IMPLEMENTING ARTIFICIAL INTELLIGENCE FOR ACCESSIBLE AND SUSTAINABLE TRADITIONAL SETTLEMENTS: CHALLENGES AND OPPORTUNITIES IN THE GREEK CONTEXT

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Abstract
Traditional settlements have unique cultural value, yet their preservation often poses challenges to achieving accessibility and social inclusion for people with disabilities. At the same time, sustainability requirements related to environmental protection, cultural integrity, and long-term viability further complicate interventions in these sensitive environments. The study examines the potential role of Artificial Intelligence (AI) in supporting accessible and sustainable development within Greek traditional settlements, while respecting their historical and architectural character. Through a critical review of current AI-driven applications including real-time obstacle detection, audio-visual navigation assistance, and immersive virtual experiences for physically inaccessible areas, technologies are evaluated for the enhancement of the experience of people with disabilities. The analysis focuses on the regulatory, technical, social, and ethical challenges associated with implementing AI in protected heritage areas, including constraints imposed by preservation policies, data availability, community acceptance, and technological infrastructure. The Greek context is used as a case study to highlight the complexity of integrating innovation into traditional settings. Despite considerable barriers, AI is anticipated to provide significant opportunities regarding accessibility, sustainability, and heritage conservation when applied through interdisciplinary planning and inclusive design approaches. Future policy and practice need to be guided by strategic directions that support inclusive and sustainable traditional settlements through responsible AI integration.

Keywords: traditional settlements' sustainability; accessibility; people with disabilities; artificial intelligence

1. INTRODUCTION

Traditional settlements constitute an important component of cultural heritage, especially in countries such as Greece where architectural continuity and historical and local urban patterns are deeply embedded in the built environment. They represent living cultural landscapes that embody historical development, collective memory, and local identity [12]. As they constitute an essential part of national cultural heritage, they contribute significantly to tourism, local economies, and community cohesion. Nevertheless, the preservation of traditional settlements often conflicts with contemporary accessibility requirements and standards. The urban agenda increasingly emphasizes inclusion, sustainability, and equal participation in public life. International frameworks, and mainly the United Nations Convention on the Rights of Persons with Disabilities (CRPD) [25], the European Green Deal [7], and the 2030 Agenda for Sustainable Development [26, Goal 11], highlight the necessity of ensuring accessible and inclusive environments for all citizens. Within the core framework for the sustainability of cities and communities, the protection of cultural heritage -of which architectural heritage forms an integral part- and also inclusion and accessibility constitute key dimensions. Together, they establish the foundation for the sustainability of architectural heritage and for ensuring access to it for all including persons with disabilities.

Artificial Intelligence (AI) has recently emerged as a transformative technological field with the capacity to support inclusive and sustainable urban development. It can play a crucial role with regard to both the field of inclusion and sustainability and the area of architectural heritage preservation. According to UNESCO [23], AI systems may encompass several methods, such as machine learning including deep learning and reinforcement learning, and machine reasoning including planning, scheduling, knowledge representation and reasoning, search, and optimization. So, Artificial Intelligence refers to computational systems capable of performing tasks that typically require human intelligence, including pattern recognition, decision-making, predictive analysis, and autonomous adaptation [9]. AI applications are increasingly integrated into urban management, transportation systems, and digital governance frameworks [16]. These technologies can provide innovative solutions for navigation assistance, personalized accessibility services, and also for predictive maintenance and environmental monitoring [2]. Heritage preservation can be facilitated by advanced data analysis, digital documentation, and smart management systems [15].

The study examines the potential role of AI in supporting accessible and sustainable development within Greek traditional settlements, and the current AI-driven applications which can be used in these settlements. In this context, it investigates the regulatory, technical, social, and ethical issues linked to the integration of AI technologies within protected heritage environments. It addresses challenges related to conservation regulations, limitations in data accessibility, and levels of community engagement and acceptance.

2. ACCESSIBILITY AND SUSTAINABILITY CHALLENGES IN GREEK TRADITIONAL SETTLEMENTS

Greek context is used as a representative case study, due to the abundance of protected settlements, the diverse topographical conditions and spatial configurations of the settlements, and the robust cultural heritage legislation. The adaptation of Greek heritage settlements to the accessibility standards is challenging due to these settlements' characteristics, the strict preservation regulations and the generally existing concerns regarding the alteration of historical authenticity [12]. The major subject of integration of innovation into traditional settings, generally and especially regarding the provision of services for persons with disabilities, is examined in the Greek context which has specific characteristics. The challenge

of identifying appropriate strategies for Greek traditional settlements' management in conjunction with the presence of multiple and diverse constraints affecting both physical and perceptual accessibility, constitute a key factor in selecting these settlements as the focus of investigation in this study.

Greek traditional settlements' development historically followed needs associated to social, economic, and environmental conditions, very different from those of contemporary cities, and has resulted in their spatial configurations which often conflict with current accessibility standards. These settlements are characterized by architectural complexity, spatial coherence, and, in most cases, a relatively small scale. Each of them has a distinctive architectural identity, enriched by historical significance, collective memory, and a close relationship with the surrounding landscape. Their enduring authenticity and timeless character further contribute to their cultural value. Many of the above characteristics of the Greek traditional settlements may constitute significant barriers to both physical and perceptual access, potentially leading to various forms of exclusion.

Regarding the Greek traditional settlements' geomorphology and their relationship with the natural environment, many of them are mountainous, located on steep slopes in mainland Greece, others in island areas with rocky terrain, on coastal slopes, mainly for the fear of pirates, and some in lowland areas. The topography has historically shaped the settlements' urban fabric. Narrow pathways, irregular street networks, stepped routes, uneven paving, abrupt changes in elevation and limited circulation space often create major challenges firstly for wheelchair users and generally individuals with mobility impairments, and also for people with visual, hearing and intellectual impairments [25], who may experience difficulties navigating such environments. The limited public facilities and transportation options are also crucial factors.

Beyond physical accessibility, the spatial complexity of traditional settlements can also affect perceptual access. The urban structure, the complicated urban fabric, which is, moreover, a blend of physical and cultural elements, the intricate arrangement of buildings, the visual discontinuities, and the limited sightlines, τhe complicated building morphology which may hinder orientation, wayfinding, and spatial understanding, constitute barriers particularly for persons with sensory, cognitive, or intellectual impairments. These persons may therefore experience additional difficulties navigating the above environments independently [3]. The absence of accessible information systems, especially digital information regarding accessible routes, legible signage, and clearly identifiable routes can further reinforce these difficulties. The history of places also often presents complexities in understanding by all. The aforementioned pose considerable accessibility constraints for persons with disabilities. As a result, they frequently encounter physical and intellectual limitations regarding their participation in social and cultural life within protected heritage areas.

Moreover, accessibility in Greek traditional settlements presents a complex challenge due to the need to reconcile inclusive access with the preservation of cultural heritage. The traditional settlements are protected under strict national legislation and conservation frameworks that aim to safeguard their architectural character, urban morphology, and historical authenticity. As a result, accessibility interventions, mainly regarding constructions such as ramps, tactile paving and widening or change of materials of pathways, as well as installation of mechanisms like lifts, elevators and stair climbers, may be restricted when they are perceived as altering the historic fabric or visual integrity of the settlement [12, 22]. Consequently, planners, architects, and conservation authorities are often required to balance the implementation of accessibility measures with heritage protection objectives, seeking solutions that enhance inclusion while minimizing impacts on the cultural significance of the site [5, 12]. This balance is particularly critical in the traditional settlements whose

characteristics regarding complex topography and protected built environments can limit more the range of feasible interventions.

The integration of sustainability considerations further complicates accessibility planning in traditional settlements. These historic environments function as sensitive socio-ecological systems that are increasingly affected by climate change, tourism pressure, infrastructure constraints, and demographic decline. Consequently, accessibility interventions should not only promote social inclusion and equal participation but also contribute to the long-term environmental, cultural, social and economic sustainability of the settlement. Sustainable accessibility strategies must therefore minimize environmental impacts, respect the historic character and authenticity of the built environment, and support the well-being and cohesion of local communities [26, 22]. Such an integrated approach is essential for ensuring that accessibility improvements enhance both the resilience and the heritage value of traditional settlements.

3. THE IMPACT OF ARTIFICIAL INTELLIGENCE IN HERITAGE PRESERVATION, ACCESSIBILITY AND EXPERIENCE

Emerging digital technologies are transforming and revolutionizing the ways cultural heritage is documented, analyzed, restored, reconstructed, and preserved over time. In parallel, they are transforming the ways in which heritage is perceived, interpreted, and experienced by diverse audiences [11]. They facilitate and increase accessibility for researchers, educators, and the public.

By supporting conservation practices, assisting historical research, and creating engaging immersive experiences, these technologies are reshaping the way heritage is safeguarded and transmitted to future generations. The rapid evolution of digital innovation continues to broaden these opportunities. Technologies such as 3D modelling, 3D scanning, and 3D visualization, together with Artificial Intelligence (AI), the Internet of Things (IoT), and augmented and virtual reality (AR/VR), are increasingly employed not only to protect and provide access to cultural heritage, but also to strengthen public awareness, understanding, and appreciation of it [13]. Regarding recent advances, particularly in machine learning, natural language processing (NLP), and computer vision, AI have significantly expanded the scope and capabilities of AI applications. Deep learning techniques contribute significantly to digital restoration, while AI-driven augmented and virtual reality (AR/VR) technologies provide immersive cultural experiences. These innovations enable audiences to remotely explore heritage sites from their own homes [13].

The responsible use of Artificial Intelligence offers significant opportunities to protect and transmit cultural heritage while fostering dynamic, accessible, and innovative cultural experiences capable of engaging and inspiring future generations [28].

3.1 The AI role in Heritage Preservation and Sustainability

The preservation of cultural heritage represents a critical endeavor aimed at safeguarding the tangible and intangible elements that shape human civilization. In recent years, Artificial Intelligence has emerged as a valuable tool in supporting this effort, offering innovative approaches to address challenges such as physical deterioration and damage to cultural sites. Through the application of technologies such as machine learning, computer vision, and natural language processing, AI enables the documentation, digitization, restoration, and protection of heritage, enhancing its preservation. In the field of conservation, Artificial Intelligence algorithms are very important for the identification of damage and the formulation of targeted restoration plans for deteriorated structures. Digital preservation plays

a crucial role in ensuring that cultural assets are accurately documented and stored in high-quality digital formats, reducing the risk of damage or loss over time [24]. Artificial Intelligence has substantially enhanced this process through the use of image recognition and pattern detection technologies [28], assisting the experts and enabling more efficient documentation, analysis, and long-term safeguarding of heritage.

AI also vitally contributes to the protection of cultural heritage sites by addressing physical effects through environmental monitoring. AI-powered sensors and data analytics - by the combination of machine learning algorithms with satellite imagery and remote sensing data- can detect and assess potential risks, threats, environmental degradation, and natural hazards such as temperature changes, humidity fluctuations and air pollution, enabling timely response to reduce environmental impacts. These technologies enable continuous observation of heritage, and necessary precautions can be taken before existing or potential risks damage it [1], which leads to more effective management strategies. A notable example is the collaboration between UNESCO and AI developers in the creation of early-warning systems that utilize remote sensing technologies to identify emerging risks to cultural monuments and historic sites [24, 28].

AI-driven urban systems can also contribute to sustainability by optimizing energy consumption, improving mobility flows, and supporting adaptive environmental management [2]. Digital twins and geospatial AI models allow planners to simulate interventions before physical implementation, reducing the risk of inappropriate modifications in sensitive heritage environments.

The effectiveness of AI applications depends on governance structures, participatory planning processes, ethical safeguards, and interdisciplinary collaboration among architects, urban planners, disability organizations, and local communities [16].

3.2 The AI role in enhancing Heritage Accessibility and Experience

Within heritage environments, AI can support both conservation and accessibility objectives. Ensuring that heritage can be accessed and experienced by diverse audiences, and thus fostering inclusivity, is crucial. Accessibility should be understood as a multidimensional concept that includes not only physical access -namely the capacity for independent attendance, movement, and use of spaces, infrastructure, services, goods, and information- but also perceptual access, which relates to how individuals perceive, interpret, and learn from the environments they encounter. Technology supports the principles of Universal Design in enabling people with disabilities to experience architectural heritage, while digital accessibility can serve as an important complement to physical accessibility. The wide range of disabilities entails specific accessibility requirements that can be addressed through technological interventions.

Regarding physical accessibility, the integration of Artificial Intelligence into assistive technologies has enabled devices and mechanisms such as stair lifts, wheelchair platforms, smart wheelchairs, and voice-controlled mobility systems to provide enhanced safety, greater user autonomy, and improved functionality.

The digitization of architectural heritage contributes to enhancing information provision, wayfinding, and perceptual accessibility. AI-powered technologies provide tailored accessibility solutions helping people with disabilities to overcome barriers that may limit their participation in cultural experiences, and can also accommodate different learning styles and user preferences, creating more engaging and personalized cultural experiences.

It should be emphasized that the experience of architectural heritage is fundamentally linked to the on-site engagement with the architectural environment, which constitutes an authentic and distinctive experience that cannot be entirely replicated through representations.

During the visit to the traditional settlement, individuals, including persons with disabilities, integrate sensory stimuli received through their senses into a comprehensive and personal understanding of the place [14]. The effort is focused on achieving physical access, but there are usually barriers that limit or prohibit the experience. So, the recording of the in situ encountered obstacles, in the open spaces or in the buildings of a traditional settlement, is crucial. The digitization of architectural heritage can contribute substantially to the construction of the heritage experience. The projection of the digital material can be distinguished into: (a) in situ, in the open public space or inside a building, and (b) outside the specific space. In the first case, 3D projections, interactive exhibits and technologically advanced applications highlight the content, maximizing the visitor's experience, and as for the second, there are possibilities for virtual tours and advanced applications [18]. Machine learning algorithms can process large volumes of spatial and environmental data to identify accessibility barriers, monitor structural conditions, and optimize visitor management strategies [27]. Computer vision technologies can support real-time obstacle detection, while natural language processing systems can provide multilingual and voice-based assistance to users with sensory impairments. For instance, text-to-speech and speech-to-text applications enable individuals with visual or hearing impairments to access cultural information through audio descriptions and real-time captions, and in addition AI-driven translation platforms, such as Google Translate and DeepL, facilitate multilingual access to cultural content [28]. The museums have largely implemented AI-enhanced visitor services, thereby expanding access to their collections.

Future developments may further enhance inclusivity through technologies such as haptic-feedback devices that allow visually impaired users to digitally perceive the textures of objects, as well as augmented reality (AR) applications that enable users to interact with virtual replicas of objects through multisensory experiences [29]. These technologies enable users to virtually navigate and explore historic urban areas and other sites, assess them remotely, and access information that supports settlements' tours and cultural exploration [17].

4. CRITICAL REVIEW OF CURRENT AI-DRIVEN APPLICATIONS AND DEVICES FOR IMPLEMENTATION IN GREEK TRADITIONAL SETTLEMENTS

The study includes a critical review of current AI-driven applications and AI enhanced devices and mechanisms for accessibility, which could support accessibility and sustainability in Greek traditional settlements. The main applications, and devices and mechanisms are the following:

a. AI-driven Applications

Smart Navigation and Wayfinding Systems

One of the most promising AI applications concerns intelligent navigation systems for people with disabilities. AI-powered mobile applications can analyze real-time spatial conditions and recommend accessible routes inside the settlement according to individual mobility needs. These systems may combine geospatial data, computer vision, and sensor technologies to identify obstacles such as steps, uneven surfaces, steep inclines, or temporary barriers [6]. In traditional settlements with complex street networks, smart navigation platforms can significantly improve independent mobility. For example, AI systems integrated with GPS and LiDAR technologies can provide voice-guided navigation for visually impaired users. Real-time updates may also help users avoid congested or inaccessible areas during peak tourism periods.

Real-Time Obstacle Detection

Computer vision and deep learning technologies can support obstacle detection via wearable devices, smartphones, or smart wheelchairs [9]. Cameras and sensors identify architectural barriers, moving objects, and environmental hazards while providing immediate audio or haptic feedback to users. In narrow traditional/historic streets where conventional accessibility infrastructure is difficult to install, such AI-supported solutions may offer non-invasive alternatives that preserve architectural authenticity. Similar systems have already been tested in urban mobility projects.

Digital Twins and 4D data visualization

Digital twins are virtual replicas of physical environments generated through AI-supported data analysis and 3D modelling. In Greek traditional settlements, digital twins can support accessibility planning by simulating pedestrian movement, evaluating intervention scenarios, and identifying critical barriers [2]. They can also offer visually impaired users the opportunity to virtually explore traditional settlements, and at the same time provide route optimization and personalized guidance for people with mobility impairments. Furthermore, and given the settlement's well-preserved traditional architecture, historic public spaces, and significant cultural value, a Digital Twin could create a comprehensive digital representation of the settlement by integrating 3D models, geospatial data, historical records, and environmental information.

The advancement of 4D data visualization on cloud-based platforms and the development of 3D digital twin simulations have significantly changed the way heritage sites are navigated, explored, and understood [17]. 4D datasets refer to 3D spatial data enriched with a temporal dimension, and enable the monitoring and analysis of changes over time. Such applications would support the preservation of cultural heritage, the monitoring of building conditions, risk assessment, and the sustainable management of tourism. At the same time, they would provide new opportunities for research, education, and digital exploration, leading to the long-term safeguarding of the settlement's identity and to its sustainability.

Immersive Virtual and Augmented Reality Experiences

Certain heritage sites and buildings cannot be fully adapted with accessibility criteria. AI-supported virtual reality (VR) and augmented reality (AR) technologies can provide alternative forms of cultural participation for people with disabilities [15]. Users can virtually interact with the 3D environment, feeling that they are part of the virtual space. However, a common challenge in 3D reconstruction is generating a large amount of data [1]. Greek traditional settlements' visitors with disabilities would benefit from the implementation of these technologies as immersive digital experiences can enable them explore inaccessible monuments, buildings and sites remotely through interactive simulations. AI-driven personalization systems can adapt content according to user preferences and accessibility needs, including subtitles, audio descriptions, sign-language interpretation, or simplified navigation interfaces.

Intelligent Public Transportation and Mobility Services

AI can also improve accessibility through smart mobility systems connecting traditional settlements with regional transportation networks. Shuttle services and demand-responsive mobility platforms facilitate movement for persons with disabilities, particularly in remote or

island settlements with limited infrastructure [27]. Such systems can also reduce private vehicle dependence and support environmentally sustainable mobility policies in heritage areas, thus safeguarding cultural integrity.

b. AI-enhanced Devices and Mechanisms for Accessibility

Artificial Intelligence technologies are increasingly being integrated into accessibility mechanisms and assistive devices, such as stair lifts, wheelchair platforms, smart wheelchairs, and voice-controlled mobility systems, which elevate safety, autonomy, and user experience. Such mechanisms and devices could be used in Greek traditional settlements to enhance accessibility. Firstly, elevators and accessibility platforms for persons with disabilities, can provide voice command recognition, automatic route, waiting-time optimization and detection of emergencies or falls. In addition, stair lifts can ensure predictive maintenance, as AI analyzes data from sensors and identifies potential faults before they occur, intelligent obstacle detection and movement optimization, as well as usage monitoring to adapt operation to the user's needs. Moreover, smart wheelchairs offer autonomous navigation, obstacle avoidance through cameras and sensors, and environmental recognition using machine learning.

5. CASE STUDY: THE OLD TOWN OF XANTHI AND THE "ECHOES" PROJECT

In Greece, the above mentioned AI-driven applications have been implemented in cities' historic urban areas. Regarding traditional settlements, the Old Town of Xanthi is one of the extremely few cases where advanced technologies for spatial perception and accessibility have been implemented, primarily focused on heritage interpretation and spatial interaction, as demonstrated by the "ECHOES" project.

"ECHOES: Reconstructing the life of traditional settlements through interactive experiences and 3D sound" [19, 20]

"ECHOES" is an innovative Greek research project that reconstructs the daily lives of historical communities through digital mobile applications, interactive storytelling, and 3D spatial sound. Visitors use their smartphones to hear authentic historical soundscapes that make them feel as if the past is springing directly from their surroundings.
Key features of the project include:

- Experience Reconstruction: Grounded in historical documents, the project builds story-worlds with characters, plots, and realistic events staged in actual physical spaces.
- 3D Soundscapes: By incorporating authentic ambient sounds and narrative dialogue, visitors travel back in time while walking through historic streets.
- Pilot Locations: The project developed pilot experiences in two distinct Greek areas:
  - Xanthi's Old Town, bringing the historical multi-cultural heritage of Thrace to life.
  - Historical Center of Athens, reconstructing the daily life of the ancient city.

About the research project

The research project "Echoes" was created by the "Athena" Research Center, under the auspices of the Greek Ministry of Development and Investment, and it was funded by "Greece 2.0 National Recovery and Resilience Plan". The project started the 1st of June 2022 and was completed the 30th of November 2024. Its main objective is the design and development of digital tools and methodology for the creation and presentation of interactive content for the

visitors of cultural sites, especially traditional settlements, by employing the innovative approach of experience reconstruction and cutting-edge technologies, with special focus on 3d sound. Experience reconstruction was based on historical sources relating to life and significant events in the settlement's past, which were used as the foundation for building a narrative world with characters, plotlines, and events. This world, being both realistic and geographically anchored in the actual site, served as a means to revive the life of the settlement. The visitor experiences this story world via a digital mobile app, the content of which goes beyond simple multimedia and encompasses a set of cutting-edge technologies, such as 3d sound and panoramic drawings.

Development methodology

The methodology began with the identification of user needs -experience creators and potential tourists in traditional settlements. The approach aimed to progressively expand the tools on a stable foundation and swiftly address integration issues among various software components, while minimising risks arising from problematic integration or inadequate communication among consortium members. Alongside software development, the project leveraged user interaction results from piloting and evaluations to capture best practices and guidelines. These resources accompanied the produced tools and supported their usage, while also facilitating the development of new corresponding experiences by cultural operators, tourism companies, and other stakeholders.

Scope and objectives

The objective was to cultivate the perception that the story world and its content originate from the visitor's surroundings rather than solely from their mobile device. Practically speaking, this entails the development of augmented reality methods and related technologies as part of the Echoes project. To implement this vision, the project piloted the experience reconstruction methodology and associated technological tools in creating two comprehensive interactive experiences for visitors exploring significant traditional settlements: the Old Town of Xanthi and the Historical Centre of Athens. The ultimate goal is to establish universal tools and methodologies capable of supporting similar immersive experiences in culturally and historically important locations.
The ECHOES project introduces two primary digital tools:
1. A web-based application for crafting interactive experiences.
2. A mobile application for presenting these experiences to visitors.

These tools integrate multiple individual technologies to provide visitors with a profound sense of immersion in a historical world that dynamically unfolds within their actual surroundings.

Interactive Stories

Discover 19th-century Athens and the Old Town of Xanthi through an innovative, sound-driven interactive experience. The Interactive Experience Presentation Tool brings monuments and landmarks to life through immersive soundscapes, storytelling, and visual content. Whether the visitors follow audio-guided routes on a map or explore indoor spaces where content is triggered in real time based on their location, they move at theirr own pace. With each step, voices from the past emerge -stories of people, moments in time, and the atmosphere of bygone eras come alive around them. This is more than a tour, it's a deeply engaging experience powered by cutting-edge audio and real-time geolocation technologies.

Visitors walk the streets, pause at key points, and let the space speak to them through layered multimedia narratives that unfold as they move. They choose when and how to hear each story and how to make it their own.

The Old Town of Xanthi

Visitors stroll through the cobbled streets of Xanthi's Old Town and immerse themselves in an experience that reveals the city's multicultural soul. Through a series of immersive audio walks, they discover the stories and characters that shaped everyday life and social dynamics in the 19th and early 20th centuries. From the Clock Tower and the Konaki of Mousafer Bey to the Club of the Greek Community and the Ahrian Mosque, each stop unveils fragments of a rich and polyphonic history. The soundscapes introduce to figures such as Isaac Daniel, a prominent Jewish merchant, and the famous Frosynoula, Miss Xanthi 1929, as well as Greeks, Turks, Armenians, workers, merchants, and townspeople, brought to life through evocative dialogues and sound environments. The narrations transport visitors to neighborhoods, marketplaces and courtyards of the Old Town. The use of 3D sound and real-time geolocation technology deepens the sense of immersion, transforming the visitor into an active participant in a vivid scene of Xanthi's social life. This is an experience that invites the visitor to hear it, walk it, and live it.

6. ETHICAL CHALLENGES, CONSTRAINTS AND OPPORTUNITIES IN THE GREEK CONTEXT

The growing integration of digital technologies into the cultural heritage sector introduces a range of ethical concerns and human rights-related challenges that demand critical attention. The UNESCO Recommendation on the ethics of artificial intelligence [23] establishes a framework of values, principles, and guidelines intended to promote the responsible and beneficial development and use of AI technologies. The study examines the ethical dimensions associated with the expanding use of technologies such as the Internet of Things (IoT), 3D modelling, artificial intelligence (AI), and augmented and virtual reality (AR/VR) in cultural heritage practices.

The implementation of IoT technologies in preventive conservation introduces several ethical concerns including risks related to unauthorized access, data security, and possible misuse of sensitive information. Likewise, the application of AR/VR systems and 3D technologies, such as 3D scanning and 3D printing, in the preservation of cultural heritage creates ethical challenges for conservation professionals, including questions surrounding the authenticity and accuracy of digital reconstructions, the decontextualization of cultural objects, and issues of cultural appropriation. The potential dissemination of inaccurate or misleading information, as flawed digital reconstructions may distort public understanding of cultural heritage, is undoubtedly a major ethical issue. There are also debates over access, ownership, control, and commercialization of digital replicas and models, mainly because of the absence of a comprehensive legal framework governing the trade and distribution of digital reproductions and replicas [13]. Environmental implications must also be considered, since 3D printing processes consume significant amounts of energy and material resources. In addition, uncertainties remain regarding the long-term safety, resilience, and durability of 3D-printed structures [4], as these technologies have not yet been sufficiently evaluated over extended periods. Moreover, an increased dependence on artificial intelligence may contribute to the gradual decline of traditional conservation techniques and specialist knowledge. As AI technologies become more integrated into heritage preservation practices, it is important to ensure that they support rather than replace the human expertise that has historically played a

fundamental role in the restoration and conservation [13]. Regarding constraints in the regulatory context, the Greek legislative framework strongly emphasizes heritage preservation, so interventions in protected settlements are subject to strict approvals by archaeological and architectural authorities. Although accessibility legislation has gradually expanded, conflicts frequently emerge between universal design principles and conservation regulations [12].

As for possible opportunities, Greece contains hundreds of officially protected traditional settlements characterized by diverse architectural typologies, climatic conditions, and topographical features. Many of these settlements are located in mountainous or island regions where accessibility barriers are intensified. At the same time, Greece has experienced increasing digital transformation initiatives associated with smart cities, tourism innovation, and European Union funding programs [8]. These developments create opportunities for integrating AI technologies into heritage management and inclusive planning regarding the country's traditional settlements.

However, significant obstacles remain. Many municipalities lack the financial resources, technical expertise, and digital infrastructure necessary for AI implementation. Data fragmentation, insufficient geospatial information, and limited interdisciplinary coordination further complicate technological integration. Social acceptance also represents a critical issue. Local communities may perceive advanced technologies or generally the integration of innovation into traditional settings, as incompatible with these cultural environments. Concerns regarding surveillance, privacy, algorithmic bias, and excessive commercialization of heritage sites may generate resistance to AI deployment [16].

7. STRATEGIC DIRECTIONS FOR POLICY AND PLANNING

The successful integration of AI into traditional settlements requires comprehensive policy frameworks combining accessibility, sustainability, and heritage conservation objectives. Governments and local authorities should promote interdisciplinary collaboration among urban planners, architects, computer scientists, disability advocates, and heritage professionals. National and regional policies should support the development of accessible digital infrastructure, open geospatial databases, and pilot projects demonstrating responsible AI applications in heritage contexts [8]. Public funding mechanisms and European Union programs can play a critical role in supporting innovation, especially in smaller municipalities with limited resources. Education and training regarding AI technologies are also of great importance. Professionals involved in heritage management and urban planning require greater awareness regarding AI technologies, universal design principles, and ethical governance standards. At the same time, local communities should actively participate in decision-making processes to strengthen social acceptance and contextual appropriateness. Finally, future planning approaches should adopt adaptive and evidence-based methodologies. AI systems must be continuously tested and evaluated regarding their social impacts, environmental performance, and cultural compatibility. Flexible governance models can facilitate innovation while protecting the historical and symbolic value of traditional settlements. Concerning traditional settlements' resilience and sustainability, enhancement of accessibility and perceptibility of settlements is deemed to constitute a basis for constant and effective addressing of environment's disasters and emergencies [10].

9. CONCLUSION

Traditional settlements represent valuable cultural environments that must simultaneously respond to contemporary demands for social inclusion and sustainability. While heritage preservation often creates constraints regarding physical interventions, Artificial Intelligence

offers new possibilities for addressing accessibility challenges through non-invasive and adaptive solutions. This study demonstrated that AI applications such as smart navigation systems, obstacle detection technologies, digital twins, immersive virtual environments, and intelligent mobility services, combined with AI-enhanced devices and mechanisms for accessibility, can significantly enhance the experience of persons with disabilities within traditional settlements. At the same time, AI can contribute to sustainability objectives through predictive management, optimized infrastructure maintenance, and environmentally sensitive planning processes [2, 27].

The Greek context illustrates both the opportunities and limitations associated with AI implementation in protected heritage environments. Regulatory complexity, limited infrastructure, financial constraints, and social acceptance issues continue to represent significant barriers. Nevertheless, interdisciplinary planning, participatory governance, and ethical AI frameworks can support more inclusive and resilient traditional settlements.

Future research should focus on empirical case studies, user-centered evaluations, and comparative international experiences examining the practical implementation of AI technologies in heritage contexts. Policymakers and practitioners must ensure that technological innovation remains aligned with human rights, cultural preservation, and sustainable development objectives. Through responsible integration, AI can become a valuable tool for promoting inclusive, accessible, and sustainable traditional settlements for present and future generations. By balancing technological innovation with ethical considerations, cultural heritage can be preserved in a sustainable and inclusive way [1]. In order to achieve this, it is necessary to strengthen interdisciplinary cooperation and community engagement.

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