While this research critiques the over-reliance on technology in smart campus initiatives, it employs AI and technology to enhance, rather than replace, user participation. The AI-generated data is a preliminary step to validate the framework, ensuring its robustness before full-scale implementation with real user input. In addition, the rules, constraints, and guidelines used in employing AI in this study are based on real users' contributions. This approach leverages technology to facilitate and improve the integration of user feedback, ultimately bridging the gap between technological advancements and the human element in smart campus development. By doing so, the framework ensures that user contributions remain central to the smart transformation process.

4 Results and Discussion

4.4.1 Overview of the AI- Generated Data

The generated dataset included 325 participants who conducted 1,000 assessments of the campus facilities. **Table 4-1** shows the distribution of participants and assessments over the user type: students, comprising 80.3% of the simulated population, conducted 82.1%, averaging 3.1

assessments each. Academic members and staff, though fewer, participated actively, simulating close to real-world engagement within a university setting.

Table 0-1 The Distribution of Participants and Assessment Over User Type.

User Type	Number of Participants	Percentage of Participants	Number of Assessments	Percentage of Assessments	Assessment Frequency
Student	261	80.3%	821	82.1%	3.1
Academic Member	37	11.4%	108	10.8%	2.9
Administrative Staff	15	4.6%	36	3.6%	2.4
Security Member	12	3.7%	35	3.5%	2.9
Total	**325**	**100.0%**	**1000**	**100.0%**	**3.1**

Table 4-2 shows that the assessments were distributed across various floors and facility categories, with the ground floor (GF), first floor (F1), and third floor (F3) receiving the highest level of interaction represented by 32.7%, 22.5%, and 17.2% of all the assessments, respectively, especially in academic use areas, open areas, and toilet, that comprise 49.5%, 28.6%, and 15.9% of all the assessments. This highlights the central role of these spaces in the simulated user experience and the system's responsiveness to high-traffic areas.

Table 0-2 Assessments Distribution Over Floor & Facilities' Category.

Floor ID / Facilities' Category	Academic Use	Open Area	Toilets	Emergency	Vertical Circulation	% By Floor
B2	1.6%	0.5%	0.5%	0.3%		**2.9%**
B1	6.2%	2.4%	1.5%	0.3%		**10.4%**
GF	18.0%	10.3%	3.1%	1.3%		**32.7%**
F1	12.3%	5.8%	3.5%	0.9%		**22.5%**

F2	0.2%	4.4%	3.4%	0.5%		**8.5%**
F3	9.3%	4.1%	3.0%	0.8%		**17.2%**
F4	1.9%	1.1%	0.9%	0.2%		**4.1%**
Vertical Circulation					1.7%	**1.7%**
% By Facilities' Category	**49.5%**	**28.6%**	**15.9%**	**4.3%**	**1.7%**	**100.0%**

The following sections will focus on the most assessed categories (academic use, public spaces, and toilets) and the three most assessed floors (ground, first, and third).

4.4.2 Users' Satisfaction

The results indicate a variation in the average satisfaction across the various assessment parameters. Parameters such as power outlet availability, seating and workspace adequacy, ventilation, and cleanliness received low scores. Indeed, scoring below the threshold of 3 is considered critical.

Figure 4-8 shows the assessment of the academic areas, including temperature and ventilation. Similarly, power outlet availability and seating adequacy received low scores, indicating a need to enhance this area. In open areas, power outlet availability and seating adequacy appear to be pressing issues in addition to noise level and cleanliness, with scores ranging between 2.54 and 2.95. Toilet facilities reveal several shortcomings, from hygiene provisions to ventilation, cleanliness, lighting, temperature, and plumbing functionality.

The shaded area beneath the bars in Figure 8 corresponds to the frequency of assessments per parameter. It reveals an increase in assessment for lower satisfaction ratings. This pattern demonstrates a common human behavior: being more claimant about critical issues than satisfactory ones (Mr & Gyasi, 2012).

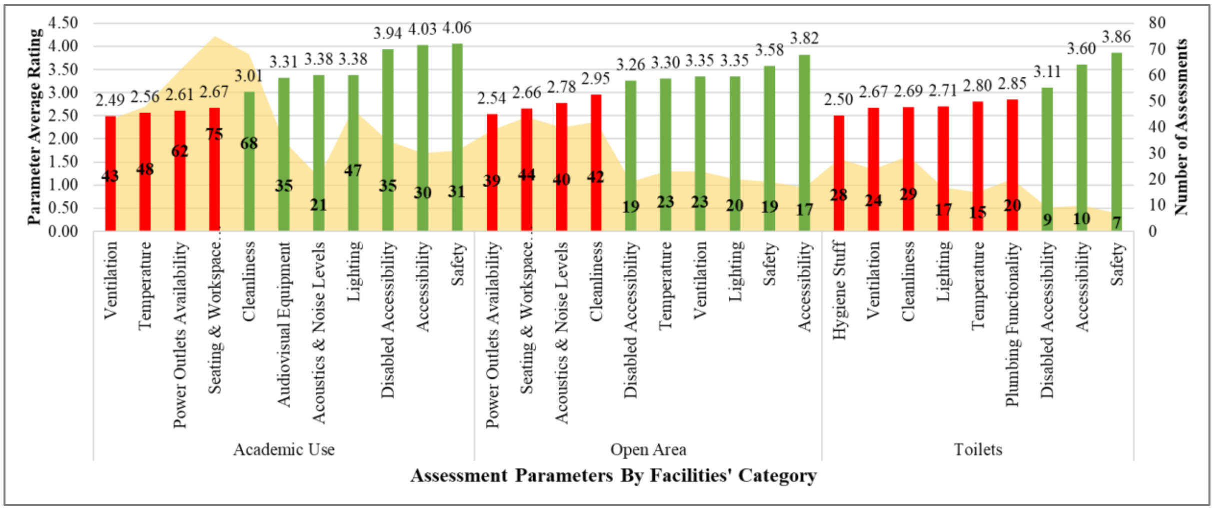

Figure 0-8 The Parameters Average Rating and Assessments Count by Facilities' Category.

Figure 4-9 presents the heat map of the spatial distribution of the parameters on most assessed floors and categories. It enables a better understanding of the assessment. For instance, the academic areas show a non-critical status for cleanliness in the initial assessment. However, the heatmap reveals that cleanliness on the ground and first floors is a critical issue that requires attention. Conversely, the public areas, previously highlighted as problematic regarding cleanliness, show this concern mainly on the third floor. The heatmap draws particular attention to the toilets' service quality across various floors, with a notable clustering of critical evaluations on the first floor. This assessment pattern suggests that while toilets on other levels meet acceptable standards, those on the first floor suffer from deficiencies that could stem from higher usage intensity or insufficient intervention.

Academic Use	**GF**	**F1**	**F3**
Ventilation	2.55	2.58	2.20
Temperature	2.44	2.47	3.14
Seating & Workspace Adequacy	2.63	2.28	2.93
Power Outlets Availability	2.67	2.71	2.75
Cleanliness	2.79	2.82	3.64
Audiovisual Equipment	3.55	2.80	3.83
Acoustics & Noise Levels	2.63	4.00	4.17
Lighting	4.14	3.00	3.25
Disabled Accessibility	3.67	3.67	4.50
Accessibility	4.22	3.43	4.50
Safety	3.90	4.13	4.00
Open Area	**GF**	**F1**	**F3**
Power Outlets Availability	2.75	2.30	2.75
Seating & Workspace Adequacy	2.68	3.00	2.50
Acoustics & Noise Levels	2.92	2.75	2.83
Cleanliness	3.29	3.00	2.00
Temperature	2.90	3.50	3.00
Lighting	2.63	3.67	3.60
Disabled Accessibility	2.75	4.00	4.00
Safety	3.25	3.50	3.33
Ventilation	4.00	3.43	3.50
Accessibility	4.50	3.75	3.50
Toilets	**GF**	**F1**	**F3**
Ventilation	2.00	2.67	2.25
Hygiene Stuff	3.00	2.83	1.83
Cleanliness	2.56	2.67	3.50
Temperature	2.60	2.67	3.00
Lighting		2.60	3.00
Plumbing Functionality	3.67	2.40	3.00
Disabled Accessibility	3.00	3.00	3.50
Accessibility		3.00	4.00
Safety	4.00		4.00

Figure 0-9 Spatial Perspective of Assessment Parameters Across Floors.

Figure 4-10 shows the temporal variation of the assessment parameters. For instance, on the third floor, the absence of critical evaluations on Wednesday contrasts with the other days of the week. This could be attributed to the nature of the use of academic facilities on that floor on Wednesday, which is characterized by a short period of use and a small number of students, unlike other days, such as Sunday and Tuesday. These days, the high concentration of activities might strain the facilities, necessitating more frequent maintenance to sustain service quality.

Moreover, temporal analysis reveals systemic issues. For example, a consistent pattern of high ratings during mid-week could indicate effective service recovery following intense usage at the week's start. Alternatively, consistently poor ratings towards the week's end may signify accumulating strain on facilities that aren't adequately addressed in real-time.

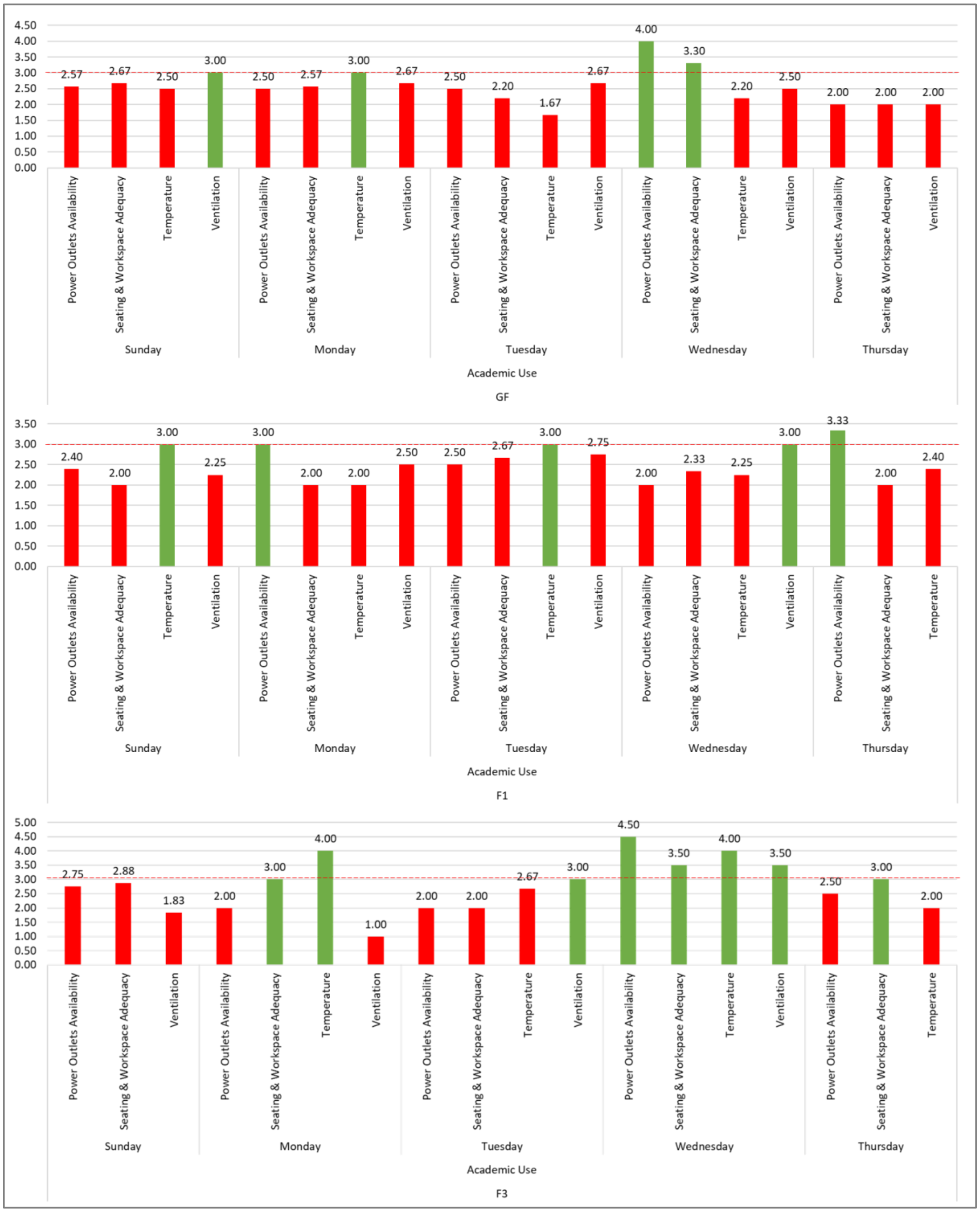

Figure 0-10 Temporal distribution of the academic areas' assessment parameters by day.

Figure 4-11 displays the assessment distribution during the day. It shows that feedback for academic facilities tends to be concentrated in the morning. Then, there's a noticeable drop during the university break time from noon to 1 PM, which coincides with the peak use of other facilities like toilets and open areas.

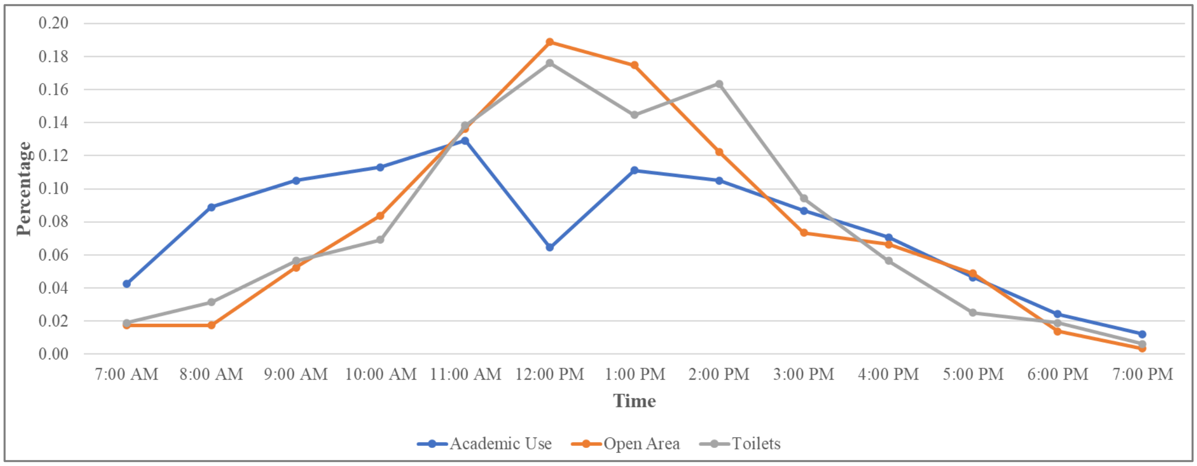

Figure 0-11 Temporal Distribution the Facilities Assessments During the Day.

4.5 Conclusion

This chapter presented a user-centric framework for developing an intelligent campus. This approach constitutes an adequate alternative in areas facing difficulties or restrictions in implementing smart sensors. In addition, it enables capturing personal aspects of the users' experience and enhances users' engagement in building a sustainable and smart campus.

AI-generated data illustrated the capacity of this framework. Analysis of these data allowed an excellent spatial and temporal survey of users' satisfaction. The results showed the spatial and temporal distribution of users' satisfaction and identified areas requiring urgent attention, such as cleanliness, seating adequacy, and toilet hygiene. These insights underscore the practical implications of user feedback in shaping campus services.

However, this research faced specific limitations that need to be addressed in the future. While AI-generated data helped validate the concept's significance implementation, it should be followed by a real use on the campus. Future research should focus on the actual implementation of this framework to learn more about the effectiveness of this approach and the social and technical barriers facing its deployment. It is also worth combining this approach with smart monitoring to complete the users' data by sensors' data and cross-data collected from both sensors and users.

Chapter 5: Leveraging Participatory Science for Tackling Water Supply Challenges in Water-Scarce Developing Regions

5.1 Introduction

This chapter presents the use of citizen science to address the challenges of the water supply in water-scarce developing regions. The significance of the chapter is twofold. First, it deals with water challenges in the scare-water regions, which are subjected to increasing pressure in securing water supply for the population because of climate change, rapid demographic growth, and lack of funding to build, extend, and modernize the water supply infrastructure. Second, it uses the innovative citizen science approach to involve the population in addressing the water challenges. Indeed, this approach is increasingly employed to support and improve the management of complex urban and environmental systems and to support decision-makers in addressing the challenges of these systems (Boretti & Rosa, 2019; Chari et al., 2017; Fraisl et al., 2022; Itair et al., 2023; Sauermann et al., 2020).

Water scarcity in developing countries poses significant threats to public health and environmental sustainability (Aboelnga et al., 2020; A. Biswas & Tortajada, 2018). In addition, the water supply system is complex and depends on physical, socioeconomic, environmental, and institutional factors (Enqvist & Ziervogel, 2019; Imad et al., 2019; Pallavi et al., 2021). The optimal management of this complex system requires a comprehensive approach that involves all the stakeholders including end-users (Behzadian & Kapelan, 2015; Yazdandoost & Yazdani, 2019).

Recent technological advances have resulted in the creation of effective water supply management methods, in particular, that use IoT and sensor-based systems (Adu-Manu et al., 2017; Agarwal et al., 2021; Wijayanti et al., 2020). However, these technologies are still expensive for developing countries and require advanced technical capacity for implementation (Chan et al., 2021). In addition, they fall short of capturing users' experiences and expectations and involving them in managing the water system (Jiménez et al., 2019). Therefore, it is essential to evolve these methods to integrate end-users as human sensors and as major water stakeholder to improve the management of the water supply system (Cosgrove & Loucks, 2015; Pallavi et al., 2021; Shahrour & Xie, 2021). End-users can provide continuous water-related spatial operating data, which is crucial for optimal water supply system management, particularly in poor-data regions. Scholars addressed the lack of urban data by using innovative solutions. (Freihardt, 2020) used social media for data collection. (Herschan et al., 2020) employed citizen science to overcome data limitations about the sanitation system. (Corbari et al., 2021) collaborated with farmers to monitor and manage the irrigation system.

The application of participatory science in the hydrological context is increasing thanks to technological advances that provide opportunities to engage citizens in more robust, open, and democratic decision-making processes. (Kelly-Quinn et al., 2022; McKinley et al., 2017; Nardi et al., 2021) created polycentric systems and a data-gathering framework that allowed knowledge generation, institutional capacity building, and policy support (Babiso et al., 2023; Buytaert et al., 2016; van Leeuwen et al., 2019). This engagement is more valuable in data-poor regions lacking participatory governance and technology deployment (Pandeya et al., 2021).

Based on the literature review, participatory science has yet to be used to address the water supply challenges in regions suffering from a deficit in the water supply. Indeed, in some regions, such as Jordan and the Palestinian territory, users can access the water supply for hours daily. This shortage is related to several factors, such as water scarcity, poor infrastructure, poor management, colossal water leaks, and illegal connections (Jabari et al., 2020). This shortage in the water supply results in social and economic tensions, particularly for low-income families. In addition, the water supply authority has limited access to data that could help to detect operating deficiencies, illegal connections, and the gap between scheduled operations and the real ones on the ground. Without a monitoring system that allows the water managers to follow the operating conditions and the quality of services, participation by end-users constitutes an efficient way to overcome this difficulty. This chapter proposes to fill this gap by developing an innovative system based on participatory science to involve the end-users in collecting data about the performance of the water supply system and in evaluating the performance of the water authority strategy. The chapter presents the development and implementation of this system and discusses the lessons learned from its implementations and limitations.

The chapter is organized as follows: First, it describes the research methodology and materials, including the study area, data collection, and data analysis. Then, it presents the case study, the participatory hub development, and a discussion of data collection and how these data help improve understanding of the water supply system operation. Finally, the chapter concludes by summarizing the main insights gained from the study, discussing its limitations, providing recommendations, and suggesting directions for future research.

5.2 Methodology and Materials

The methodology developed in this study is based on extensive literature about the role of citizen engagement and low-cost technologies in tackling urban water supply challenges. Brouwer et al. (Brouwer et al., 2018) and Buytaert et al. (Buytaert et al., 2016) have underscored the effectiveness of community participation in water management. Additionally, George et al. (George et al., 2021) and Cottam et al. (Cottam et al., 2021) provided valuable insights into the practical applications of low-cost technologies in this field. The methodology also integrates broader participatory science frameworks as discussed in recent contributions by Corbari et al. (Corbari et al., 2022), Itair et al. (Itair et al., 2024), Pejovic & Skarlatidou (Pejovic & Skarlatidou, 2020), and Pandeya et al. (Pandeya et al., 2021), which advocate for active community involvement in urban planning. Furthermore, the methodology incorporates strategies for synthesizing multi-source data to construct multidimensional systems (Aljer et al., 2024; Beck et al., 2021; Mansour et al., 2024; Zhang et al., 2023).

Figure 5-1 shows the research methodology, which leverages smart technology applications for smart cities and smart water systems, as discussed in works by Shahrour and Xie (Shahrour & Xie, 2021), Requier et al. (Requier et al., 2020), and Mashhadi et al. (Mashhadi et al., 2021). The methodology includes setting the goal and objectives of the water supply participatory project, gathering the necessary data, and employing data analysis to convert this data into services.

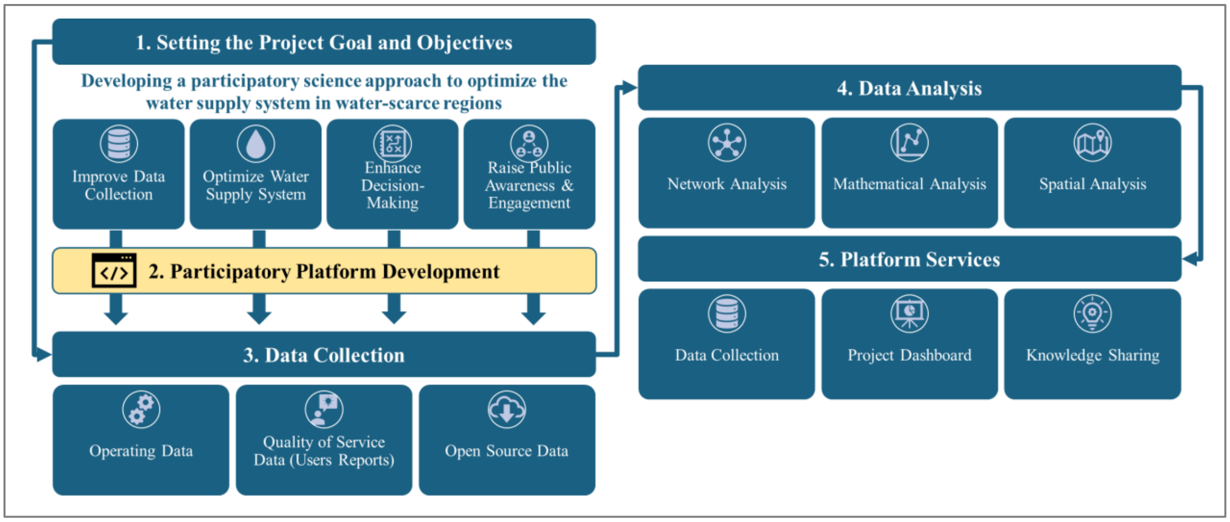

Figure 0-1 Research Methodology.

This research aims to develop a participatory science system to enhance the management and operation of the water supply system in water-scarce regions, focusing on the following objectives:

- Improve Data Collection: Engage end-users to collect ground-level data on water supply conditions, which, in turn, helps to address the data lack and capture users' experience.
- Optimize Water Supply System: Identify operational issues and deficiencies. Simultaneously, assess the service quality from the users' perspective to ensure their experiences and expectations are met.
- Enhance Decision-Making: Utilize the collected data to inform and improve the decision-making processes of the water supply local authority.
- Raise Public Awareness & Engagement: Increase the community's understanding of water supply issues and foster active participation in water management efforts.

5.2.1 Participatory Platform

Implementing the participatory approach requires creating a platform for collecting, analyzing, and transforming collected data into services for citizens, technical staff, and decision-makers. The primary objective is to ensure citizens' active participation and support the municipality in managing the water supply system. The platform design should be user-friendly and informative. It should include tools for the following services:

- Data Collection: This service integrates operational data and citizen-collected data. The water supply department shares operational data in a depositary space. Citizen-collected data is gathered through the platform's user-friendly interface, enabling residents to report on water supply service quality.

- Project Dashboard: This service offers information about the municipality's water supply system and insights from the data collection and analysis processes. This information is presented in a user-friendly way to help users understand the challenges in water supply distribution. Additionally, the dashboard features educational materials on water conservation, water management, and other relevant topics, aiming to raise public awareness and promote sustainable water management practices.

Results & Knowledge Sharing: The platform serves as a tool for sharing analysis results and disseminating knowledge. It provides regular updates and reports, offering insights into patterns and trends in the data and their implications for water supply management. This continuous sharing of information ensures that participants and other stakeholders remain engaged and informed, fostering a collaborative environment for water management. The platform builds a sustainable framework for ongoing community involvement and data-driven decision-making in water-scarce regions through these services.

5.3 Case Study

5.3.1 Presentation of the Water System and Challenges

This research was applied to Kharas, a northwest town of Hebron City in the West Bank, Palestine. The city covers an area of 6.8 km² with a population estimated at 10,000. Kharas has been suffering from a severe water shortage because of insufficient water supply and high degradation of the water network. The latter resulted in severe water losses, which reached up to 50% of the water supply.

Because of technical and financial issues, the city has not implemented a monitoring system to follow the water operation and detect leaks. The participatory science approach presented an excellent opportunity for the town to engage citizens in improving the water supply system. Through this engagement, the city wanted to (i) enhance citizens' awareness about the value of water preservation and (ii) collect data that help understand the water operation system and identify the defaults of this system.

The Palestinian Water Authority (PWA) selected this city as the first pilot project in Palestine. The PWA will use the results of this experimentation to extend participatory science to other Palestinian cities. The city was selected for its vast water shortage and small size, which facilitates the implementation of participatory science and the great interest of city decision-makers and technical staff in this approach.

5.3.2 Implementation of the Participatory Approach

The project started by working with the technical staff to adapt the participatory platform to Karas City. This adaptation included creating the digital model of the water supply system, volunteers' engagement, and users' data collection and analysis.

- **Creation of the Digital Model of The Water System**

The research team worked with the technical staff to collect data about the water supply system, including water pipes' location and characteristics, water distribution tanks, and end-user connections. Collected data was used to build a comprehensive GIS system that includes all the collected data (**Figure 5-2**). The water system includes 63.1 km of pipes, two distribution tanks, and 1200 user connections. The city is organized into 13 areas according to the water operation system.

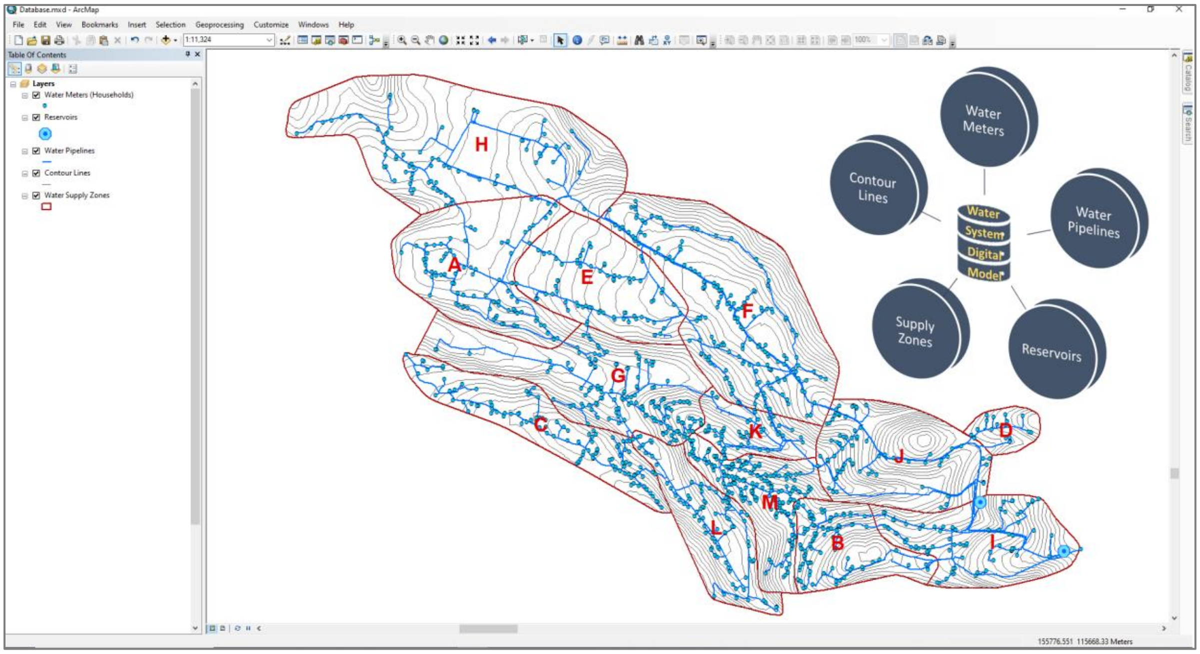

Figure 0-2 GIS of the Water System.

Two reservoirs serve the study area. The main reservoir, located at the highest elevation of 721 meters, has a capacity of 1000 cubic meters. It feeds a secondary reservoir, which holds 250 cubic meters and is situated at a lower elevation of 628 meters.

The shortest distance was calculated using ArcMap software to analyze the water pipeline network and establish the most direct path for water to flow from the closest reservoir to each meter involved in the case study. This detailed mapping aids in understanding how topographical and infrastructural factors may impact water distribution and quality across different town zones.

- **Citizens' Engagement and Training**

Given the city's and users' expectations, the first application of the participatory platform targeted the quality of the water supply. This focus was chosen due to the critical nature of water shortages for residents and the city. To address this issue, citizens were asked to report the water supply quality using three qualitative statuses:

- Blue (★ ★ ★): Good water supply
- Yellow (★ ★): Degraded water supply
- Red (★): Interrupted water supply

To ensure user privacy, the project concentrated on water quality, which involves external factors and does not require personal data. Volunteers agreed to participate in this pilot project through a formal agreement with the city, stipulating that the data would be used solely for this project and subsequently deleted.

The following sections present the collected data and how it was utilized to understand the operation of the water system.

5.3.3 Data Collection

Data collection spanned six months, from June to December 2023, during which 175 citizens participated. **Figure 5-3** shows the distribution of participants across different zones. Central zones such as B, K, and M, close to the municipality building where workshops took place, and zones I, J, and G, with high populations, attracted more participants.

A total of 596 Quality Supply (QS) reports were collected. They were classified into three categories: 260 reports (44%) were rated as 'Bleu,' indicating good water supply conditions; 276 reports (46%) were marked as 'Yellow,' signifying a degraded water supply; and 60 reports (10%) were considered 'Red,' highlighting interrupted supply. With a confidence level of 85% and a margin of error of 5%, this data set is statistically significant.

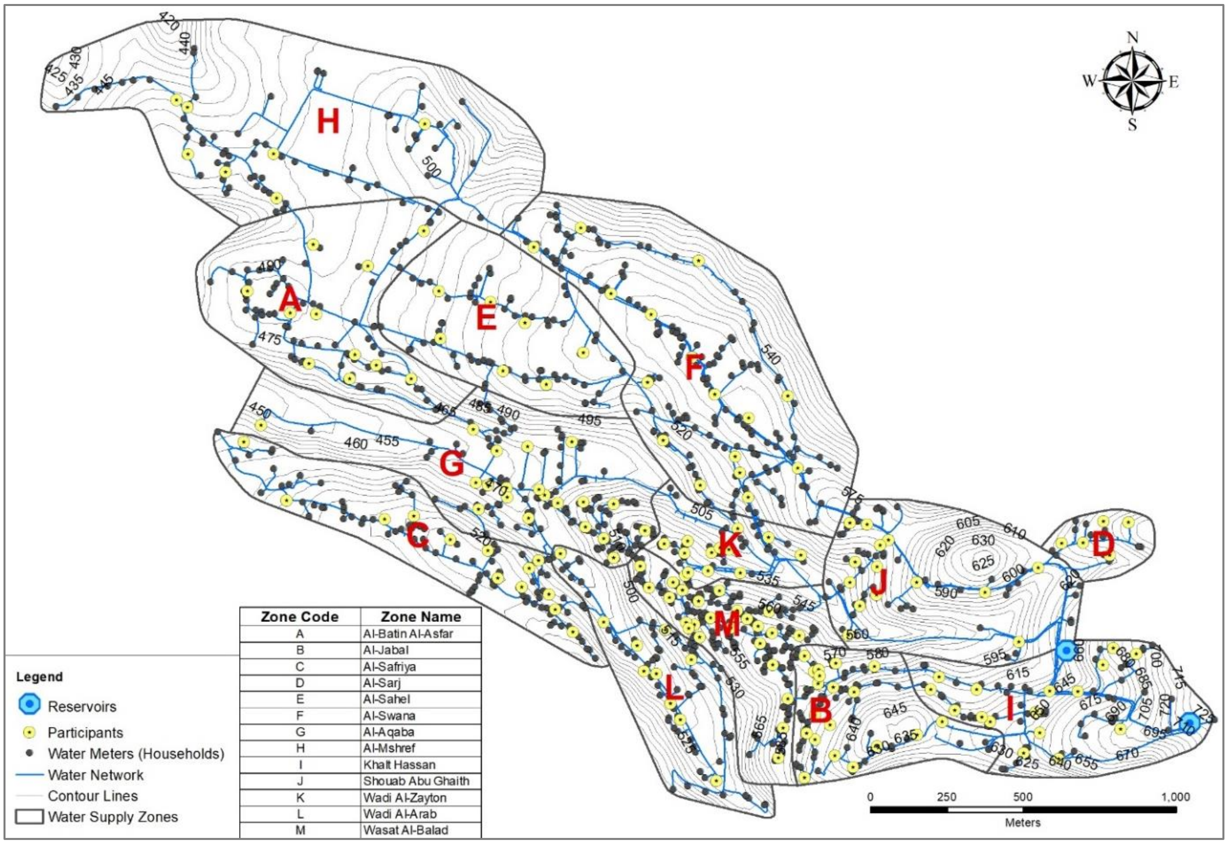

Figure 0-3 Water Supply Zones & Participants Spatial Distribution.

Table 5-1 summarizes the population number and the total reports for each geographic zone. It shows that reporting covers all geographic zones. The ratio of the total report to the population number varies between 10.13% and 29.41%, with an average value of 14.58%. Highly reported zones, as earlier mentioned, are either central or high-population zones, except zone D, which consists of only 17 households all belonging to the same family. This demonstrates how participation is highly influenced by social factors, such as kinship, in zone D.

Table 0-1 Participants' Distribution by Water Supply Zone.

Zone Code	Zone Name	Total (Participants)	Total (Population)	Percentage
A	Al-Batin Al-Asfar	11	86	12.79%
B	Al-Jabal	19	94	20.21%
C	Al-Safriya	13	110	11.82%

D	Al-Sarj	5	17	29.41%
E	Al-Sahel	7	65	10.77%
F	Al-Swana	16	158	10.13%
G	Al-Aqaba	20	142	14.08%
H	Al-Mshref	7	67	10.45%
I	Khalt Hassan	16	76	21.05%
J	Shouab Abu Ghaith	14	71	19.72%
K	Wadi Al-Zayton	13	51	25.49%
L	Wadi Al-Arab	10	81	12.35%
M	Wasat Al-Balad	24	182	13.19%
Grand Total		175	1200	14.58%

To maintain high data accuracy and consistency standards, clear guidelines, definitions, and assumptions were provided during the workshops to the municipality and participating users to ensure the accuracy and consistency of the data. **Table 5-2** represents the main assumptions and definitions related to the data collection process:

Table 0-2 Data Collection Assumptions and Definitions.

Assumptions
• Each report is for a noticeable change in the Supply Quality (SQ).
• All sampled reports are only for external reasons.
• All sampled reports are not related to the type or quality of internal installations.
• Each participant represents an independent household.
• Each water meter serves an independent Residential Unit.
• The absence of new reporting indicates maintaining the last reported status.

Definitions
• Blue (Good): A normal water flow that participants anticipate. • Yellow (Degraded): A water flow that is disrupted, neither good nor bad. • Red (Interrupted): The lowest quality of water flow encountered by participants.

5.3.4 Analysis and Results

This study uses a combination of methods to address the data collected, giving attention to temporal trends and spatial variations. These methods include (i) mathematical analysis to tackle users' reports statistically and building regression models to quantify the relationship between the water supply parameters and observed quality issues and (ii) spatial analysis to map the distribution of supply quality and identify geographic patterns.

Additionally, this chapter emphasizes the critical need for quality testing of participatory data, which often needs to be added in many participatory science studies, particularly those needing readings from citizen-conducted experiments that can be evaluated against specific standards, as in the case of Steinke et al. (Steinke et al., 2017). Despite several frameworks discussing ensuring participatory data quality (Maund et al., 2022), adherence to these frameworks does not necessarily eliminate participation bias, especially when contributions are based on opinions and experiences rather than measurement tools, as seen in this study. This study presents an example of how to test the quality of collected data to ensure it is unbiased.

- **Participatory Data Quality Test - Bias Testing**

This analysis was prompted by the municipality's concerns about potential bias in evaluations influenced by social factors. Such bias could undermine the quality and credibility of the analysis and results. Therefore, it was necessary to examine whether there was a bias in the individuals' contributions related to their families (31 family affiliations vs. 3 categories of supply quality). Using a chi-square test, the results reveal that the participants' reports are not significantly influenced by their family affiliations, indicating that the collected sample is unbiased ($\chi2(60) = 0.931$).

- **Temporal Variations in Water Supply Quality**

Figure 5-4 shows the variation of the water supply quality during the observation period. It indicates an increase in the sound reports “Good” in Winter and a decrease in the “Degraded” and “Interrupted” reports. This result could be attributed to the low water consumption in Winter, which reduces the pressure on the water supply system. This figure also shows an increase in the “Degraded” reporting in summer, which results from the increase in the water demand.

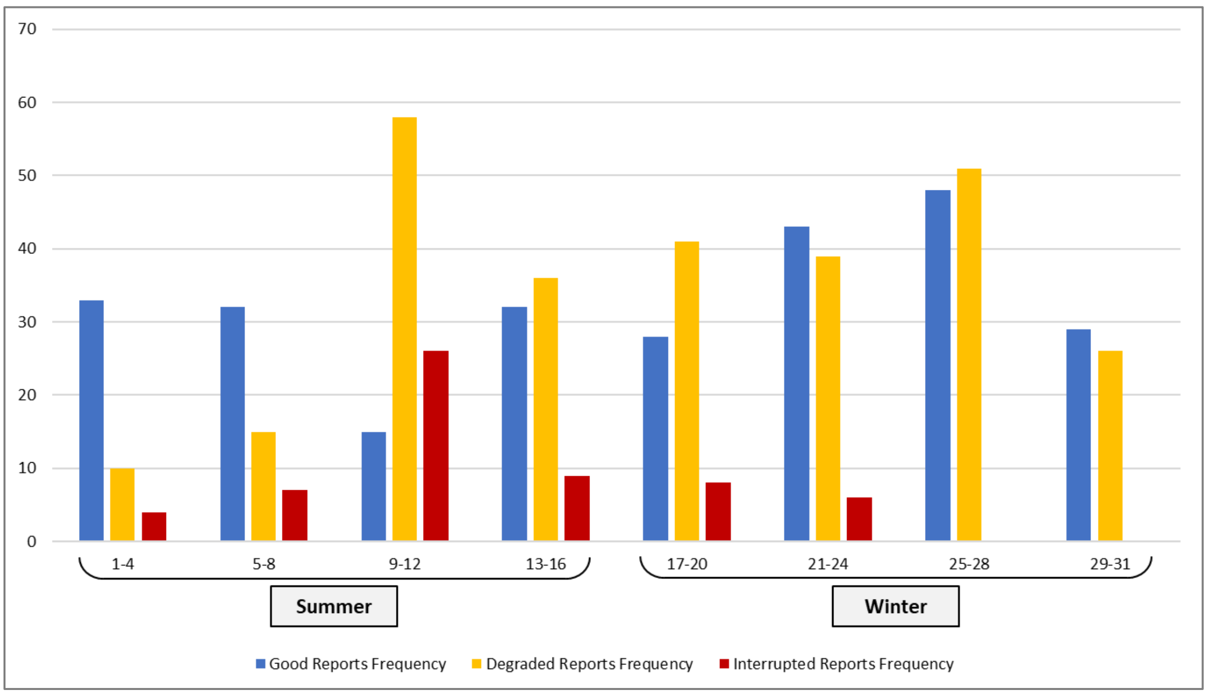

Figure 0-4 Number of Supply Quality Reports (QR) per Week and Season.

From now on, both the “Degraded” and “Interrupted” reports will be considered as 'Not Good' reports because, in such services, users expect to have good water quality service. However, it is argued that users tend to report negative experiences more than the positives.

Table 5-3 confirms an earlier observation that during summer (weeks 10 to 14), there was a notable increase in the frequency of ‘Not Good’ SQ reports. This is attributed to the higher seasonal water consumption during this period. However, some Not Good SQ reports were also identified in autumn (weeks 16 to 28). To better understand this relative increase in Not Good SQ reports, we will examine the spatial dimension of these reports.

Table 0-3 Frequency of Not Good SQ Reports per Week.

Duration (Week Numbers)	Total Frequency of NOT Good SQ Reports	Relative Frequency
1-4	14	0.042
5-8	22	0.065
9-12	84	0.250
13-16	45	0.134
17-20	49	0.146
21-24	45	0.134
25-28	51	0.152
29-31	26	0.077
Sum	336	1

- **Spatial Variations in Water Supply Quality**

To determine if there is a relationship between the zones and the water supply quality, a chi-square test was conducted. The results indicate a strong enough statistical relationship between the zones and the supply quality reported by participants, at an 80% confidence interval ($\chi2(24) = 0.166$). The strength of the relationship is justified as certain zones significantly impact the supply quality.

Figure 5-5 and **Table 5-4** illustrate the water quality reports per zone. They show a high degradation of the water quality services in zones B (Al-Jabal), F (Al-Swana), G (Al-Aqaba), and J (Shouab Abu Ghaith), regardless of the season. The poor water services in these zones could be attributable to the degradation of the water infrastructure or their geographical location. This issue will be discussed in the following section.

Table 0-4 Frequency of Not Good SQ Reports by Zone.

Zone Code	Zone Name	Frequency of Supply Quality Reports				
		Good	Degraded	Interrupted	Total Sum	NOT Good
A	Al-Batin Al-Asfar	11	16	7	34	23
B	Al-Jabal	27	33	7	67	40
C	Al-Safriya	24	22	5	51	27
D	Al-Sarj	6	10	0	16	10
E	Al-Sahel	28	18	10	56	28
F	Al-Swana	19	32	5	56	37
G	Al-Aqaba	38	40	4	82	44
H	Al-Mshref	15	14	4	33	18
I	Khalt Hassan	9	11	4	24	15
J	Shouab Abu Ghith	17	28	6	51	34
K	Wadi Al-Zayton	19	17	3	39	20
L	Wadi Al-Arab	22	16	0	38	16
M	Wasat Al-Balad	25	19	5	49	24
Sum		260	276	60	596	336

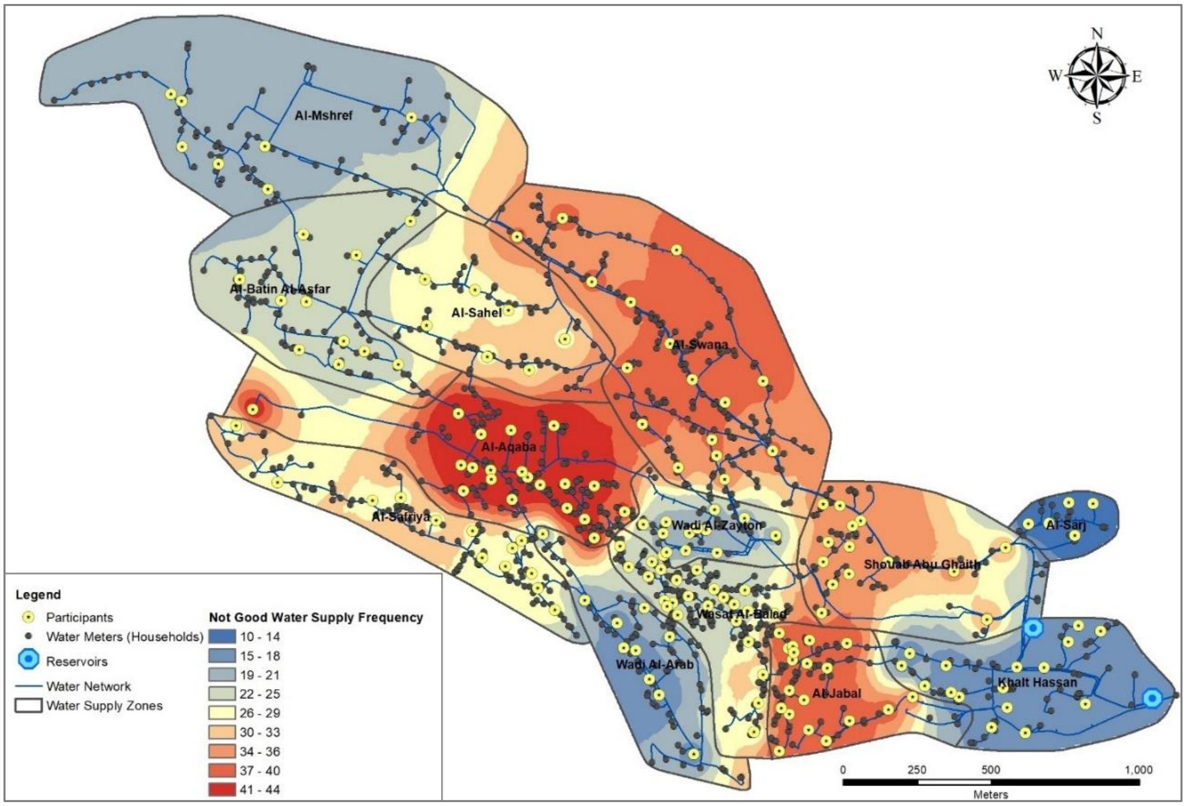

Figure 0-5 Spatial Distribution of the Frequency of Not Good SQ.

- **Analysis of Influencing Factors on the Water Supply Quality**

This section analyses the impact of the following factors on the quality of the water supply: The number of connections preceding the user water service, water pipe diameter, distance from the water tank, and the altitude of the user water supply unit.

The number of connections before the meter was calculated using ArcMap network analysis. **Figure 5-6** shows a poor correlation (Pearson's correlation coefficient = 0.167) between this parameter and the water quality service.

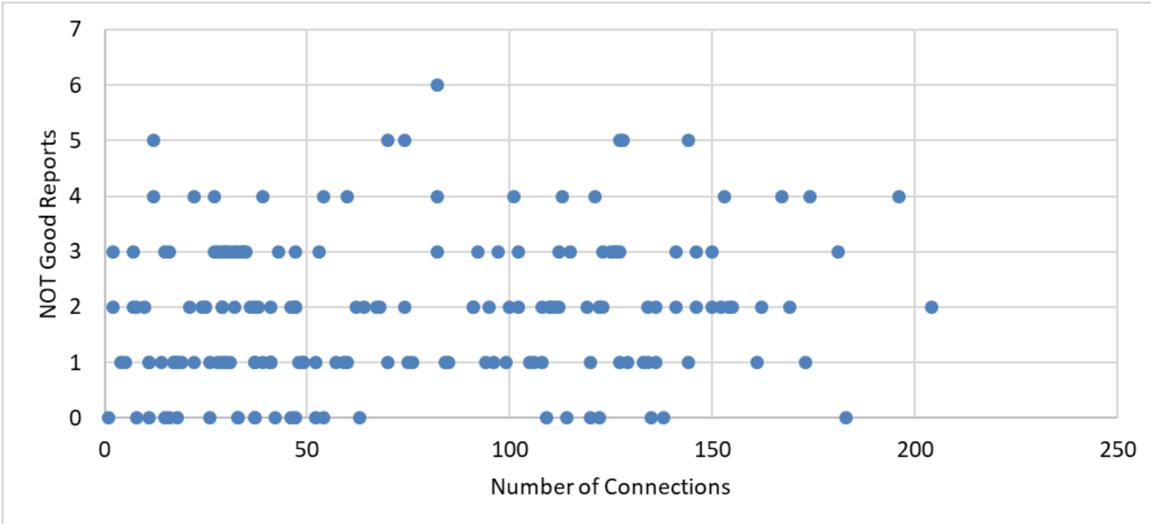

Figure 0-6 The Number of Connections before a Sampled Water Meter -Residential Unit- and the NOT Good Reports.

Table 5-5 shows the variation of the water quality parameter with the pipes' diameter. It shows a net decrease in the poor water quality with the increase in the water diameter, with a negative Pearson's correlation coefficient of 0.976.

Table 0-5 The correlation between the diameter of pipes and the frequency of Not Good SQ reports.

Diameter	Frequency of Not Good SQ Reports	Relative Frequency of Not Good SQ Reports
2	140	0.417
3	90	0.268
4	85	0.253
6	21	0.063
	Pearson's Correlation Coefficient	-0.976

Figure 5-7 shows that the relationship between the frequency of "Not Good" SQ reports and the user unit's distance is neither positively direct nor linear. It does not indicate a clear trend between these factors.

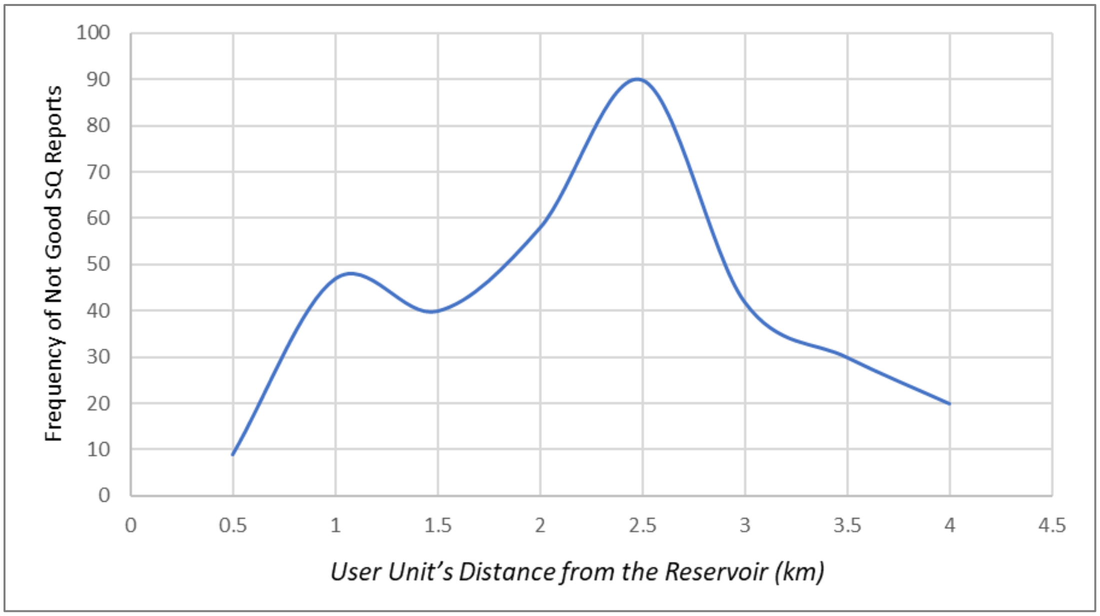

Figure 0-7 Not Good SQ Frequency by User Unit's Distance.

Figures 5-8 and **5-9** show the variation in the elevation of the water supply unit with the distance from the water reservoirs. Graphs extend from the east's main reservoir to the west's farthest water meter, passing through different zones. All zones along either line are mainly fed by the main reservoir, which feeds the secondary reservoir.

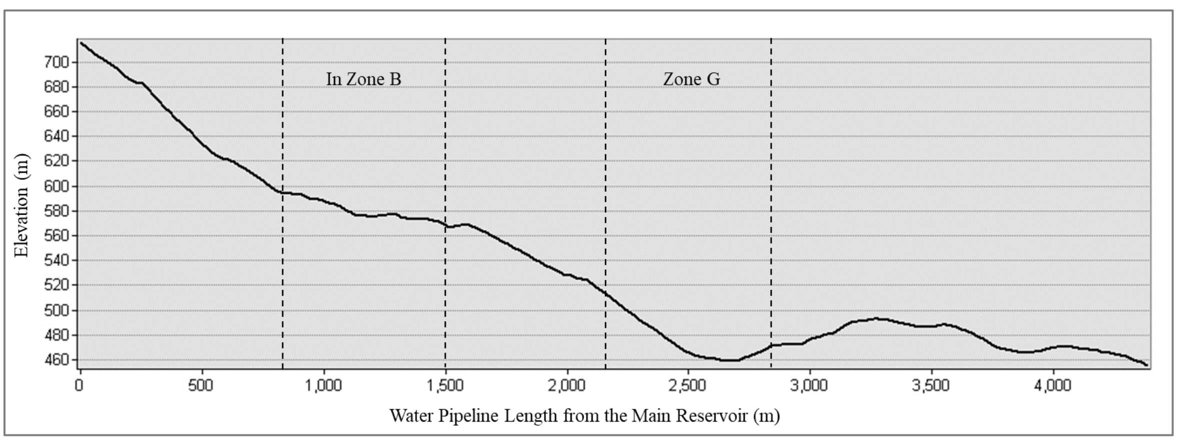

Figure 0-8 First Main Water Line Profile.

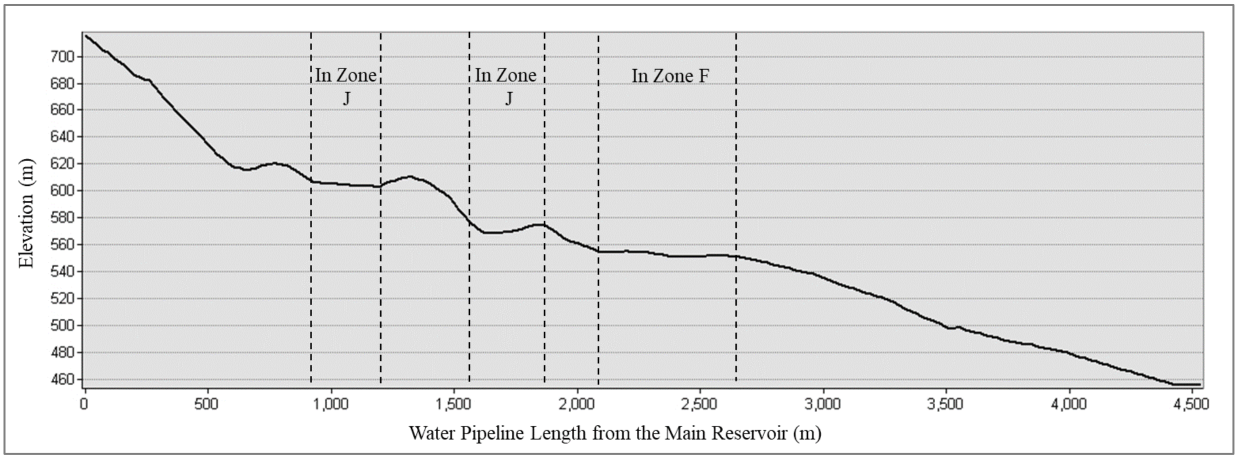

Figure 0-9 Second Main Water Line Profile.

These figures indicate that each primary water line includes at least two nearly level segments of varying lengths, all with a maximum slope ratio of 0.02. This issue arises from constructing water lines beneath roads aligned with contour lines, reducing water flow pressure. This explains the high frequency of 'Not Good' reports in zones B (Al-Jabal), J (Shouab Abu Ghaith), and F (Al-Swana).

Although zone G (Al-Aqaba) has a high slope ratio, as shown in Figure 8, it also experiences a high frequency of 'Not Good' reports. It should be mentioned that the first prime water line in, as shown in Figure 10, has pipe diameters decreasing from 6 inches to only 2. Almost 88% of its length comprises pipes with diameters less than 4 inches. Contrary to that, 79% of the size of the second primary line has pipes with a diameter equal to or greater than 4 inches. However, Figure 10 shows two secondary water lines branching off from the first primary line toward lower elevation zones and before reaching zone G. This situation, with inadequate pipe diameters, elucidates the high frequency of Not Good SQ reports received from zone G. These reports indicate that sampled participants from zone G may experience insufficient water volumes in addition to lower water pressure.

It is worth highlighting that the findings, particularly those related to zone G, were discussed with the municipality. The municipality acknowledged that the water lines in this area require maintenance and upgrades. Existing pipes need to be replaced with larger-diameter ones, and the branching network needs to be reorganized. Additionally, the municipality has prioritized the maintenance of this line, recognizing its critical role in improving water service quality and ensuring the reliability of the supply network in zone G.

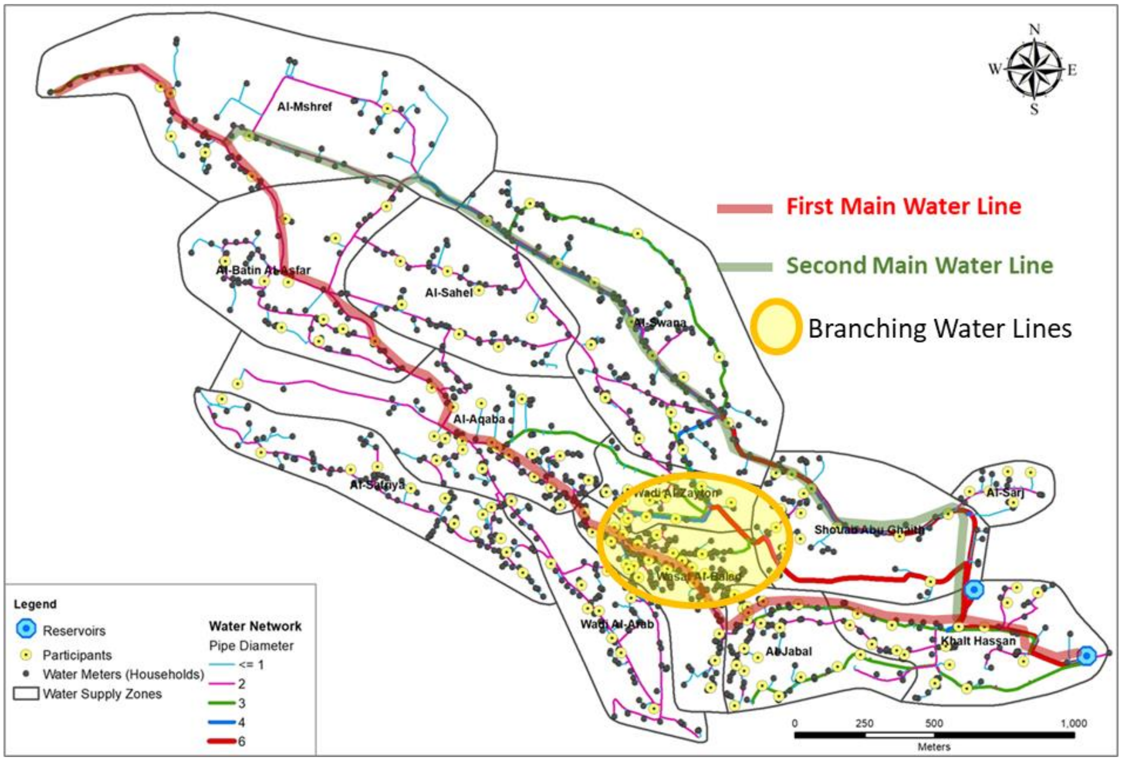

Figure 0-10 Main Water Lines and Pipes Diameter.

These secondary branches could address network layout deficiencies and improve efficiency. This could be achieved if they function as collector lines, connecting necessary zones with primary line segments with high slope ratios. To avoid adverse results such as those experienced in zone G, increasing the diameter of smaller pipelines in primary lines would be necessary for this enhancement.

5.4 Conclusion

This study underscores the efficacy of participatory science in addressing water supply challenges in water-scarce developing regions. By engaging citizens in data collection and evaluation, valuable ground-level insights into water supply conditions could be obtained, facilitating the identification of operational deficiencies and the optimization of the water distribution system.

This research showed that implementing a participatory platform in Kharas, Palestine, facilitated citizen engagement, overcame data lack, and enhanced understanding of water system dynamics. Spatial and temporal analyses revealed critical determinants of water supply quality, including pipe diameter, water branching density, distance from reservoirs, and terrain characteristics. Areas with narrower pipe diameters exhibited higher incidences of degraded water supply. These findings prompted municipal authorities to prioritize infrastructure upgrades and maintenance in affected zones, illustrating the practical impact of participatory data on decision-making processes.

However, this research encountered the following limitations. First, while participants were engaged in the project conception and data collection stages, they needed more time and resources to discuss the results and analysis. Second, ensuring ongoing participation is a significant challenge in all participatory research. To address this, the study collaborated with the local authority to regularly remind and communicate with citizens throughout the project to maintain continuous engagement.

Chapter 6: General Conclusion and Perspectives

Overview

This research explored the application of participatory science in addressing urban challenges in developing countries. It established an agile framework that combines participatory science and advanced digital technology to enhance citizen engagement in data collection and assessing solutions and processes in urban areas. The framework's potential was evaluated through its application in the Palestinian context. The core components of this framework include:

- **Digital Platforms for Data Collection:** This program utilizes mobile applications and online platforms to facilitate citizens' easy reporting of urban issues. These tools are designed to be user-friendly and accessible, ensuring broad participation.
- **Citizen Involvement and Engagement:** Encourages citizen participation through community outreach programs, educational workshops, and regular feedback mechanisms. Promotes transparency by providing citizens with access to the collected data and insights, ensuring they are informed about the progress and impact of their contributions.
- **Advanced Digital Technologies:** Incorporates technologies such as Geographic Information Systems (GIS), Building Information Modeling (BIM), and Artificial Intelligence (AI) to enhance data collection, analysis, and dissemination.

The framework's applications included:

- **Inclusive Urban Public Spaces:** Identifying deficiencies in public spaces and emphasizing the need for citizen involvement and smart technologies to enhance inclusivity.
- **User-Centric Smart Campus:** Capturing users' experiences to create sustainable and smart campus environments.
- **Water Supply Management:** Engaging citizens in data collection and assessment to optimize water distribution systems in water-scarce regions.

However, implementing this framework was complex and fraught with social, political, and technical challenges. These obstacles can significantly hinder the success of participatory science projects. The following sections will explore the nature of these challenges, the interactions among various stakeholders, and the strategies for mitigating or overcoming their impact.

Challenges, Barriers, and Limitations

Understanding the challenges related to participatory science projects involved examining the roles and interactions of the main stakeholders: the research team and the participants. Each stakeholder had distinct goals and considerations that influenced the success of the projects.

Interactions between these stakeholders were critical, necessitating effective communication channels and a focus on trust and transparency, particularly between participants and local authorities who represented the research team in this study's projects. Cooperation varied significantly across cases, influenced by technical, financial, and socio-political factors.

The study identified several limitations categorized into local authority limitations, participant limitations, research team limitations, and external limitations. Among local authorities, technical and financial capabilities varied significantly, impacting cooperation levels. For instance, larger municipalities like Nablus had robust resources but faced socio-political concerns affecting engagement, while smaller cities like Kharas, despite limited resources, exhibited smoother cooperation. Participant limitations included differing technical skills and awareness levels, which influenced their ability to use the developed tools effectively. In Case 3[1], lower technical proficiency and awareness posed significant challenges compared to Cases 1[2] and 2[3], where participants were more familiar with similar projects and had higher technical skills. Additionally, trust and transparency issues between participants and local authorities were prevalent, affecting the overall engagement.

Research team limitations involved difficulties in data accessibility, the need for constant presence, resource constraints, and tight timelines. Access to comprehensive data was more straightforward in some cases, like Case 1, due to the availability of extensive databases, while in

[1] Case 1: The Use of the Smart Technology for Creating an Inclusive Urban Public Space
[2] Case 2: Use of Participatory Science and Artificial Intelligence for the Creation of a User-Centric Smart Campus
[3] Leveraging Participatory Science for Tackling Water Supply Challenges in Water-Scarce Developing Regions

others, data sharing was restricted. The team's permanent presence facilitated smoother processes, whereas remote operations in other cases led to challenges in addressing obstacles promptly. External factors such as political instability significantly impacted the study, particularly in Cases 2 and 3, which were implemented in the midst of an unfortunate political conflict. However, support from higher authorities, like the Water Authority in Case 3, helped mitigate some obstacles and enhance cooperation. These multifaceted challenges highlight the complex interplay of technical, social, and political factors in participatory science projects.

General Recommendations

To enhance the effectiveness of participatory science and address related barriers, several recommendations are proposed:

- **Building Institutional Capacity:** Enhance technical and financial capabilities of local authorities through targeted training, resource allocation, and clear frameworks defining stakeholder roles and responsibilities.
- **Enhancing Citizen Engagement:** Implement education and awareness campaigns to inform citizens about the benefits of participation and the impact of their contributions, focusing on technical literacy and understanding urban challenges.
- **Utilizing Advanced Digital Technologies:** Develop user-friendly tools and leverage advanced data analytics to improve data collection, processing, and interpretation.
- **Fostering Trust and Transparency:** Promote transparency in data collection, analysis, and decision-making processes and maintain open lines of communication between the participants and the research team.
- **Ensuring Political and Social Stability:** Engaging higher authorities and government bodies can provide support and legitimacy to participatory projects, especially in politically unstable regions. Developing strategies to mitigate political risks by forming partnerships with non-governmental organizations (NGOs) and international bodies that can offer stability and additional support is also essential.

- **Addressing Technical and Financial Constraints:** Optimize resource use, adopt cost-effective technologies, seek external funding, and implement projects incrementally, starting with pilot programs.

This research contributes to participatory science and urban systems, advancing understanding in conflict-affected regions. The developed frameworks and digital platforms are valuable tools for policymakers, urban planners, and community organizations, emphasizing the importance of citizen engagement in urban governance.

Acknowledging several limitations, future efforts should strengthen local authorities, improve educational outreach, and develop robust frameworks to support participatory initiatives. Addressing these barriers will help developing countries harness the benefits of participatory science for more inclusive, sustainable, and resilient urban environments.

In conclusion, this thesis demonstrates the transformative potential of participatory science in addressing urban challenges in developing regions. By integrating advanced digital technologies and fostering citizen engagement, the research provides a robust framework for sustainable urban development, offering valuable guidance for future implementations and contributing to the global advancement of innovative urban systems and participatory governance.

References

Aboelnga, H. T., El-Naser, H., Ribbe, L., & Frechen, F.-B. (2020). Assessing Water Security in Water-Scarce Cities: Applying the Integrated Urban Water Security Index (IUWSI) in Madaba, Jordan. *Water*, *12*(5), Article 5. https://doi.org/10.3390/w12051299

Abreu, N., Pinto, A., Matos, A., & Pires, M. (2023). Procedural Point Cloud Modelling in Scan-to-BIM and Scan-vs-BIM Applications: A Review. *ISPRS International Journal of Geo-Information*, *12*(7), Article 7. https://doi.org/10.3390/ijgi12070260

Abuhasirah, M., & Shahrour, I. (2021). Participatory Governance Comprehensive Approach A Proposed Model based on Practices and Experience. *International Journal of Engineering Research*, *10*(05), 6.

Aburas, H., Shahrour, I., & Giglio, C. (2024). Route Planning under Mobility Restrictions in the Palestinian Territories. *Sustainability*, *16*(2), Article 2. https://doi.org/10.3390/su16020660

Abusaada, H., & Elshater, A. (2021). Effect of people on placemaking and affective atmospheres in city streets. *Ain Shams Engineering Journal*, *12*(3), 3389–3403. https://doi.org/10.1016/j.asej.2021.04.019

Adu-Manu, K., Tapparello, C., Heinzelman, W., Katsriku, F., & Abdulai, J.-D. (2017). Water Quality Monitoring Using Wireless Sensor Networks: Current Trends and Future Research Directions. *ACM Transactions on Sensor Networks*, *13*, 1–41. https://doi.org/10.1145/3005719

Agarwal, R., Dixit, A., & Karatangi, S. V. (2021). Application of IoT in Water Supply Management. In *Predictive Analytics*. CRC Press.

Ahmed, V., Khatri, M. F., Bahroun, Z., & Basheer, N. (2023). Optimizing Smart Campus Solutions: An Evidential Reasoning Decision Support Tool. *Smart Cities*, *6*(5), Article 5. https://doi.org/10.3390/smartcities6050106

Ahmimed, C. (2018). *Inclusive cities: Trends and new initiatives* (p. 20). Department for Economic and Social Affairs (UNDESA) Division for Social Policy and Development. https://www.un.org/development/desa/family/wp-content/uploads/sites/23/2018/05/Inclusivecities-DESAEGM16May2018CAHMIMED.pdf

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., & Airaksinen, M. (2017). What are the differences between sustainable and smart cities? *Cities*, *60*, 234–245. https://doi.org/10.1016/j.cities.2016.09.009

Albrecht, F., Moser, J., & Hijazi, I. (2013). Assessing façade visibility in 3D city models for city marketing. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, *XL-2/W2*, 1–5. https://doi.org/10.5194/isprsarchives-XL-2-W2-1-2013

Ali, Z., Shah, M. A., Almogren, A., Ud Din, I., Maple, C., & Khattak, H. A. (2020). Named Data Networking for Efficient IoT-based Disaster Management in a Smart Campus. *Sustainability*, *12*(8), Article 8. https://doi.org/10.3390/su12083088

Aljer, A., Itair, M., Akil, M., & Sharour, I. (2024). Knowledge Infrastructure Data Wizard (KIDW): A Cooperative Approach for Data Management and Knowledge Dissemination. In M. Ben Ahmed, A. A. Boudhir, R. El Meouche, & İ. R. Karaş (Eds.), *Innovations in Smart Cities Applications Volume 7* (pp. 34–43). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-53824-7_4

Al-Omari, G. (2023, February 28). *To Prevent the PA from Unraveling, Address Internal Reform*. The Washington Institute. https://www.washingtoninstitute.org/policy-analysis/prevent-pa-unraveling-address-internal-reform

Alrashed, S. (2020). Key performance indicators for Smart Campus and Microgrid. *Sustainable Cities and Society*, *60*, 102264. https://doi.org/10.1016/j.scs.2020.102264

Angelidou, M., Psaltoglou, A., Komninos, N., Kakderi, C., Tsarchopoulos, P., & Panori, A. (2017). Enhancing sustainable urban development through smart city applications. *Journal of Science and Technology Policy Management*, *9*(2), 146–169. https://doi.org/10.1108/JSTPM-05-2017-0016

ANU-FEIT. (2023). *Welcome Message | Faculty of Engineering and Information Technology*. Faculty Of Engineering And Information Technology, An-Najah National University. https://eng.najah.edu/en/about/welcome-message/

Arnstein, S. R. (1969). A Ladder of Citizen Participation. *Journal of the American Planning Association*, *85*(1), 24–34. https://doi.org/10.1080/01944363.2018.1559388

Asingizwe, D., Poortvliet, P. M., Koenraadt, C. J. M., van Vliet, A. J. H., Ingabire, C. M., Mutesa, L., & Leeuwis, C. (2020). Why (not) participate in citizen science? Motivational factors and barriers to participate in a citizen science program for malaria control in Rwanda. *PLoS ONE*, *15*(8), e0237396. https://doi.org/10.1371/journal.pone.0237396

Babiso, W. Z., Ayano, K. K., Haile, A. T., Keche, D. D., Acharya, K., & Werner, D. (2023). Citizen Science for Water Quality Monitoring in the Meki River, Ethiopia: Quality Assurance and Comparison with Conventional Methods. *Water*, *15*(2), Article 2. https://doi.org/10.3390/w15020238

Barns, S., Cosgrave, E., Acuto, M., & Mcneill, D. (2017). Digital Infrastructures and Urban Governance. *Urban Policy and Research*, *35*(1), 20–31. https://doi.org/10.1080/08111146.2016.1235032

Bastos, D., Fernández-Caballero, A., Pereira, A., & Rocha, N. P. (2022). Smart City Applications to Promote Citizen Participation in City Management and Governance: A Systematic Review. *Informatics*, *9*(4), Article 4. https://doi.org/10.3390/informatics9040089

Batsaikhan, A., Hachinger, S., Kurtz, W., Heller, H., & Frank, A. (2020). Application of Modern Web Technologies to the Citizen Science Project BAYSICS on Climate Research and Science Communication. *Sustainability*, *12*(18), Article 18. https://doi.org/10.3390/su12187748

Beck, S. F., Abualdenien, J., Hijazi, I. H., Borrmann, A., & Kolbe, T. H. (2021). Analyzing Contextual Linking of Heterogeneous Information Models from the Domains BIM and UIM. *ISPRS International Journal of Geo-Information*, *10*(12), Article 12. https://doi.org/10.3390/ijgi10120807

Behzadian, K., & Kapelan, Z. (2015). Advantages of integrated and sustainability based assessment for metabolism based strategic planning of urban water systems. *Science of The Total Environment*, *527–528*, 220–231. https://doi.org/10.1016/j.scitotenv.2015.04.097

Benyei, P., Skarlatidou, A., Argyriou, D., Hall, R., Theilade, I., Turreira-García, N., Latreche, D., Albert, A., Berger, D., Cartró-Sabaté, M., Chang, J., Chiaravalloti, R., Cortesi, A., Danielsen, F., Haklay, M. (Mordechai), Jacobi, E., Nigussie, A., Reyes-García, V., Rodrigues, E., … Woods, T. (2023). Challenges, Strategies, and Impacts of Doing Citizen Science with Marginalised and Indigenous Communities: Reflections from Project

Coordinators. *Citizen Science: Theory and Practice*, *8*(1). https://doi.org/10.5334/cstp.514

Biswas, A., & Tortajada, C. (2018). *Assessing Global Water Megatrends* (pp. 1–26). https://doi.org/10.1007/978-981-10-6695-5_1

Biswas, R., Jana, A., Arya, K., & Ramamritham, K. (2019). A good-governance framework for urban management. *Journal of Urban Management*, *8*(2), 225–236. https://doi.org/10.1016/j.jum.2018.12.009

Bonney, R., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science*, *25*(1), 2–16. https://doi.org/10.1177/0963662515607406

Borchers, M., Tavanapour, N., & Bittner, E. (2023). *Designing Mobile Applications for Citizen Participation in Urban Planning*. https://hdl.handle.net/10125/102682

Boretti, A., & Rosa, L. (2019). Reassessing the projections of the World Water Development Report. *Npj Clean Water*, *2*(1), Article 1. https://doi.org/10.1038/s41545-019-0039-9

Bosch, A., Volker, L., & Koutamanis, A. (2015). BIM in the operations stage: Bottlenecks and implications for owners. *Built Environment Project and Asset Management*, *5*, 331–343. https://doi.org/10.1108/BEPAM-03-2014-0017

Boulianne, S. (2020). Twenty Years of Digital Media Effects on Civic and Political Participation. *Communication Research*, *47*(7), 947–966. https://doi.org/10.1177/0093650218808186

Braddon, A. E., Robinson, S., Alati, R., & Betts, K. S. (2023). Exploring the utility of synthetic data to extract more value from sensitive health data assets: A focused example in perinatal epidemiology. *Paediatric and Perinatal Epidemiology*, *37*(4), 292–300. https://doi.org/10.1111/ppe.12942

Brouwer, S., Van der Wielen, P. W. J. J., Schriks, M., Claassen, M., & Frijns, J. (2018). Public Participation in Science: The Future and Value of Citizen Science in the Drinking Water Research. *Water*, *10*(3), Article 3. https://doi.org/10.3390/w10030284

Buytaert, W., Dewulf, A., De Bièvre, B., Clark, J., & Hannah, D. M. (2016). Citizen Science for Water Resources Management: Toward Polycentric Monitoring and Governance? *Journal of Water Resources Planning and Management*, *142*(4), 01816002. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000641

Buytaert, W., Zulkafli, Z., Grainger, S., Acosta, L., Alemie, T. C., Bastiaensen, J., De Bièvre, B., Bhusal, J., Clark, J., Dewulf, A., Foggin, M., Hannah, D. M., Hergarten, C., Isaeva, A., Karpouzoglou, T., Pandeya, B., Paudel, D., Sharma, K., Steenhuis, T., … Zhumanova, M. (2014). Citizen science in hydrology and water resources: Opportunities for knowledge generation, ecosystem service management, and sustainable development. *Frontiers in Earth Science*, *2*. https://www.frontiersin.org/articles/10.3389/feart.2014.00026

Campos, R. (2023). The many paths for an open, participatory, and inclusive science. *Septentrio Conference Series*, *1*, Article 1. https://doi.org/10.7557/5.7138

Cardamone, C., & Lobel, L. (2016). Using Citizen Science to Engage Introductory Students: From Streams to the Solar System. *Journal of Microbiology & Biology Education*, *17*(1), 117–119. https://doi.org/10.1128/jmbe.v17i1.1082

Cardullo, P., & Kitchin, R. (2019). Being a 'citizen' in the smart city: Up and down the scaffold of smart citizen participation in Dublin, Ireland. *GeoJournal*, *84*(1), 1–13. https://doi.org/10.1007/s10708-018-9845-8

Chan, K., Schillereff, D. N., Baas, A. C., Chadwick, M. A., Main, B., Mulligan, M., O'Shea, F. T., Pearce, R., Smith, T. E., van Soesbergen, A., Tebbs, E., & Thompson, J. (2021). Low-cost electronic sensors for environmental research: Pitfalls and opportunities. *Progress in Physical Geography: Earth and Environment*, *45*(3), 305–338. https://doi.org/10.1177/0309133320956567

Chari, R., Matthews, L., Blumenthal, M., Edelman, A., & Jones, T. (2017). *The Promise of Community Citizen Science*. RAND Corporation. https://doi.org/10.7249/PE256

Chigudu, A., Chavunduka, C. M., Maja, I., & Chirisa, I. (2022). Urbanization, Planning Law, and the Future of Developing World Cities. In R. C. Brears (Ed.), *The Palgrave Encyclopedia of Urban and Regional Futures* (pp. 2101–2110). Springer International Publishing. https://doi.org/10.1007/978-3-030-87745-3_67

Chiu, C.-C., & Lee, L.-C. (2018). System satisfaction survey for the App to integrate search and augmented reality with geographical information technology. *Microsystem Technologies*, *24*(1), 319–341. https://doi.org/10.1007/s00542-017-3333-9

Corbari, C., Paciolla, N., Ben Charfi, I., Skokovic, D., Sobrino, J. A., & Woods, M. (2022). Citizen science supporting agricultural monitoring with hundreds of low-cost sensors in comparison to remote sensing data. *European Journal of Remote Sensing*, *55*(1), 388–408. https://doi.org/10.1080/22797254.2022.2084643

Corbari, C., Paciolla, N., Ben Charfi, I., & Woods, M. (2021). *Remote Sensing and Citizen science supporting irrigation monitoring in the Capitanata Irrigation Consortium (Italy)*. EGU21-13318. EGU General Assembly Conference Abstracts. https://doi.org/10.5194/egusphere-egu21-13318

Cornish, F., Breton, N., Moreno-Tabarez, U., Delgado, J., Rua, M., de-Graft Aikins, A., & Hodgetts, D. (2023). Participatory action research. *Nature Reviews Methods Primers*, *3*(1), 1–14. https://doi.org/10.1038/s43586-023-00214-1

Cosgrove, W. J., & Loucks, D. P. (2015). Water management: Current and future challenges and research directions: Water management research challenges. *Water Resources Research*, *51*(6), 4823–4839. https://doi.org/10.1002/2014WR016869

Cottam, D., McGuire, C., Mossop, D., Davis, G., Donlen, J., Friend, K., Lewis, B., Boucher, E., Kirubakaran, H., Goulding, R., Jovanovic, D., McCarthy, D., Seymore, A., Martino, C., & Zuccala, K. (2021). Drain Detectives: Lessons Learned from Citizen Science Monitoring of Beach Drains. *Citizen Science: Theory and Practice*, *6*(1), Article 1. https://doi.org/10.5334/cstp.383

Crompton, A. (2017). *Towards Inclusive Community Engagement: Engaging Marginalized Residents in the Urban Planning Process* [Thesis]. https://tspace.library.utoronto.ca/handle/1807/79195

Cross, I. D. (2022). "Changing behaviour, changing investment, changing operations": Using citizen science to inform the management of an urban river. *Area*, *54*(3), 490–500. https://doi.org/10.1111/area.12597

D'Amico, S., Dall'Olio, D., Sala, C., Dall'Olio, L., Sauta, E., Zampini, M., Asti, G., Lanino, L., Maggioni, G., Campagna, A., Ubezio, M., Russo, A., Bicchieri, M. E., Riva, E., Tentori, C. A., Travaglino, E., Morandini, P., Savevski, V., Santoro, A., … Della Porta, M. G. (2023). Synthetic Data Generation by Artificial Intelligence to Accelerate Research and Precision Medicine in Hematology. *JCO Clinical Cancer Informatics*, *7*, e2300021. https://doi.org/10.1200/CCI.23.00021

Dembski, F., Wössner, U., Letzgus, M., Ruddat, M., & Yamu, C. (2020). Urban Digital Twins for Smart Cities and Citizens: The Case Study of Herrenberg, Germany. *Sustainability*, *12*(6), Article 6. https://doi.org/10.3390/su12062307

Deng, M., Menassa, C., & Kamat, V. (2021). From BIM to digital twins: A systematic review of the evolution of intelligent building representations in the AEC-FM industry. *Journal of Information Technology in Construction*, *26*, 58–83. https://doi.org/10.36680/j.itcon.2021.005

Di Cecco, G. J., Barve, V., Belitz, M. W., Stucky, B. J., Guralnick, R. P., & Hurlbert, A. H. (2021). Observing the Observers: How Participants Contribute Data to iNaturalist and Implications for Biodiversity Science. *BioScience*, *71*(11), 1179–1188. https://doi.org/10.1093/biosci/biab093

Dick, E. (2021). Current and Potential Uses of AR/VR for Equity and Inclusion. *INFORMATION TECHNOLOGY*.

Dudek, M., Bashynska, I., Filyppova, S., Yermak, S., & Cichoń, D. (2023). Methodology for assessment of inclusive social responsibility of the energy industry enterprises. *Journal of Cleaner Production*, *394*, 136317. https://doi.org/10.1016/j.jclepro.2023.136317

Ellery, P. J., & Ellery, J. (2019). Strengthening Community Sense of Place through Placemaking. *Urban Planning*, *4*(2), 237–248. https://doi.org/10.17645/up.v4i2.2004

Eltamaly, A. M., Alotaibi, M. A., Alolah, A. I., & Ahmed, M. A. (2021). IoT-Based Hybrid Renewable Energy System for Smart Campus. *Sustainability*, *13*(15), Article 15. https://doi.org/10.3390/su13158555

Enqvist, J. P., & Ziervogel, G. (2019). Water governance and justice in Cape Town: An overview. *WIREs Water*, *6*(4), e1354. https://doi.org/10.1002/wat2.1354

Esfandfard, E., Wahab, M. H., & Amat, R. C. (2018). UNIVERSAL DESIGN IN URBAN PUBLIC SPACES FOR PEOPLE WITH DISABILITY. CASE STUDY OF TEHRAN, IRAN. *PLANNING MALAYSIA*, *16*, 10. https://doi.org/10.21837/pm.v16i5.421

Essex, J., & Haxton, K. (2018). Characterising patterns of engagement of different participants in a public STEM-based analysis project. *International Journal of Science Education, Part B*, *8*(2), 178–191. https://doi.org/10.1080/21548455.2017.1423128

European Commission. (2019). *How can public space in a city help to address future urban challenges?* European Commission. https://urban.jrc.ec.europa.eu/thefutureofcities/

Everett, G., & Geoghegan, H. (2016). Initiating and continuing participation in citizen science for natural history. *BMC Ecology*, *16*(1), 13. https://doi.org/10.1186/s12898-016-0062-3

Farooq, K., & Kustor, P. (2021, February 2). *How can mobile government (mGov) work in developing countries?* World Bank Blogs. https://blogs.worldbank.org/en/governance/how-can-mobile-government-mgov-work-developing-countries

Ferreira, L. M. R., Carosso, G. A., Montellano Duran, N., Bohorquez-Massud, S. V., Vaca-Diez, G., Rivera-Betancourt, L. I., Rodriguez, Y., Ordonez, D. G., Alatriste-Gonzalez, D. K., Vacaflores, A., Gonzalez Auza, L., Schuetz, C., Alvarado-Arnez, L. E., Alexander-Savino, C. V., Gandarilla, O., & Mostajo-Radji, M. A. (2019). Effective participatory science education in a diverse Latin American population. *Palgrave Communications*, *5*(1), 1–18. https://doi.org/10.1057/s41599-019-0275-0

Filippi, F. D., Coscia, C., & Guido, R. (2020). How Technologies Can Enhance Open Policy Making and Citizen-Responsive Urban Planning: MiraMap - A Governing Tool for the Mirafiori Sud District in Turin (Italy). In *Sustainable Infrastructure: Breakthroughs in Research and Practice* (pp. 501–522). IGI Global. https://doi.org/10.4018/978-1-7998-0948-7.ch023

Fortes, S., Santoyo-Ramón, J. A., Palacios, D., Baena, E., Mora-García, R., Medina, M., Mora, P., & Barco, R. (2019). The Campus as a Smart City: University of Málaga Environmental, Learning, and Research Approaches. *Sensors (Basel, Switzerland)*, *19*(6), 1349. https://doi.org/10.3390/s19061349

Fraisl, D., Campbell, J., See, L., Wehn, U., Wardlaw, J., Gold, M., Moorthy, I., Arias, R., Piera, J., Oliver, J. L., Masó, J., Penker, M., & Fritz, S. (2020). Mapping citizen science contributions to the UN sustainable development goals. *Sustainability Science*, *15*(6), 1735–1751. https://doi.org/10.1007/s11625-020-00833-7

Fraisl, D., Hager, G., Bedessem, B., Gold, M., Hsing, P.-Y., Danielsen, F., Hitchcock, C. B., Hulbert, J. M., Piera, J., Spiers, H., Thiel, M., & Haklay, M. (2022). Citizen science in environmental and ecological sciences. *Nature Reviews Methods Primers*, *2*(1), Article 1. https://doi.org/10.1038/s43586-022-00144-4

Freihardt, J. (2020). Can Citizen Science using social media inform sanitation planning? *Journal of Environmental Management*, *259*, 110053. https://doi.org/10.1016/j.jenvman.2019.110053

García-del-Amo, D., Mortyn, P. G., & Reyes-García, V. (2020). Including indigenous and local knowledge in climate research: An assessment of the opinion of Spanish climate change researchers. *Climatic Change*, *160*(1), 67–88. https://doi.org/10.1007/s10584-019-02628-x

Gearin, E., & Hurt, C. S. (2024). Making Space: A New Way for Community Engagement in the Urban Planning Process. *Sustainability*, *16*(5), Article 5. https://doi.org/10.3390/su16052039

Geekiyanage, D., Fernando, T., & Keraminiyage, K. (2021). Mapping Participatory Methods in the Urban Development Process: A Systematic Review and Case-Based Evidence Analysis. *Sustainability*, *13*(16), Article 16. https://doi.org/10.3390/su13168992

George, G., Menon, N. N., Abdulaziz, A., Brewin, R. J. W., Pranav, P., Gopalakrishnan, A., Mini, K. G., Kuriakose, S., Sathyendranath, S., & Platt, T. (2021). Citizen Scientists Contribute to Real-Time Monitoring of Lake Water Quality Using 3D Printed Mini Secchi Disks. *Frontiers in Water*, *3*. https://www.frontiersin.org/articles/10.3389/frwa.2021.662142

Ghadban, S. S. (2008). Architecture in Palestine. In H. Selin (Ed.), *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures* (pp. 225–238). Springer Netherlands. https://doi.org/10.1007/978-1-4020-4425-0_8904

Glebova, E., & Desbordes, M. (2022). Smart Sports in Smart Cities. In *Smart Cities and Tourism: Co-creating experiences, challenges and opportunities: Co-creating experiences, challenges and opportunities* (pp. 60–73). https://books.google.fr/books?hl=en&lr=&id=TaWaEAAAQBAJ&oi=fnd&pg=PA60&dq=Smart+Sports+in+Smart+Cities&ots=MBCL6s3szX&sig=VvVe_j7RmSSDU8MhATW6XJYohMU&redir_esc=y#v=onepage&q=Smart%20Sports%20in%20Smart%20Cities&f=false

Gracias, J. S., Parnell, G. S., Specking, E., Pohl, E. A., & Buchanan, R. (2023). Smart Cities—A Structured Literature Review. *Smart Cities*, *6*(4), Article 4. https://doi.org/10.3390/smartcities6040080

Granier, B., & Kudo, H. (2016). How are citizens involved in smart cities? Analysing citizen participation in Japanese ``Smart Communities''. *Information Polity*, *21*, 61–76. https://doi.org/10.3233/IP-150367

Hadba, L., Ashqar, H. I., Tuqan, N. A. S., & Lourenço, J. (2014, September). *Effects of public participation in urban planning: The case of Nablus city*. http://repositorium.sdum.uminho.pt/

Haklay, M. (2013). Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation. In *Volunteered Geographic Information, Public Participation and Crowdsourced Production of Geographic Knowledge* (pp. 105–122). https://doi.org/10.1007/978-94-007-4587-2_7

Haklay, M., Dörler, D., Heigl, F., Manzoni, M., Hecker, S., & Vohland, K. (2021). *What Is Citizen Science? The Challenges of Definition* (pp. 13–33). https://doi.org/10.1007/978-3-030-58278-4_2

Hamad, A. M. A., Indriyani, R., Ramadan, A. M. M. A., & Fitriono, R. A. (2022). Separation of Powers in the Palestinian Law: Does it Reflect the Democratic System? (A Comparative Approach with Indonesia). *Lex Scientia Law Review*, *6*(2), Article 2. https://doi.org/10.15294/lesrev.v6i2.58038

Head, B. W. (2023). Wicked Problems in Public Policy. In M. van Gerven, C. Rothmayr Allison, & K. Schubert (Eds.), *Encyclopedia of Public Policy* (pp. 1–8). Springer International Publishing. https://doi.org/10.1007/978-3-030-90434-0_43-1

Hecker, S., Wicke, N., Haklay, M., & Bonn, A. (2019). How Does Policy Conceptualise Citizen Science? A Qualitative Content Analysis of International Policy Documents. *Citizen Science: Theory and Practice*, *4*(1), Article 1. https://doi.org/10.5334/cstp.230

Herman Assumpção, T., Popescu, I., Jonoski, A., & Solomatine, D. (2018). Citizen observations contributing to flood modelling: Opportunities and challenges. *Hydrology and Earth System Sciences*, *22*, 1473–1489. https://doi.org/10.5194/hess-22-1473-2018

Herschan, J., King, R., Mkandawire, T., Okurut, K., Lapworth, D. J., Malcolm, R., & Pond, K. (2020). The Potential for Citizen Science to Improve the Reach of Sanitary Inspections. *Resources*, *9*(12), Article 12. https://doi.org/10.3390/resources9120142

Hijazi, I. H., Krauth, T., Donaubauer, A., & Kolbe, T. (2020). 3DCITYDB4BIM: A SYSTEM ARCHITECTURE FOR LINKING BIM SERVER AND 3D CITYDB FOR BIM-GIS-INTEGRATION. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *V-4–2020*, 195–202. XXIV ISPRS Congress, Commission IV (Volume V-4-2020) - 2020 edition. https://doi.org/10.5194/isprs-annals-V-4-2020-195-2020

Hittmeir, M., Ekelhart, A., & Mayer, R. (2019). On the Utility of Synthetic Data: An Empirical Evaluation on Machine Learning Tasks. *Proceedings of the 14th International Conference on Availability, Reliability and Security*, 1–6. https://doi.org/10.1145/3339252.3339281

Horlings, L. G., Lamker, C., Puerari, E., Rauws, W., & van der Vaart, G. (2021). Citizen Engagement in Spatial Planning, Shaping Places Together. *Sustainability*, *13*(19), Article 19. https://doi.org/10.3390/su131911006

Ibaid, M. (2021). *Digital Government in the State of Palestine: Strategies & Recommendations | Harvard Kennedy School*. https://www.hks.harvard.edu/centers/mrcbg/publications/awp/awp166

Imad, H. U., Akhund, M. A., Ali, M., Pathan, A. A., & Ahmed, A. (2019). Non-Volumetric Pricing is a Threat to Water Reserves. *Civil Engineering Journal*, *5*(2), Article 2. https://doi.org/10.28991/cej-2019-03091256

Itair, M., & Armoush, H. (2024). Unveiling Disparities: Investigating the Gap Between Palestinian Authority Counter Segregation Policies and Local Implementation Amid Deteriorating Conditions in the West Bank. *Global Journal of Human-Social Science*, *24*(F1), 19–29. https://doi.org/10.34257/GJHSSFVOL24IS1PG19

Itair, M., Hijazi, I., Mansour, S., & Shahrour, I. (2024). Empowering Sustainability Advancement in Urban Public Spaces Through Low-Cost Technology and Citizen Engagement. In M. Ben Ahmed, A. A. Boudhir, R. El Meouche, & İ. R. Karaş (Eds.), *Innovations in Smart Cities Applications Volume 7* (pp. 292–299). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-53824-7_26

Itair, M., Hijazi, I., Qanazi, S., Zaidalkilani, S., & Issa, A. (2022a). Localizing Sustainable Development Goals in Strategic Development Planning Procedures. Case Study: Local Development Planning Manual for the Palestinian Cities and Towns. *An-Najah University Journal for Research - B (Humanities)*, *37*(8), 1491–1526. https://doi.org/10.35552/0247.37.8.2074

Itair, M., Hijazi, I., Qanazi, S., Zaidalkilani, S., & Issa, A. (2022b). Localizing sustainable development goals in strategic development planning procedures. Case study: Local development planning manual for the Palestinian cities and towns. *An-Najah University Journal for Research - B (Humanities)*, *37*(8), None-None. https://doi.org/10.35552/0247.37.8.2074

Itair, M., Shahrour, I., & Hijazi, I. (2023). The Use of the Smart Technology for Creating an Inclusive Urban Public Space. *Smart Cities*, *6*(5), Article 5. https://doi.org/10.3390/smartcities6050112

ITU. (2021). *Measuring digital development—Facts and figures 2021*. https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2021.pdf

Jabari, S., Shahrour, I., & El Khattabi, J. (2020). Assessment of the Urban Water Security in a Severe Water Stress Area–Application to Palestinian Cities. *Water*, *12*(7), Article 7. https://doi.org/10.3390/w12072060

Jabbar, W. A., Wei, C. W., Azmi, N. A. A. M., & Haironnazli, N. A. (2021). An IoT Raspberry Pi-based parking management system for smart campus. *Internet of Things*, *14*, 100387. https://doi.org/10.1016/j.iot.2021.100387

Jiménez, A., LeDeunff, H., Giné, R., Sjödin, J., Cronk, R., Murad, S., Takane, M., & Bartram, J. (2019). The Enabling Environment for Participation in Water and Sanitation: A Conceptual Framework. *Water*, *11*(2), Article 2. https://doi.org/10.3390/w11020308

Joia, L. A., & Kuhl, A. (2019). Smart City for Development: A Conceptual Model for Developing Countries. In P. Nielsen & H. C. Kimaro (Eds.), *Information and Communication Technologies for Development. Strengthening Southern-Driven Cooperation as a Catalyst for ICT4D* (pp. 203–214). Springer International Publishing. https://doi.org/10.1007/978-3-030-19115-3_17

Kaplan Mintz, K., Arazy, O., & Malkinson, D. (2023). Multiple forms of engagement and motivation in ecological citizen science. *Environmental Education Research*, *29*(1), 27–44. https://doi.org/10.1080/13504622.2022.2120186

Karvonen, A., Cvetkovic, V., Herman, P., Johansson, K., Kjellström, H., Molinari, M., & Skoglund, M. (2021). The 'New Urban Science': Towards the interdisciplinary and transdisciplinary pursuit of sustainable transformations. *Urban Transformations*, *3*(1), 9. https://doi.org/10.1186/s42854-021-00028-y

Katapally, T. R. (2019). The SMART Framework: Integration of Citizen Science, Community-Based Participatory Research, and Systems Science for Population Health Science in the Digital Age. *JMIR mHealth and uHealth*, *7*(8), e14056. https://doi.org/10.2196/14056

Kelly-Quinn, M., Biggs, J. N., Brooks, S., Fortuño, P., Hegarty, S., Jones, J. I., & Regan, F. (2022). Opportunities, approaches and challenges to the engagement of citizens in filling small water body data gaps. *Hydrobiologia*. https://doi.org/10.1007/s10750-022-04973-y

Kent, E. (2019). Leading urban change with people powered public spaces. The history, and new directions, of the Placemaking movement. *The Journal of Public Space*, *4*(1), 127–134. https://doi.org/10.32891/jps.v4i1.1158

Kobori, H., Dickinson, J. L., Washitani, I., Sakurai, R., Amano, T., Komatsu, N., Kitamura, W., Takagawa, S., Koyama, K., Ogawara, T., & Miller-Rushing, A. J. (2016). Citizen science: A new approach to advance ecology, education, and conservation. *Ecological Research*, *31*(1), 1–19. https://doi.org/10.1007/s11284-015-1314-y

KoboToolbox. (2023). *KoboToolbox*. KoboToolbox. https://www.kobotoolbox.org/

Koenecke, A., & Varian, H. (2020). *Synthetic Data Generation for Economists* (arXiv:2011.01374). arXiv. https://doi.org/10.48550/arXiv.2011.01374

Koop, S. H. A., & van Leeuwen, C. J. (2017). The challenges of water, waste and climate change in cities. *Environment, Development and Sustainability*, *19*(2), 385–418. https://doi.org/10.1007/s10668-016-9760-4

Korakakis, M., Mylonas, P., & Spyrou, E. (2018). A short survey on modern virtual environments that utilize AI and synthetic data. *MCIS 2018 Proceedings*. https://aisel.aisnet.org/mcis2018/34

Kurvinen, A., & Saari, A. (2020). Urban Housing Density and Infrastructure Costs. *Sustainability*, *12*(2), Article 2. https://doi.org/10.3390/su12020497

Landman, K. (2020). Inclusive public space: Rethinking practices of mitigation, adaptation and transformation. *URBAN DESIGN International*, *25*(3), 211–214. https://doi.org/10.1057/s41289-020-00136-4

Land-Zandstra, A. M., Devilee, J. L. A., Snik, F., Buurmeijer, F., & van den Broek, J. M. (2016). Citizen science on a smartphone: Participants' motivations and learning. *Public Understanding of Science*, *25*(1), 45–60. https://doi.org/10.1177/0963662515602406

Lau, B. P. L., Wijerathne, N., Ng, B. K. K., & Yuen, C. (2018). Sensor Fusion for Public Space Utilization Monitoring in a Smart City. *IEEE Internet of Things Journal*, *5*(2), 473–481. IEEE Internet of Things Journal. https://doi.org/10.1109/JIOT.2017.2748987

Lauria, M., & Slotterback, C. S. (Eds.). (2020). *Learning from Arnstein's Ladder: From Citizen Participation to Public Engagement*. Routledge. https://doi.org/10.4324/9780429290091

Lee, K. A., Lee, J. R., & Bell, P. (2020). A review of Citizen Science within the Earth Sciences: Potential benefits and obstacles. *Proceedings of the Geologists' Association*, *131*(6), 605–617. https://doi.org/10.1016/j.pgeola.2020.07.010

Lewenstein, B. V. (2022). Is Citizen Science a Remedy for Inequality? *The ANNALS of the American Academy of Political and Social Science*, *700*(1), 183–194. https://doi.org/10.1177/00027162221092697

Liñán, S., Salvador, X., Álvarez, A., Comaposada, A., Sanchez, L., Aparicio, N., Rodero, I., & Piera, J. (2022). A new theoretical engagement framework for citizen science projects: Using a multi-temporal approach to address long-term public engagement challenges.

Environmental Research Letters, *17*(10), 105006. https://doi.org/10.1088/1748-9326/ac939d

Lingo, R. (2023). *Exploring the Potential of AI-Generated Synthetic Datasets: A Case Study on Telematics Data with ChatGPT* (arXiv:2306.13700). arXiv. https://doi.org/10.48550/arXiv.2306.13700

Lu, Y., Shen, M., Wang, H., Wang, X., van Rechem, C., & Wei, W. (2023). *Machine Learning for Synthetic Data Generation: A Review*. https://doi.org/10.48550/ARXIV.2302.04062

Lytras, M. D., Visvizi, A., Chopdar, P. K., Sarirete, A., & Alhalabi, W. (2021). Information Management in Smart Cities: Turning end users' views into multi-item scale development, validation, and policy-making recommendations. *International Journal of Information Management*, *56*, 102146. https://doi.org/10.1016/j.ijinfomgt.2020.102146

Mansour, S., Sassine, R., & Guibert, S. (2024). Leveraging Diverse Data Sources for ESTP Campus Digital Twin Development: Methodology and Implementation. In M. Ben Ahmed, A. A. Boudhir, R. El Meouche, & İ. R. Karaș (Eds.), *Innovations in Smart Cities Applications Volume 7* (pp. 243–257). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-54376-0_22

Mashhadi, N., Shahrour, I., Attoue, N., El Khattabi, J., & Aljer, A. (2021). Use of Machine Learning for Leak Detection and Localization in Water Distribution Systems. *Smart Cities*, *4*(4), Article 4. https://doi.org/10.3390/smartcities4040069

Masters, K. L., & Team, G. Z. (2019). Twelve years of Galaxy Zoo. *Proceedings of the International Astronomical Union*, *14*(S353), 205–212. https://doi.org/10.1017/S1743921319008615

Maund, P. R., Bentley, J. W., Austen, G. E., Irvine, K. N., Fish, R., Dallimer, M., & Davies, Z. G. (2022). The features and processes underpinning high-quality data generation in participatory research and engagement activities. *Methods in Ecology and Evolution*, *13*(1), 68–76. https://doi.org/10.1111/2041-210X.13746

McKenna, H. P. (2017). Adaptive Reuse of Cultural Heritage Elements and Fragments in Public Spaces: The Internet of Cultural Things and Applications as Infrastructures for Learning in Smart Cities. *2017 13th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS)*, 479–484. https://doi.org/10.1109/SITIS.2017.84

McKinley, D. C., Miller-Rushing, A. J., Ballard, H. L., Bonney, R., Brown, H., Cook-Patton, S. C., Evans, D. M., French, R. A., Parrish, J. K., Phillips, T. B., Ryan, S. F., Shanley, L. A., Shirk, J. L., Stepenuck, K. F., Weltzin, J. F., Wiggins, A., Boyle, O. D., Briggs, R. D., Chapin, S. F., … Soukup, M. A. (2017). Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation*, *208*, 15–28. https://doi.org/10.1016/j.biocon.2016.05.015

Miller, J. A., Khatib, F., Hammond, H., Cooper, S., & Horowitz, S. (2020). Introducing Foldit Education Mode. *Nature Structural & Molecular Biology*, *27*(9), Article 9. https://doi.org/10.1038/s41594-020-0485-6

Min-Allah, N., & Alrashed, S. (2020). Smart campus—A sketch. *Sustainable Cities and Society*, *59*, 102231. https://doi.org/10.1016/j.scs.2020.102231

Ministry of Municipal Rural Affairs and Housing. (2015). *المعايير التخطيطية للخدمات العامة والاقليمية المحلية ومستوياتها المختلفة Planning standards for local public and regional services and their different levels*. https://momrah.gov.sa/ar/node/13020

MoLG. (2013a). *دليل التخطيط العمراني- دليل إجراءات وأدوات إعداد المخططات الهيكلية في الضفة الغربية وقطاع غزة (Urban Planning Manual—A guide to procedures and tools for preparing master plans in the West Bank and Gaza Strip)*. https://procurement-notices.undp.org/view_file.cfm?doc_id=139183

MoLG. (2013b). *دليل تخطيط الطرق والمواصلات في المناطق الحضرية بفلسطين (Guide to Planning Roads and Transportation in Urban Areas in Palestine)*. https://urbanplanninglibrary.blogspot.com/2022/01/ROADS-MANUAL.html

MoLG. (2018). *دليل التخطيط التنموي المحلي (Strategic Development & Investment Plan)* (3rd ed.). https://www.mdlf.org.ps/Document/SDIP%20manual%202018(1).pdf

Moor, T. D., Rijpma, A., & López, M. P. (2019). Dynamics of Engagement in Citizen Science: Results from the “Yes, I do!”-Project. *Citizen Science: Theory and Practice*, *4*(1). https://doi.org/10.5334/cstp.212

Mr, N., & Gyasi, S. (2012, July 15). *Customer Dissatisfaction and Complaining Responses Towards Mobile Telephony Services*. https://www.semanticscholar.org/paper/Customer-Dissatisfaction-and-Complaining-Responses-Mr-Gyasi/3d6682e267ccdaa698c5b8a381eaa6de53646add

Muchunguzi, S. (2022). Participatory management of natural resources in Africa: An imperative policy direction for sustainable development. *Management of Environmental Quality: An International Journal*, *34*(3), 704–720. https://doi.org/10.1108/MEQ-06-2022-0170

Murindahabi, M. M., Takken, W., Hakizimana, E., Vliet, A. J. H. van, Poortvliet, P. M., Mutesa, L., & Koenraadt, C. J. M. (2022). A handmade trap for malaria mosquito surveillance by citizens in Rwanda. *PLOS ONE*, *17*(5), e0266714. https://doi.org/10.1371/journal.pone.0266714

Nachandiya, N., Gambo, Y., Joel, N. B., & Davwar, P. (2018). Smart Technologies for Smart Campus Information System. *Asian Journal of Research in Computer Science*, 1–7. https://doi.org/10.9734/ajrcos/2018/v2i228738

Nardi, F., Cudennec, C., Abrate, T., Allouch, C., Annis, A., Assumpção, T., Aubert, A. H., Bérod, D., Braccini, A. M., Buytaert, W., Dasgupta, A., Hannah, D. M., Mazzoleni, M., Polo, M. J., Sæbø, Ø., Seibert, J., Tauro, F., Teichert, F., Teutonico, R., … Grimaldi, S. (2021). Citizens AND HYdrology (CANDHY): Conceptualizing a transdisciplinary framework for citizen science addressing hydrological challenges. *Hydrological Sciences Journal*, *67*(16), 2534–2551. https://doi.org/10.1080/02626667.2020.1849707

Nascimento, S., Iglesias, J. M. R., Owen, R., Schade, S., & Shanley, L. (2018). Citizen science for policy formulation and implementation. In S. Hecker, M. Haklay, A. Bowser, Z. Makuch, J. Vogel, & A. Bonn (Eds.), *Citizen Science* (pp. 219–240). UCL Press. https://www.jstor.org/stable/j.ctv550cf2.23

Ni, M., & Cattaneo, T. (2019). Design for Urban Resilience: A Case of Community-led Placemaking Approach in Shanghai China. In P.-L. P. Rau (Ed.), *Cross-Cultural Design. Culture and Society* (pp. 207–222). Springer International Publishing. https://doi.org/10.1007/978-3-030-22580-3_16

OHCHR. (2020). *Policy Guidelines for Inclusive Sustainable Development Goals: SUSTAINABLE CITIES AND COMMUNITIES*.

Omotayo, T., Moghayedi, A., Awuzie, B., & Ajayi, S. (2021). Infrastructure Elements for Smart Campuses: A Bibliometric Analysis. *Sustainability*, *13*(14), Article 14. https://doi.org/10.3390/su13147960

Owuondo, J. (2024). Community Engagement in Urban Planning: A Catalyst for Sustainable Development. *International Journal of Research and Innovation in Social Science*. https://rsisinternational.org/journals/ijriss/articles/community-engagement-in-urban-planning-a-catalyst-for-sustainable-development/

Palestinian Central Bureau of Statistics. (2018). *Preliminary Results of the Population, Housing and Establishments Census 2017*. https://www.pcbs.gov.ps/Downloads/book2364-1.pdf

Pallavi, S., Yashas, S. R., Anilkumar, K. M., Shahmoradi, B., & Shivaraju, H. P. (2021). Comprehensive Understanding of Urban Water Supply Management: Towards Sustainable Water-socio-economic-health-environment Nexus. *Water Resources Management*, *35*(1), 315–336. https://doi.org/10.1007/s11269-020-02734-x

Pandeya, B., Uprety, M., Paul, J. D., Sharma, R. R., Dugar, S., & Buytaert, W. (2021). Mitigating flood risk using low-cost sensors and citizen science: A proof-of-concept study from western Nepal. *Journal of Flood Risk Management*, *14*(1), e12675. https://doi.org/10.1111/jfr3.12675

Parkinson, S., Woods, S. M., Sprinks, J., & Ceccaroni, L. (2022). A Practical Approach to Assessing the Impact of Citizen Science towards the Sustainable Development Goals. *Sustainability*, *14*(8), Article 8. https://doi.org/10.3390/su14084676

Paul, J. D., Cieslik, K., Sah, N., Shakya, P., Parajuli, B. P., Paudel, S., Dewulf, A., & Buytaert, W. (2020a). Applying Citizen Science for Sustainable Development: Rainfall Monitoring in Western Nepal. *Frontiers in Water*, *2*. https://www.frontiersin.org/articles/10.3389/frwa.2020.581375

Paul, J. D., Cieslik, K., Sah, N., Shakya, P., Parajuli, B. P., Paudel, S., Dewulf, A., & Buytaert, W. (2020b). Applying Citizen Science for Sustainable Development: Rainfall Monitoring in Western Nepal. *Frontiers in Water*, *2*. https://www.frontiersin.org/articles/10.3389/frwa.2020.581375

Pejovic, V., & Skarlatidou, A. (2020). Understanding Interaction Design Challenges in Mobile Extreme Citizen Science. *International Journal of Human–Computer Interaction*, *36*(3), 251–270. https://doi.org/10.1080/10447318.2019.1630934

Pereira, Â. G., & Völker, T. (2020). Chapter 8—Engaging With Citizens. In V. Šucha & M. Sienkiewicz (Eds.), *Science for Policy Handbook* (pp. 78–95). Elsevier. https://doi.org/10.1016/B978-0-12-822596-7.00008-5

Pineda, V. S. (2022). What is Inclusive and Accessible Public Space? *The Journal of Public Space*, *7*(2), 5–8. https://doi.org/10.32891/jps.v7i2.1607

Pocock, M. J. O., Chapman, D. S., Sheppard, L. J., & Roy, H. E. (2015). *Choosing and using citizen science: A guide to when and how to use citizen science to monitor biodiversity and the environment* (p. 24). https://nora.nerc.ac.uk/id/eprint/510644/

Pocock, M. J. O., Roy, H. E., August, T., Kuria, A., Barasa, F., Bett, J., Githiru, M., Kairo, J., Kimani, J., Kinuthia, W., Kissui, B., Madindou, I., Mbogo, K., Mirembe, J., Mugo, P., Muniale, F. M., Njoroge, P., Njuguna, E. G., Olendo, M. I., … Trevelyan, R. (2019). Developing the global potential of citizen science: Assessing opportunities that benefit people, society and the environment in East Africa. *Journal of Applied Ecology*, *56*(2), 274–281. https://doi.org/10.1111/1365-2664.13279

Polin, K., Yigitcanlar, T., Limb, M., & Washington, T. (2023). The Making of Smart Campus: A Review and Conceptual Framework. *Buildings*, *13*(4), Article 4. https://doi.org/10.3390/buildings13040891

Polko, P., & Kimic, K. (2022). Gender as a factor differentiating the perceptions of safety in urban parks. *Ain Shams Engineering Journal*, *13*(3), 101608. https://doi.org/10.1016/j.asej.2021.09.032

Prandi, C., Barricelli, B. R., Mirri, S., & Fogli, D. (2023). Accessible wayfinding and navigation: A systematic mapping study. *Universal Access in the Information Society*, *22*(1), 185–212. https://doi.org/10.1007/s10209-021-00843-x

Prandi, C., Monti, L., Ceccarini, C., & Salomoni, P. (2020). Smart Campus: Fostering the Community Awareness Through an Intelligent Environment. *Mobile Networks and Applications*, *25*(3), 945–952. https://doi.org/10.1007/s11036-019-01238-2

Project for Public Spaces. (2018, December 31). *What Role can Design Play in Creating Safer Parks?* https://www.pps.org/article/what-role-can-design-play-in-creating-safer-parks

Prudic, K. L., Wilson, J. K., Toshack, M. C., Gerst, K. L., Rosemartin, A., Crimmins, T. M., & Oliver, J. C. (2019). Creating the Urban Farmer's Almanac with Citizen Science Data. *Insects*, *10*(9), Article 9. https://doi.org/10.3390/insects10090294

Radu, L.-D. (2020). Disruptive Technologies in Smart Cities: A Survey on Current Trends and Challenges. *Smart Cities*, *3*(3), Article 3. https://doi.org/10.3390/smartcities3030051

Rambonnet, L., Vink, S. C., Land-Zandstra, A. M., & Bosker, T. (2019). Making citizen science count: Best practices and challenges of citizen science projects on plastics in aquatic environments. *Marine Pollution Bulletin*, *145*, 271–277. https://doi.org/10.1016/j.marpolbul.2019.05.056

Raza, M. S., Tayeh, B. A., Abu Aisheh, Y. I., & Maglad, A. M. (2023). Potential features of building information modeling (BIM) for application of project management knowledge areas in the construction industry. *Heliyon*, *9*(9), e19697. https://doi.org/10.1016/j.heliyon.2023.e19697

Reiner Benaim, A., Almog, R., Gorelik, Y., Hochberg, I., Nassar, L., Mashiach, T., Khamaisi, M., Lurie, Y., Azzam, Z. S., Khoury, J., Kurnik, D., & Beyar, R. (2020). Analyzing Medical Research Results Based on Synthetic Data and Their Relation to Real Data Results: Systematic Comparison From Five Observational Studies. *JMIR Medical Informatics*, *8*(2), e16492. https://doi.org/10.2196/16492

Requier, F., Andersson, G., Oddi, F., & Garibaldi, L. (2020). Citizen science in developing countries: How to improve volunteer participation. *Frontiers in Ecology and the Environment*, *18*. https://doi.org/10.1002/fee.2150

Rieder, E., Schmuck, M., & Tugui, A. (2023). A Scientific Perspective on Using Artificial Intelligence in Sustainable Urban Development. *Big Data and Cognitive Computing*, *7*(1), Article 1. https://doi.org/10.3390/bdcc7010003

Riesch, H., & Potter, C. (2014). Citizen science as seen by scientists: Methodological, epistemological and ethical dimensions. *Public Understanding of Science*, *23*(1), 107–120. https://doi.org/10.1177/0963662513497324

Riyaz, M. (2022). Citizen Science: A Significant Contribution to Biodiversity Monitoring and Conservation. *Computational Biology and Bioinformatics*, *10*, 60–67. https://doi.org/10.11648/j.cbb.20221002.12

Roche, A. J., Rickard, L. N., Huguenard, K., & Spicer, P. (2022). Who's Tapped Out and What's on Tap? Tapping Into Engagement Within a Place-Based Citizen Science Effort. *Society & Natural Resources*, *35*(6), 667–683. https://doi.org/10.1080/08941920.2022.2056668

Roche, J., Bell, L., Galvão, C., Golumbic, Y. N., Kloetzer, L., Knoben, N., Laakso, M., Lorke, J., Mannion, G., Massetti, L., Mauchline, A., Pata, K., Ruck, A., Taraba, P., & Winter, S. (2020). Citizen Science, Education, and Learning: Challenges and Opportunities. *Frontiers in Sociology*, *5*. https://www.frontiersin.org/articles/10.3389/fsoc.2020.613814

Rymarzak, M., den Heijer, A., Curvelo Magdaniel, F., & Arkesteijn, M. (2020). Identifying the influence of university governance on campus management: Lessons from the Netherlands and Poland. *Studies in Higher Education*, *45*(7), 1298–1311. https://doi.org/10.1080/03075079.2019.1616167

Sagers, M. (2020). *How Can Citizen Science be used Effectively Within Environmental Education in order to Foster Environmental Change?* https://core.ac.uk/download/pdf/353812047.pdf

Saleh, A., Rafi, A., Woods, P., Senan, Z., & Marei, K. (2011). An investigation of user participation in the architectural design process in Palestine. *Proceedings - 2011 IEEE Student Conference on Research and Development, SCOReD 2011*. https://doi.org/10.1109/SCOReD.2011.6148787

Salimi, M., & Al-Ghamdi, S. G. (2020). Climate change impacts on critical urban infrastructure and urban resiliency strategies for the Middle East. *Sustainable Cities and Society*, *54*, 101948. https://doi.org/10.1016/j.scs.2019.101948

San Llorente Capdevila, A., Kokimova, A., Sinha Ray, S., Avellán, T., Kim, J., & Kirschke, S. (2020). Success factors for citizen science projects in water quality monitoring. *Science of The Total Environment*, *728*, 137843. https://doi.org/10.1016/j.scitotenv.2020.137843

Sanabria-Z, J., Alfaro-Ponce, B., González Peña, O. I., Terashima-Marín, H., & Ortiz-Bayliss, J. C. (2022). Engagement and Social Impact in Tech-Based Citizen Science Initiatives for

Achieving the SDGs: A Systematic Literature Review with a Perspective on Complex Thinking. *Sustainability*, *14*(17), Article 17. https://doi.org/10.3390/su141710978

Santos-Tapia, C., Verderau, M., Borràs, S., Flórez-Santasusana, M., Flórez, F., Morales, J. J., Moli, P., Borràs, A., Cirach, M., & Ubalde-López, M. (2024). Citizen science and social innovation as citizen empowerment tools to address urban health challenges: The case of the urban health citizen laboratory in Barcelona, Spain. *PLOS ONE*, *19*(3), e0298749. https://doi.org/10.1371/journal.pone.0298749

Sauermann, H., Vohland, K., Antoniou, V., Balázs, B., Göbel, C., Karatzas, K., Mooney, P., Perelló, J., Ponti, M., Samson, R., & Winter, S. (2020). Citizen science and sustainability transitions. *Research Policy*, *49*(5), 103978. https://doi.org/10.1016/j.respol.2020.103978

Schmuderer, S., Zink, R., & Gamerith, W. (2019). Citizen Participation via Digital Maps: A Comparison of Current Applications. *GI_Forum 2019, Volume 7,* 34–46. https://doi.org/10.1553/giscience2019_02_s34

Schnetzer, J., Kopf, A., Bietz, M. J., Buttigieg, P. L., Fernandez-Guerra, A., Ristov, A. P., Glöckner, F. O., & Kottmann, R. (2016). MyOSD 2014: Evaluating Oceanographic Measurements Contributed by Citizen Scientists in Support of Ocean Sampling Day. *Journal of Microbiology & Biology Education*, *17*(1), 163–171. https://doi.org/10.1128/jmbe.v17i1.1001

SciStarter. (2020). *What is Citizen Science*. SciStarter. https://scistarter.org/citizen-science

Shahrour, I., & Xie, X. (2021). Role of Internet of Things (IoT) and Crowdsourcing in Smart City Projects. *Smart Cities*, *4*(4), Article 4. https://doi.org/10.3390/smartcities4040068

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., McCallie, E., Minarchek, M., Lewenstein, B. V., Krasny, M. E., & Bonney, R. (2012). Public

Participation in Scientific Research: A Framework for Deliberate Design. *Ecology and Society*, *17*(2). https://www.jstor.org/stable/26269051

Silvertown, J. (2009). A new dawn for citizen science. *Trends in Ecology & Evolution*, *24*(9), 467–471. https://doi.org/10.1016/j.tree.2009.03.017

Soliman, M., Sulin, L., & Karlıdağ-Dennis, E. (2022). Building Capabilities of Youth Through Participatory Oral History Project: The South Hebron Hills, a Palestinian Case Study. *Journal of Human Development and Capabilities*, *23*(1), 116–135. https://doi.org/10.1080/19452829.2021.2019690

State of Palestine. (2021). *National Development Plan 2021-2023*.

Steinke, J., van Etten, J., & Zelan, P. M. (2017). The accuracy of farmer-generated data in an agricultural citizen science methodology. *Agronomy for Sustainable Development*, *37*(4), 32. https://doi.org/10.1007/s13593-017-0441-y

Stewart, C., Labrèche, G., & González, D. L. (2020). A Pilot Study on Remote Sensing and Citizen Science for Archaeological Prospection. *Remote Sensing*, *12*(17), Article 17. https://doi.org/10.3390/rs12172795

Sullivan, B. L., Aycrigg, J. L., Barry, J. H., Bonney, R. E., Bruns, N., Cooper, C. B., Damoulas, T., Dhondt, A. A., Dietterich, T., Farnsworth, A., Fink, D., Fitzpatrick, J. W., Fredericks, T., Gerbracht, J., Gomes, C., Hochachka, W. M., Iliff, M. J., Lagoze, C., La Sorte, F. A., … Kelling, S. (2014). The eBird enterprise: An integrated approach to development and application of citizen science. *Biological Conservation*, *169*, 31–40. https://doi.org/10.1016/j.biocon.2013.11.003

Swanson, A., Kosmala, M., Lintott, C., & Packer, C. (2016). A generalized approach for producing, quantifying, and validating citizen science data from wildlife images. *Conservation Biology*, *30*(3), 520–531. https://doi.org/10.1111/cobi.12695

Szczepańska, A., Kaźmierczak, R., & Myszkowska, M. (2023). Smart City Solutions from a Societal Perspective—A Case Study. *International Journal of Environmental Research and Public Health*, *20*(6), 5136. https://doi.org/10.3390/ijerph20065136

Tan, S. Y., & Taeihagh, A. (2020). Smart City Governance in Developing Countries: A Systematic Literature Review. *Sustainability*, *12*(3), Article 3. https://doi.org/10.3390/su12030899

The World Bank. (2021). *Palestinian Cities Get a Boost Through Integrated Urban Planning and Innovation* [Text/HTML]. World Bank. https://doi.org/10/14/palestinian-cities-get-a-boost-through-integrated-urban-planning-and-innovation

Turbé, A., Barba, J., Pelacho, M., Mugdal, S., Robinson, L. D., Serrano-Sanz, F., Sanz, F., Tsinaraki, C., Rubio, J.-M., & Schade, S. (2019). Understanding the Citizen Science Landscape for European Environmental Policy: An Assessment and Recommendations. *Citizen Science: Theory and Practice*, *4*(1). https://doi.org/10.5334/cstp.239

Tuzcuoğlu, D., de Vries, B., Yang, D., & Sungur, A. (2022). What is a smart office environment? An exploratory study from a user perspective. *Journal of Corporate Real Estate*, *25*(2), 118–138. https://doi.org/10.1108/JCRE-12-2021-0041

UN DESA. (2015). *Goal 11 | Department of Economic and Social Affairs*. https://sdgs.un.org/goals/goal11

UN General Assembly. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs*. https://sdgs.un.org/2030agenda

UN Habitat. (2015). *Background note by UN Habitat- Proposal for a public open space indicator*. https://unstats.un.org/unsd/post-2015/activities/egm-on-indicator-framework/docs/Background%20note%20by%20UN%20Habitat-%20Proposal%20for%20a%20public%20open%20space%20indicator-EGM_Feb2015.pdf

UN-Habitat (Ed.). (2022). *Envisaging the future of cities*. UN-Habitat.

UNITED NATIONS DEPARTMENT FOR ECONOMIC AND SOCIAL AFFAIRS. (2023). *SUSTAINABLE DEVELOPMENT GOALS REPORT 2023: Special edition*. UNITED NATIONS.

Valks, B., Arkesteijn, M. H., Koutamanis, A., & den Heijer, A. C. (2021). Towards a smart campus: Supporting campus decisions with Internet of Things applications. *Building Research & Information*, *49*(1), 1–20. https://doi.org/10.1080/09613218.2020.1784702

Valks, B., Arkesteijn, M., Koutamanis, A., & Den Heijer, A. (2021). Towards Smart Campus Management: Defining Information Requirements for Decision Making through Dashboard Design. *Buildings*, *11*(5), Article 5. https://doi.org/10.3390/buildings11050201

van Leeuwen, K., Hofman, J., Driessen, P. P. J., & Frijns, J. (2019). The Challenges of Water Management and Governance in Cities. *Water*, *11*(6), Article 6. https://doi.org/10.3390/w11061180

Vaughn, L. M., & Jacquez, F. (2020). Participatory Research Methods – Choice Points in the Research Process. *Journal of Participatory Research Methods*, *1*(1). https://doi.org/10.35844/001c.13244

Villegas-Ch, W., Palacios-Pacheco, X., & Luján-Mora, S. (2019). Application of a Smart City Model to a Traditional University Campus with a Big Data Architecture: A Sustainable Smart Campus. *Sustainability*, *11*(10), Article 10. https://doi.org/10.3390/su11102857

Waddington, H., Sonnenfeld, A., Finetti, J., Gaarder, M., John, D., & Stevenson, J. (2019). Citizen engagement in public services in low- and middle-income countries: A mixed-methods systematic review of participation, inclusion, transparency and accountability (PITA) initiatives. *Campbell Systematic Reviews*, *15*(1–2), e1025. https://doi.org/10.1002/cl2.1025

Wang, J., Nguyen, D. Q., Bonkalo, T., & Grebennikov, O. (2021). Smart governance of urban data. *E3S Web of Conferences*, *301*, 05005. https://doi.org/10.1051/e3sconf/202130105005

Wellenstein, A., & García Mora, M. E. (2021, December 3). *Breaking barriers and reconstructing a disability-inclusive society*. https://blogs.worldbank.org/latinamerica/breaking-barriers-and-reconstructing-disability-inclusive-society

Weyer, D., Bezerra, J. C., & De Vos, A. (2019). Participatory Mapping in a Developing Country Context: Lessons from South Africa. *Land*, *8*(9), Article 9. https://doi.org/10.3390/land8090134

WHO. (2021). *Violence against women*. https://www.who.int/news-room/fact-sheets/detail/violence-against-women

Wijayanti, Y., Fittkow, M., Budihardjo, K., Purwadi, & Setyandito, O. (2020). Sustainable water management: A review study on integrated water supply (case study on special district of Yogyakarta). *IOP Conference Series: Earth and Environmental Science*, *426*(1), 012056. https://doi.org/10.1088/1755-1315/426/1/012056

Wojnowska-Heciak, M., Suchocka, M., Błaszczyk, M., & Muszyńska, M. (2022). Urban Parks as Perceived by City Residents with Mobility Difficulties: A Qualitative Study with In-Depth Interviews. *International Journal of Environmental Research and Public Health*, *19*(4), 2018. https://doi.org/10.3390/ijerph19042018

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. *Landscape and Urban Planning*, *125*, 234–244. https://doi.org/10.1016/j.landurbplan.2014.01.017

World Health Organization. Regional Office for Europe. (2016). *Urban green spaces and health* (WHO/EURO:2016-3352-43111-60341). World Health Organization. Regional Office for Europe. https://apps.who.int/iris/handle/10665/345751

Wu, M., Yan, B., Huang, Y., & Sarker, M. N. I. (2022). Big Data-Driven Urban Management: Potential for Urban Sustainability. *Land*, *11*(5), Article 5. https://doi.org/10.3390/land11050680

Yang, J., Zhao, Y., Zou, Y., Xia, D., Lou, S., Liu, W., & Ji, K. (2022). Effects of Tree Species and Layout on the Outdoor Thermal Environment of Squares in Hot-Humid Areas of China. *Buildings*, *12*(11), Article 11. https://doi.org/10.3390/buildings12111867

Yazdandoost, F., & Yazdani, S. A. (2019). A New Integrated Portfolio Based Water-Energy-Environment Nexus in Wetland Catchments. *Water Resources Management*, *33*(9), 2991–3009. https://doi.org/10.1007/s11269-019-02280-1

Yeager, J. (2021). *Using Technology and Analytics to Enhance Stakeholder Engagement in Environmental Decision-Making* (p. 49). https://www.businessofgovernment.org/report/using-technology-and-analytics-enhance-stakeholder-engagement-environmental-decision-making

Yip, C., Zhang, Y., Lu, E., & Dong, Z. Y. (2022). A hybrid assessment framework for human-centred sustainable smart campus: A case study on COVID-19 impact. *IET Smart Cities*, *4*(3), 184–196. https://doi.org/10.1049/smc2.12038

Zhang, Z., Zeng, Y., Huang, Z., Liu, J., & Yang, L. (2023). Multi-Source Data Fusion and Hydrodynamics for Urban Waterlogging Risk Identification. *International Journal of Environmental Research and Public Health*, *20*(3), Article 3. https://doi.org/10.3390/ijerph20032528

Zheng, S., Li, H., Fang, T., Bo, G., Yuan, D., & Ma, J. (2022). Towards citizen science. On-site detection of nitrite and ammonium using a smartphone and social media software. *Science of The Total Environment*, *815*, 152613. https://doi.org/10.1016/j.scitotenv.2021.152613

Zhou, S. (2019, September 20). *Understanding 'Inclusiveness' in Public Space: Learning from Existing Approaches*. Sustain.Ubc.Ca. https://sustain.ubc.ca/about/resources/understanding-inclusiveness-public-space-learning-existing-approaches

Zooniverse. (2024). *Zooniverse*. https://www.zooniverse.org/