TeMA

Journal of Land Use, Mobility and Environment

print ISSN 1970-9889 e-ISSN 1970-9870
FedOA press - University of Naples Federico II

DOAJ | anvur Rivista scientifica di classe A - 08/F1 | Scopus | WEB OF SCIENCE

NEW CHALLENGES FOR CITIES IN THE TWENTY-FIRST CENTURY

Regenerative Design - Climate Adaptation & Mitigation
Circular Economy - Citizen Agency - Urban Livability

Vol.19 n.1
April 2026

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Published by
Laboratory of Land Use, Mobility and Environment
DICEA - Department of Civil, Building and Environmental Engineering
University of Naples Federico II, Italy

TeMA is realized by CAB - Center for Libraries at University of Naples Federico II using Open Journal System

Editor-in-Chief: Rocco Papa
print ISSN 1970-9889 | online ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n°6 of 29/01/2008

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The cover image was created using an AI tool, taking into account the thematic content of the articles included in this issue.

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TeMA
Journal of
Land Use, Mobility and Environment

TeMA 1 (2026) 151-170
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/11551
Received 5th January 2025, Accepted 8th March 2026, Available online 30th April 2026

CITISENSE. Enhancing urban well-being through smart design, data and AI in Italy's historic centres

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Abstract

Italian historic centres face critical challenges balancing heritage conservation with contemporary needs, particularly in regions like Calabria where smaller settlements experience depopulation, decay, and inadequate services. Traditional smart city frameworks have inadequately addressed these contexts, focusing primarily on contemporary urban environments with adaptable infrastructure. This study examines how GeoAI-enabled urban analysis and participatory design methodologies can enhance urban well-being while preserving cultural heritage in small and medium-sized historic centres. The research develops a replicable methodological framework combining advanced technologies (AI, big data, wearable devices) with Living Lab participatory processes. The approach operationalizes "urban well-being" through three measurable dimensions: physical comfort (route optimization based on weather, terrain, facilities), cultural access (personalized itineraries considering tourist density), and perceived safety (recommendations using social media sentiment, lighting data, population density). Data governance follows GDPR protocols ensuring privacy protection and algorithmic transparency through Explainable AI (XAI). Pilot sites in Calabria represent diverse typologies: peripheral centres, high-tourism destinations, isolated villages, coastal settlements, and centres near natural parks. Expected impacts span individual (enhanced comfort, safety), community (social cohesion, participation), territorial (sustainable tourism, economic vitality), and governance (data-driven resource allocation) levels. The study demonstrates that technology, integrated within strategic vision and participatory practices, can support heritage-respectful urban regeneration oriented toward collective well-being.

Keywords

GeoAI; Living lab; Community engagement; Urban wellbeing; Italian historic centres

How to cite item in APA format

Celani, P., Sardo, D. E., Zupi, M., Tufarelli, M., Bisello, A. (2024). CITISENSE. Enhancing urban well-being through smart design, data and AI. *TeMA - Journal of Land Use, Mobility and Environment*, *19* (1), 151-170. http://dx.doi.org/10.6093/1970-9870/11551

1. Introduction

Rapid advances in geospatial technologies, ICT, and computational power, along with exponential growth of urban big data, have created fertile ground for collaboration between urban planning, smart cities, and GeoScience (Lazzeretti et al., 2023). Recent computational design methods and data-driven approaches fundamentally alter how designers address urban design problems, enabling more objective, evidence-based decision-making (Gün, 2023; Aidaoui et al., 2024).

Technological change plays a fundamental role in understanding and envisioning future urban scenarios. New technology adoption substantially influences city behaviours and usage patterns (Fistola & La Rocca, 2024). Digital Twin (DT), Artificial Intelligence (AI), Internet of Things (IoT), Big Data Analytics, and City Information Modeling (CIM) provide municipal authorities powerful toolsets to make cities smarter, safer, cleaner, and more inclusive (Deng et al., 2021).

As planning, designing, and managing cities undergoes profound change, a renewed cultural approach enhancing informed decision-making based on knowledge is indispensable (Pultrone, 2023). Connected and digital technologies have historically found expression in the smart city paradigm, though defining what makes a city "intelligent" remains contested (Gaglione, 2023). Some authors focus on ICT technologies, sensor networks, and Big Data analysis for efficiency (Li et al., 2020); others emphasize improving quality of life and strengthening human and social capital through IT infrastructure and information management capabilities (Caragliu et al., 2013).

However, integrating advanced technologies in historic centres presents unique challenges inadequately addressed in existing smart city frameworks. Traditional approaches, criticized for technocentric limitations (Angelidou, 2017), focus on contemporary contexts with adaptable infrastructure, while historic centres require balancing: heritage conservation with technological innovation; cultural identity preservation with modern service requirements; physical constraints with contemporary infrastructure needs; and community wellbeing with tourism management.

In Europe, approximately 75% of the population lives in urban areas, projected to reach 80% by 2050. The European landscape comprises predominantly small and medium-sized cities. In Italy, many possess historic centres of extraordinary cultural significance but face management complexity, abandonment, and decay—particularly in regions like Calabria.

Current literature reveals three critical gaps: First, while computational urban design methods have advanced significantly (Koenig et al., 2020), their application remains largely experimental, with limited participatory approach integration (Gün, 2023). GeoAI technologies offer significant potential for sustainable urban planning through machine learning and predictive modelling (Aidaoui et al., 2024), yet implementation in heritage contexts requires careful adaptation.

Second, existing smart city frameworks inadequately address historic centres' specific vulnerabilities and opportunities. Risk governance literature focuses primarily on single-hazard approaches rather than integrated, multi-risk frameworks necessary for complex historic urban systems (Ferramosca & Terracciano, 2023).

Third, insufficient theorization exists on how data-driven tools can enhance rather than replace human-centred, experience-based urban design. Gün (2023) emphasizes that technology-driven urban design must balance computational power with intuitive design thinking, moving "like a pendulum" between traditional and computational approaches.

This study[1] addresses these gaps through a specific research question: How can GeoAI-enabled urban analysis and participatory design methodologies improve urban well-being while preserving cultural heritage in small and medium-sized historic centres? Research objectives are: to develop a replicable methodological framework for GeoAI-based urban regeneration in historic centres; to operationalize "urban well-being" through

[1] The study described in this article moves from the Citisense project, a research proposal developed for participation in the 2024 FISA (Italian Fund for Applied Sciences) Call. The proposal is currently under evaluation

measurable indicators adaptable to historical contexts; to test Living Lab processes for co-creating technology-based urban solutions.

2. Facing the challenge of transitions

Contemporary urban development is shaped by three interconnected transitions: digital, ecological, and cultural. The digital transition extends beyond technological adoption, encompassing fundamental shifts in how cities collect, process, and utilize data to inform decision-making (Kitchin, 2021). The ecological transition addresses climate change mitigation and adaptation, requiring cities to reimagine their metabolic flows and resource consumption patterns (Pinson & Morel Journel, 2016). The cultural transition involves evolving social values, expectations of participatory governance, and redefined relationships between citizens and urban environments. Recognition of these interconnected challenges has catalysed new policy frameworks and conceptual models at international and European levels. The United Nations' 2030 Agenda for Sustainable Development, the European Union's Green Deal, and initiatives such as the New European Bauhaus exemplify coordinated responses across technological, environmental, and social dimensions.

Artificial intelligence's role in achieving the UN 2030 Agenda goals presents a fundamentally ambivalent picture. Recent comprehensive analyses reveal that AI can act as both enabler and inhibitor across the 17 Sustainable Development Goals (SDGs) and their 169 targets (Vinuesa et al., 2020). Positively, AI applications demonstrate significant potential for urban sustainability: predictive algorithms can optimize energy distribution and reduce consumption (SDG 7, 11, 13), machine learning models can enhance public health surveillance and personalized healthcare delivery (SDG 3), and computer vision systems can improve traffic management and reduce emissions (SDG 11, 13). However, this technological optimism must be tempered by acknowledging AI's negative externalities and potential to exacerbate existing inequalities. Algorithmic bias embedded in training data can perpetuate or amplify social discrimination, particularly affecting marginalized urban populations (Eubanks, 2018). AI-powered surveillance system deployment raises fundamental questions about privacy, autonomy, and democratic governance in urban spaces (Zuboff, 2019). Moreover, AI capability concentration in technologically advanced regions and among well-resourced actors risks widening the digital divide between and within cities (SDG 10), creating "smart" enclaves alongside digitally excluded communities. This dual nature necessitates careful, ethically-informed approaches that maximize benefits while actively mitigating risks.

The New European Bauhaus (NEB) initiative[2] represents a paradigmatic shift in conceptualizing relationships between technological innovation, environmental sustainability, and human well-being in urban contexts. Moving beyond purely technocratic approaches, the NEB integrates three inseparable core values: sustainability (addressing environmental challenges through circular economy principles and nature-based solutions), quality of experience (emphasizing aesthetics, design excellence, and cultural richness), and inclusion (ensuring accessibility, affordability, and participation across diverse social groups).

The NEB's transdisciplinary approach, bringing together architects, engineers, designers, artists, scientists, and citizens, resonates strongly with emerging perspectives on urban technology deployment. It recognizes that data-driven and AI-powered tools are not value-neutral instruments but must be consciously oriented toward human-centred outcomes that respect cultural diversity and enhance collective well-being.

The 2030 Agenda goals, combined with the New European Bauhaus vision and emerging technology potential, open new horizons for building truly smart cities, helping overcome long-standing challenges that have hindered this paradigm. The smart city concept has evolved over time, allowing us to identify at least three phases.

[2] New European Bauhaus (NEB) is a policy and funding initiative that makes green transition in built environments and beyond enjoyable, attractive and convenient for all. https://new-european-bauhaus.europa.eu/index_en

The "smart city" notion emerged in the 1990s at the confluence of multiple technological, economic, and urban development trends. Initially, the term was closely associated with information and communication technologies (ICTs) rise and their potential application to urban management and service delivery (Hollands, 2008). Early conceptualizations emphasized digital infrastructure deployment—sensors, networks, databases, and control systems—to enhance operational efficiency in energy distribution, traffic management, and public services (Caragliu et al., 2011). This first-generation smart city model was largely technology-centric and vendor-driven, with major technology corporations promoting comprehensive urban operating systems as solutions to complex urban challenges (Söderström et al., 2014). However, this techno-deterministic perspective often overlooked social, political, and cultural dimensions of urban life, treating cities primarily as systems to be optimized rather than as complex socio-spatial formations shaped by diverse actors, interests, and values (Papa et al., 2013).

The 2010s witnessed a significant critical turn in smart city discourse. Researchers began systematically interrogating assumptions underlying technology-driven urbanism, revealing issues of corporate capture of urban governance, surveillance and privacy concerns, algorithmic bias, and potential for smart city technologies to reproduce or amplify existing social inequalities (Kitchin, 2014). First-generation smart city projects often failed to deliver promised benefits, particularly to marginalized communities, while generating new forms of digital exclusion and spatial inequality (Angelidou, 2017).

This critical scholarship catalyzed a paradigm shift toward more participatory, citizen-centric models positioning residents not as passive recipients of smart services but as active co-producers of urban intelligence. European Union policies have been particularly influential in promoting this evolution, with initiatives such as the European Innovation Partnership on Smart Cities and Communities[3] explicitly foregrounding citizen engagement, co-creation methodologies, and governance innovations alongside technological deployment.

Climate urgency and digital transformation convergence has fundamentally reshaped smart city discourse over the past decade. Contemporary smart city frameworks increasingly recognize that urban intelligence must serve not only efficiency or economic competitiveness but, fundamentally, environmental sustainability and resilience (Bibri & Krogstie, 2017). This integration of ecological imperatives with digital innovation—what scholars term the socio-ecological-digital transition—represents a third major evolution of the smart city paradigm (Yigitcanlar et al., 2019).

3. Integrating technologies into urban planning

With the advent of the new millennium, the urban data landscape has been radically transformed, shifting from small data to big data, in which data generation is continuous, system-wide, fine-grained, relational, and cross-domain (Kitchin, 2014). This production has been accompanied by new analyses for extracting information from vast dynamic datasets, grouped into four main classes: data mining and pattern recognition, data visualization, statistical analysis, and forecasting or optimization (Miller, 2010). These rely on machine learning and increased computing power, enabling a new data-driven science that generates hypotheses and insights "born from data" (Kelling et al., 2009). This has led to the rise of 'urban informatics' (Foth, 2009),a human-computer interaction approach to understanding urban processes, and 'urban science', a computational modelling discipline merging geocomputing, data science, and social physics (Batty, 2013). While urban informatics focuses on human–technology–space interactions, urban science aims to explain and simulate city processes and forecast future scenarios, providing city managers with valuable decision-making tools.

The current frontier of smart cities lies in integrating advanced computational technologies (big data analytics, digital twins, and artificial intelligence) into urban planning and governance. Big data, generated by sensors

[3] The European Innovation Partnership on Smart Cities and Communities (EIP-SCC) is a major market changing undertaking supported by the European Commission bringing together cities, industries, SMEs, investors, researchers and other smart city actors. https://smart-cities-marketplace.ec.europa.eu/sites/default/files/EIP_Brochure.pdf

and mobile devices, complements traditional sources such as census and remote sensing data. Yet transforming this data flood into actionable insights requires robust analytical frameworks, awareness of data quality and bias, and attention to ethical and privacy concerns.

Digital twins, dynamic virtual replicas of physical systems enabling simulation, prediction, and scenario analysis, offer promising opportunities for evidence-based planning (Dembski et al., 2020). Deng et al. (2021) emphasize that, combined with IoT, 5G, blockchain, and AI, digital twins can foster responsive, adaptive smart cities. However, without participatory governance and explicit social and environmental aims, they risk reproducing technocentric smart city limitations.

Artificial intelligence adds new capabilities (pattern recognition, predictive modelling, optimization, and generative design) that are transforming planning practice (Batty, 2018). Machine learning detects hidden urban patterns, predicts trajectories, and generates design alternatives meeting multiple criteria. Recent work on generative AI for digital twins highlights its potential for autonomously producing urban data, scenarios, and 3D models (Xu et al., 2024).

AI has also entered spatial analysis, forming Geospatial Artificial Intelligence (GeoAI), which expands quantitative research possibilities. In spatial planning, GeoAI enhances the analysis, visualization, and simulation of how users perceive and navigate spaces; supports public engagement and collaborative planning; and informs land use, transport, and environmental policy. GeoAI employs two planning methodologies: the top-down, knowledge-based approach and the bottom-up, data-driven one, the latter grounded in ML techniques and now dominant due to its accuracy in defining smart city scenarios (Li & Hsu, 2022). Among ML methods, deep learning, particularly convolutional neural networks (CNNs), is valued for robust feature extraction and projection performance

GeoAI leverages methodological and technical tools from GIScience. In recent years, GIS-based applications have integrated statistical techniques to manage diverse territorial contexts toward smart cities. Their functional integration supports decision design and evaluation, giving rise to Spatial Decision Support Systems (SDSS) or Planning Support Systems (PSS) (Thomas, 2002).

However, incorporating AI into planning raises challenges regarding interpretability, accountability, bias mitigation, and balancing algorithmic recommendations with human judgment (Thakuriah et al., 2017). As Gün (2023) notes, technology-driven design tools reshape designers' engagement with data but cannot replace intuitive and heuristic design skills. Critical approaches are needed to combine technological potential with transparency, fairness, and democratic participation.

Terracciano and Ferramosca (2023), analyzing the Messina case, show that GIS-based risk assessments must be complemented by expert judgment and local knowledge to address urban vulnerability complexity. Their findings reveal that purely technical, optimization-oriented approaches risk neglecting non-quantifiable cultural, social, and identity values essential to historic centre regeneration.

4. The digital opportunity for historic centres. A focus on Calabria

Issues relating to historic settlements represent a shared challenge not only at the national level, but across the entire European Union. In this context, various European policies and initiatives have recognized the strategic value of urban historic heritage as a driver of sustainable development and social cohesion. The EU's New Urban Agenda[4] promotes an integrated approach to sustainable urban development that explicitly includes the enhancement of cultural heritage as a factor in quality of life and territorial attractiveness. The aforementioned New European Bauhaus links the European Green Deal to everyday living spaces, emphasizing

[4] The Urban Agenda for the EU brings together the Commission, national ministries, city authorities and other stakeholders to promote better laws, easier access to funding and more knowledge sharing on issues relevant for cities. https://commission.europa.eu/eu-regional-and-urban-development/topics/cities-and-urban-development/urban-agenda-eu_en#urban-agenda-for-the-eu

the importance of making the green transition accessible, beautiful, and inclusive, with a particular focus on the restoration and redevelopment of existing heritage. The Faro Convention[5] emphasizes the value of cultural heritage for society, recognizing the right of communities to actively participate in its management and enhancement. The EU's green and digital transition strategies[6] emphasize the importance of an integrated approach that combines conservation, technological innovation, and quality of life, promoting smart, sustainable, and inclusive cities and territories. These guidelines are particularly relevant for regions such as Calabria, where the restoration of historic settlements can contribute significantly to territorial resilience and the well-being of local communities. Historic settlements represent a significant heritage for Calabria, although many are unfortunately in a state of deterioration, some even in advanced decay. However, some key centres still have the potential for regeneration, which could significantly improve the territorial and landscape quality of the region, as well as its cultural and historical-artistic offerings. Particularly relevant is the heritage of smaller historic centres, a distinctive feature of Italy and Calabria, which constitute a widespread network of identity and cultural landmarks often neglected by traditional urban policies. The central challenge concerns the liveability and attractiveness of Calabrian historic centres, which require an integrated approach capable of addressing the multiple and diverse dimensions of contemporary transition. Legambiente's *Urban Ecosystem Report*[7], with the exception of the positive performance of the city of Cosenza (thirteenth and the only city in the south among the top 15), ranks the other four principals centres (Catanzaro, Crotone, Vibo Valentia, Reggio Calabria) among the worst 10 Italian cities, with a significant deficit in the field of urban services. The Sole 24 Ore *Quality of Life Survey*[8] also ranks the five Calabrian provinces in the bottom twenty positions, highlighting poor performance in terms of services for children, the elderly, and women, demonstrating the need for targeted interventions to improve social inclusion and public well-being. However, these data refer mainly to larger Calabrian settlements and do not provide a complete picture of the condition of smaller historic centres. Recent studies and research on small Calabrian villages have highlighted the complexity and multidimensionality of the challenges that characterize these contexts. Villages with fewer than 5,000 inhabitants, which represent 70% of Italian municipalities and are particularly numerous in Calabria (source: ANCI), face structural problems such as progressive abandonment, deterioration of the building stock, insufficient basic services, limited accessibility, and accelerated depopulation (Francini et al., 2012). Specific studies on the Calabrian context (Giuliani et al., 2021) have analysed the risk factors linked to the seismic vulnerability of the historical heritage of villages, highlighting how exposure to environmental risks (seismic, hydrogeological, instability) is intertwined with phenomena of socio-economic marginalization, creating conditions of systemic fragility. Research conducted on inland areas has documented the dynamics of depopulation and demographic aging that characterize the villages of inland Calabria, with some of the highest rates of demographic decline in the country (De Rossi, 2018). At the same time, these studies recognize the intrinsic value of these centres in terms of architectural, landscape, and cultural heritage. Teti's work (2017, 2022) on abandoned villages and the remaining population in inland areas of Calabria has highlighted not only the rich identity and culture of these places, but also the forms of creative resistance and local bottom-up regeneration strategies. More recent analyses (Viesti, 2021; Carrosio, 2019) emphasize how smaller villages can represent laboratories of social innovation and alternative models of development, provided that

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5 https://www.coe.int/en/web/culture-and-heritage/faro-convention

6 https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/twin-green-digital-transition-how-sustainable-digital-technologies-could-enable-carbon-neutral-eu-2022-06-29_en

7 Since 1994, Legambiente has published the Urban Ecosystem Report every year, produced in collaboration with Ambiente Italia and Il Sole 24 Ore, which measures the environmental performance of Italian cities. The ranking is based on twenty indicators that are normalized according to their distance from the reference threshold. The 2024 Report is available at the link: https://www.legambiente.it/wp-content/uploads/2021/11/Ecosistema-Urbano_libro2024.pdf

8 Published annually since 1990, it examines 90 indicators relating to six macro-categories (wealth and consumption; business and work; environment and services; demography, society, and health; justice and security; culture and leisure). The 2024 ranking is available at: https://lab24.ilsole24ore.com/qualita-della-vita/tabelle/

differentiated policies and strategies are implemented that take into account the specificities of smaller contexts, their endogenous potential, and the need to strengthen essential services and physical and digital connectivity. Unlike contexts characterized by overtourism, Calabria and its smaller historic centres suffer mainly from undertourism, a condition of underutilization of tourism potential accompanied by deficiencies in essential services and quality of daily life. The primary objective must therefore be the well-being of resident communities, pursued through the improvement of services, accessibility, and economic opportunities. Restoration work must allow for the functional adaptation of heritage assets so that they can serve residential or tourist purposes, while protecting their historical and cultural character. Furthermore, in a region such as Calabria, which is highly exposed to environmental risks, conservation and enhancement objectives must also include the assessment of the causes and risk factors that threaten the integrity and survival of these historic areas. An effective protection and enhancement policy must integrate economic, social, urban, and building policies, promoting the introduction of services, accommodation, and hospitality options. This integrated approach must recognize the specific characteristics of smaller contexts and promote the liveability and attractiveness of historic centres as an essential condition for the authentic and lasting regeneration of the Calabrian territory. In this scenario, new digital and computational technologies can play a strategic role in enhancing the well-being and liveability of smaller historic centres, overcoming some of the structural limitations that characterize these contexts.

5. Methodology

From a methodological perspective, the challenges described earlier are addressed through two main approaches: integrating innovative technologies and using Living Labs for community engagement.

5.1 Technological approach

The Citisense approach aims to leverage advanced technologies, such as Artificial Intelligence (AI), big data, and wearable technologies, to facilitate the transformation of historic centres into intelligent, resilient, and citizen-centred environments. Specifically, it focuses on the following areas:

AI-Driven data analysis and integration

Complex data sets subjected to advanced AI-driven analysis come from various sources, including personal devices (such as wearables, smartphones, apps), public interfaces (QR codes, signage, access to public spaces), and databases (such as geolocation data) in an intelligent AI-powered system. Depending on the different data sources, the information collected may include:

- Personal data from wearable devices and mobile applications (e.g., fitness data, health monitoring);
- Geolocation data (public space usage patterns) to optimize the use and management of public spaces;
- Statistical data related to urban resource consumption and access of public services;
- Environmental data, such as weather conditions or dangerous situations (extreme temperatures);
- Sentiment analysis on social media to assess perceptions of safety and comfort.

This data is managed in compliance with the European Union's General Data Protection Regulation (GDPR)[9], requiring explicit and informed consent, anonymization protocols (K-anonymity and spatial and temporal data aggregation), and data retention and deletion rules. Furthermore, the application of a Data Protection Impact Assessment (DPIA) allows us to identify risks (re-identification from location trajectories; discrimination from algorithmic bias in route recommendations; invasion of privacy from continuous monitoring; data breaches; secondary uses beyond the stated purposes) and define mitigation measures (differential privacy techniques

[9] https://gdpr-info.eu/

by adding calibrated noise to aggregated data; fairness audits of AI algorithms by testing for biases between demographic groups; strictly enforced data minimization and purpose limitation; end-to-end encryption for data transmission; transparent documentation of all data uses).

System integration for citizen wellbeing and urban management

Collecting and organizing the data described above allows us to provide citizens with informative feedback through dynamic maps, customized based on user preferences and real-time conditions, to improve their level of urban well-being. Urban well-being is defined as a combination of physical comfort, access to culture, and perceived safety.

- Physical comfort. Real-time maps suggest routes for pedestrians based on weather conditions (sunny or shaded areas), route difficulty (uphill or downhill), and the presence of public facilities (parks, benches, fountains, etc.). Alerts are available to highlight potentially dangerous areas to avoid temporary adverse weather events (heavy rain, flooding) or scheduled activities (construction sites, noisy activities, etc.).
- Access to culture. Urban well-being also includes the ability to access artistic and architectural heritage and urban services. To this end, the feedback provided includes information on areas that could improve the visitor experience: uncrowded squares or less frequented scenic spots, contemporary architecture or street art, traditional venues or attractive contemporary areas. Visit itineraries are customized based on user preferences.
- Perceived safety. In this case, the suggestions focus on safer and better-lit routes for nighttime mobility, reducing the perceived risk of walking alone at night, based on data collected from social media, public lighting, and population density. It uses sentiment data extracted from social media to highlight areas that might be perceived as less safe.

Citizen experience and multi-access visualization

Users access information both through immediate data visualization on personal devices and by enhancing the physical urban environment. This latter aspect draws on suggestions from community engagement initiatives, with the aim of highlighting and promoting " well-being places" located in the urban context. "Well-being places" are public spaces identified through participatory mapping (as part of Living Labs) and validated by composite scores that combine assessments of aesthetic quality and frequency of social interaction. Visualization is therefore intended as a multi-level offering tool, consisting of:

- AI-generated insights, which will be displayed through interactive dashboards accessible via smartphone;
- Physical touchpoints and visualization elements, such as totems or information points located in public spaces;
- Access to relevant information identified in places classified as "well-being places".

This system offers a user-friendly experience, allowing citizens to interact with their urban environment in ways that optimize safety, comfort, and efficiency, while also enabling local authorities to dynamically manage public resources and spaces.

5.2 Living lab: community design and engagement

The implementation of Living Labs represents a key strategy in managing urban participatory processes. These environments bring together companies, public institutions, universities, and citizens in public–private–people partnerships (4Ps) to test and develop innovations in real-world scenarios (Westerlund & Leminen, 2011).

Introduced in the 1990s and consolidated in 2006 with the European Commission’s initiative (Dutilleul et al., 2011), this model effectively bridges the gap between technological development and user needs by

integrating technical expertise with creativity. Living Labs embody a philosophy of mediation between top-down institutional approaches and bottom-up citizen initiatives (Coenen et al., 2014).
In urban Living Labs, citizens can assume multiple roles, ranging from simple informants to testers, collaborators, and co-creators in the development process (Juujärvi & Pesso, 2013). Their participation often stems from a connection to the territory and a sense of belonging to the community (Horelli, 2013). Municipal administrations act as facilitators, orchestrating interactions among different stakeholders.
This approach fosters participatory innovation in smart cities by emphasizing the role of users as innovators and promoting effective multi-stakeholder collaboration. These are environments in which the openness of innovation manages to transcend the organizational infrastructures that are traditionally operating in the city and to invent new institutional figures for, or ways of, dialoguing between citizens and institutions (De Bonis et al., 2014).
At the international level, several initiatives have demonstrated the effectiveness of the Living Lab model, offering valuable lessons for its implementation. The European Network of Living Labs (ENoLL), founded in 2006, is the most significant international network of Living Labs, bringing together over 400 active initiatives worldwide (Schuurman et al., 2016). ENoLL's experience has highlighted the importance of the long-term sustainability of Living Labs, the creation of standardized methodologies for evaluating results, and the need to balance commercial interests and social benefits (Leminen et al., 2012). Other relevant experiences include the Amsterdam Living Lab, which has developed innovative solutions for urban mobility through collaboration between citizens and technology developers and the Manchester Urban Living Lab, focused on energy sustainability and community engagement (Voytenko et al., 2016).
These practices have shown that the success of Living Labs depends on the ability to maintain genuine citizen engagement beyond the initial phase, the effective integration of user data and feedback into decision-making processes, and the creation of flexible governance structures that allow for adaptation to local needs (Steen & van Bueren, 2017).
In conclusion, three main advantages can be identified from the implementation of Living Labs in cities (Veeckman & van der Graaf 2015): i) they facilitate citizen participation and collaboration; ii) they enable co-creation processes in urban settings; iii) they empower citizens.
Citisense Living Labs are conceived as dynamic spaces for real-life testing, co-design, and open innovation, where citizens and stakeholders collaborate to develop and validate smart city technologies. The focus will be on creating solutions that enhance urban safety, social wellbeing, and quality of life in Italian historic centres. The Living Lab methodology emphasizes a user-centred approach, ensuring that the technologies developed respond to real urban needs.
The methodology is based on four key phases:

Community involvement and co-design

Citizens and administrations are involved in a participatory design process, playing an active role in co-creating solutions to address urban challenges, thereby gaining a sense of ownership of the ideas developed.
Participants are recruited through different channels: institutional (government websites and social media); third sector (in collaboration with local, cultural, environmental, or neighbourhood associations); educational institutions (secondary schools to involve young people); tourist offices (to capture the perspective of visitors). The inclusion criteria provide for distribution among different categories of users: residents, visitors, key stakeholders (local entrepreneurs, cultural operators, municipal officials); with a focus on sampling strategies to achieve a uniform distribution in terms of age groups, gender, socio-economic status, mobility profiles, and levels of digital literacy.
The phases and activities of the living lab include:

- Workshops, brainstorming sessions, and focus groups to identify local needs, define objectives, and co-design smart urban solutions;
- Co-design to enable participants to collaborate on prototyping and testing technologies, providing feedback on how well they meet their needs, thus promoting mutual learning between users and designers;
- Continuous feedback cycle to ensure constant citizen involvement and make iterative improvements to technologies based on real-time data and user feedback.

Laboratory governance and citizen training

Stakeholder coordination is ensured by the presence of a Living Lab manager (responsible for day-to-day coordination, communication with participants, logistics and documentation management) and a Panel manager (responsible for participant recruitment, database management and engagement maintenance). In general, the staff responsible for managing Living Labs takes on the task of facilitating participants, ensuring that the user-centred design approach is maintained and that citizens feel comfortable adopting the technology.

To this end, citizens participating in Living Labs are trained in the use of the smart technologies being tested (e.g., accessing data via dashboards and using dynamic maps). These sessions focus on facilitating digital learning and familiarizing citizens with AI-based systems, avoiding the phenomenon of the "AI black box." This approach promotes social equity and ensures that the benefits of smart city solutions are accessible to all.

Community ICT interaction and data access

The project focuses on developing an intuitive user experience that allows citizens to easily interact with the technologies being tested and developed, ensuring a multi-channel data access system and high-quality design. The methodology guarantees:

- Data visualization tools. Interactive dashboards accessible via smartphone provide real-time information (e.g., personalized route suggestions, safety alerts, and cultural recommendations);
- Physical touchpoints. Information kiosks and public access points complement digital access, ensuring that even those less familiar with ICT tools can interact with the system. These contact points are located in strategic locations, such as libraries or tourist centres, providing real-time information for all citizens.

The user interface is designed with an inclusive approach, ensuring that the experience is accessible to users with different levels of digital literacy.

Scalability and transferability of solutions

To enable comparative analysis and assess the transferability of solutions, the pilots (described in the previous paragraph) share: common data collection protocols (standardized sensor deployment, comparable survey tools), a shared technology platform, parallel Living Lab timelines (synchronized phases for cross-site learning), and inter-pilot exchanges (for knowledge sharing).

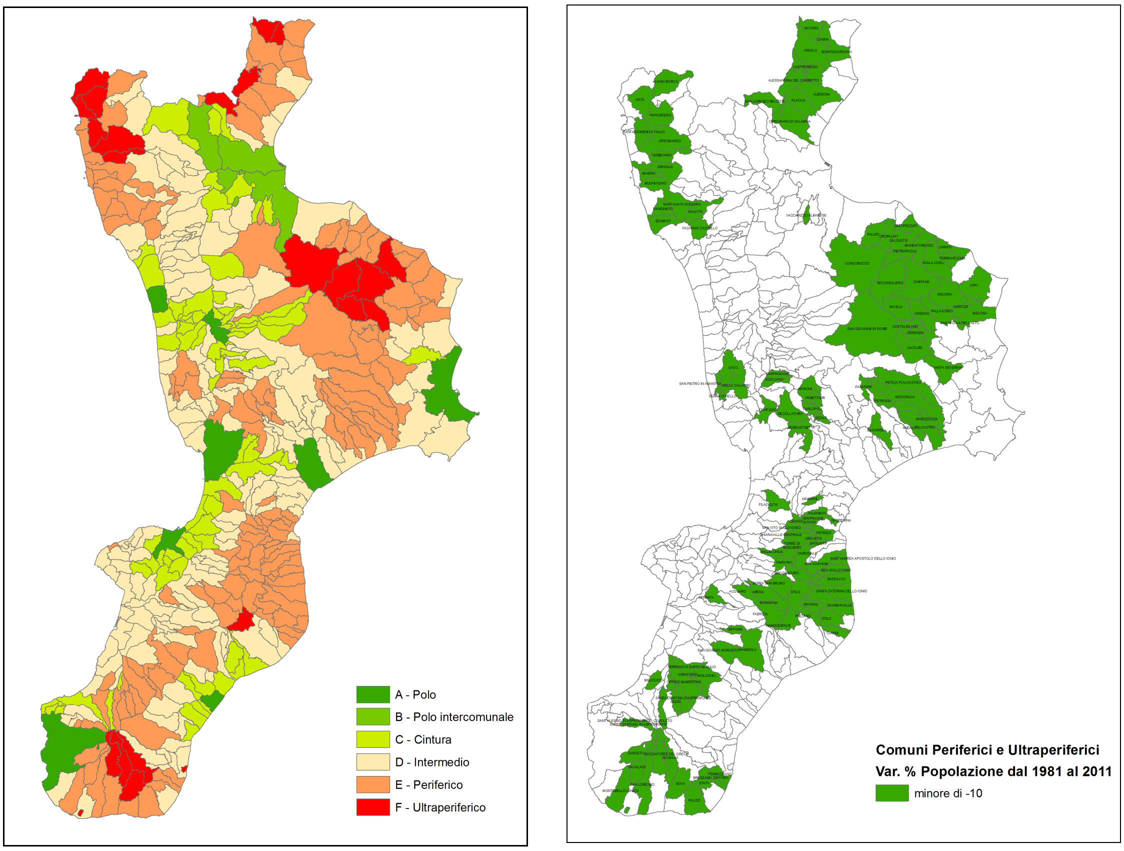
5.3 Selection of pilot

Within the Calabria region, identified as the experimentation area, criteria were established for selecting pilot municipalities to ensure they reflect a comprehensive taxonomy of the various types of historic centres in the territory. These diverse settings will allow the project to test its solutions across different urban environments, ensuring that the technologies developed are adaptable and scalable to varying challenges.

Calabria has a complex and articulated settlement pattern, characterized by 404 municipalities distributed over a predominantly mountainous territory (53.5% of municipalities are entirely mountainous) that is home to

28% of the regional population[10]. The Calabrian territory is affected by significant demographic and socioeconomic dynamics that have profoundly influenced the evolution of historic centres. Between 1951 and 2019, while the main urban centres maintained relative demographic stability, the inland areas of southern Italy lost a total of 1.2 million residents, with an average annual rate of decline of -2.5‰, and one in three municipalities has been systematically losing population since 1951 (Bianchino et al., 2022). In Calabria, this trend is reflected in a continuous demographic decline: between 2020 and 2024, the region recorded a net loss of 28,459 inhabitants, distributed across all provinces.

According to the classification of the National Strategy for Internal Areas (SNAI)[11] a significant proportion of Calabrian municipalities fall into the 'intermediate', 'peripheral' and 'ultra-peripheral', characterized by greater distance from essential services (health, education, rail transport) and by phenomena of territorial marginalization. The population of Calabria's internal areas is on average older than that of urban centres, with an old-age index that reaches over 223 elderly people per 100 young people in ultra-peripheral municipalities, compared to 178.8 in urban centres. The Calabria Region has identified seven SNAI areas for the 2021-2027 cycle, comprising a total of 58 municipalities in the initial pilot areas[12].



(a) (b)

Fig.1 (a) Classification of inner areas in Calabria (b) SNAI intervention areas in Calabria

From a socioeconomic point of view, inland areas of Calabria have higher levels of poverty risk (14.3-14.4% in peripheral and ultra-peripheral municipalities) than urban centres, although the incidence of absolute poverty is distributed in a more complex way across the territory (Bianchino et al., 2022). These dynamics are intertwined with the presence of a significant historical and cultural heritage and with diverse tourism

10 Data taken from "Rapporto Montagne Italia 2025", Rubbettino Editore.
11 https://www.agenziacoesione.gov.it/strategia-nazionale-aree-interne/
12 https://calabriaeuropa.regione.calabria.it/wp-content/uploads/2024/05/DGR-n_490-del-27.11.2015 - Approvazione-Strategia-Regionale-per-le-Aree-Interne.pdf

opportunities, ranging from isolated villages of scenic beauty to coastal centres with high tourist appeal, such as Tropea, which attracts significant national and international flows, to the peripheral historic centres of major urban areas.

In light of these general considerations on the structure of the regional territory, the selection of pilot sites was carried out using a multi-criteria framework that considers the following aspects: Demographic criteria (population size and density, demographic trends, age structure); geographical criteria (topography, accessibility, environmental risks, climate zone); socio-economic criteria (employment indices, tourist intensity, infrastructure quality); heritage/cultural criteria (presence of cultural sites, integrity of the historic centre, cultural vitality, state of the building heritage).

The application of these criteria resulted in the selection of pilot sites, which are outlined below in both qualitative and quantitative terms:

- Historic centres that have become peripheral due to subsequent urban expansions, yet still retain administrative and representational functions. These areas are affected by housing issues, such as the replacement of residents with socially disadvantaged groups, social insecurity, and the lack of adaptation to contemporary life. While they typically hold historical and architectural heritage, they attract only modest tourism flows and are often subject to selective rehabilitation efforts.
- Historic centres with intense tourism flows, representing a few cases (e.g., Tropea, Pizzo Calabro) that attract significant national and international tourist influxes. These areas often exceed their carrying capacity during certain times of the year, which is increasingly frequent and intense, leading to problems related to mobility, liveability, environmental pressure, and the overall enjoyment of these spaces.
- Isolated historic villages, among the most characteristic elements of the regional settlement system, face depopulation, ageing, and abandonment. Situated within valuable landscape or environmental settings that enhance their value, these villages are often far from essential services and are classified as ultra-peripheral centres under the taxonomy of Internal Areas. They hold historical and cultural values that could be leveraged to attract niche tourism.
- Coastal historic centres, which are of two main types: fishing villages located near the coast and mid-coastal centres that have expanded along the shoreline, forming modern settlements known as "marine". These areas experience seasonal population fluctuations due to the presence of numerous "second homes" used in the summer and return tourism from emigrants.
- Historic centres near Natural Parks. The central spine of Calabria is continuously intersected by three national parks: Pollino National Park, Sila National Park, and Aspromonte National Park. While the perimeters of these protected areas often exclude inhabited centres, these towns are still strongly influenced by their proximity to the parks and the relationships they maintain with these natural areas.

Fig.2 qualitative description of the pilot sites

Each of these urban settings provide a unique context for testing the smart city technologies developed within the four intervention domains of the project, ensuring a broad application of solutions.

6. Discussion

Through the integration of planning, regeneration and Geo-AI, the Citisense project sets a series of objectives aimed at promoting the liveability and attractiveness of historic centres, with particular attention to the heritage of smaller historic centres, which are a distinctive feature of Italy. In particular:

- Enhancing citizens' perceived wellbeing and comfort by improving individual rewarding experiences for both residents and visitors. This objective focuses on improving the individual urban experience by creating personalized journeys that take into account different preferences, such as physical comfort (shade or sun, noise levels), emotional well-being (safety and personal security), and aesthetic preferences and interests (art, architecture, or cultural heritage). By delivering dynamic, data-driven maps and recommendations based on real-time data, the project aims to tailor the experience to the specific needs of residents, tourists, and other urban users.
- Ensuring public spaces are accessible, safe, and suitable places of interaction by fostering social interaction, community engagement and inclusivity. The objective targets the creation of inclusive public spaces that foster social interaction and community cohesion. By creating accessible and liveable urban environments, cultural divides are reduced, improving the experience of both locals and visitors, ensuring that urban spaces can accommodate diverse needs. The system is also open to feedback and suggestions from city users.
- Support urban governance by enabling local governments to manage urban resources more efficiently using big data, thus anticipating urban needs and providing timely and dynamic action. Local governments face challenges in managing limited urban resources and maintaining public services in historic centres. Data-driven governance systems that provide real-time information on urban needs help city governments make informed and dynamic decisions. By anticipating demand, the system allows for more efficient urban management, reducing congestion and improving the overall quality of life for citizens and increasing sense of belonging.

All aforementioned objectives align on a wider scope with the New European Bauhaus (NEB) initiative by combining beauty, functionality, and sustainability criteria, to sustain the development of cities that are human-centred and resilient.

6.1 Potential socio-economic impacts

The socio-economic impacts resulting from the Citisense approach operate at various levels (individual, community, territorial, public administration).

Individual impact

At individual level the project ensures a consistent impact, given that access to information will be conveyed via real-time data to citizens while they carry out ordinary activities. Immediateness of access to such new data and tools significantly enhances the comfort, matching simultaneously with activities that citizens carry out as a part of their relevant interests associated with their mobility, or by enjoyment of cultural experience. The typical use of dynamic maps does not currently foresee access to a wellbeing dataset, as proposed by Citisense. A brand-new set of information can be widely perceived by citizens as a tangible effort to meet their real needs. Indeed, the population is made up of different individuals, with varying characteristics that shape individual perception, for example in relation to age, physical mobility or limitations, emotional stress, etc. As a result, increasing citizens' and tourists' confidence in using public spaces, as well as the perceived individual safety provides for more attractive cities for residents and visitors.

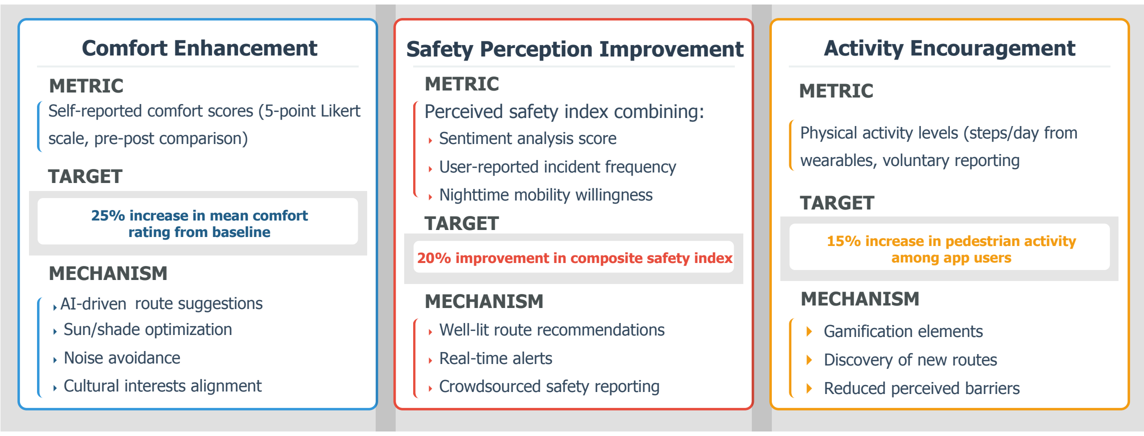


Fig.3 Individual impact assessment metric

Community impact

The activities carried out within the framework of the Living Labs help to foster a sense of belonging and responsibility among residents. As citizens collaborate with local authorities, researchers, and businesses, they develop a shared vision for the future of their cities, thereby strengthening social cohesion. This aspect is particularly important, as it contributes to creating a favourable environment in which smart city services can operate effectively.

This is a significant impact, as it relies on the relational bonds within a community and strengthens its ability to be resilient, supportive, and inclusive.

More cohesive cities are certainly a fundamental foundation that preserves the integrity and authenticity of historic centres themselves, as they help reduce depopulation and promote the inclusion of disadvantaged groups in civic initiatives.

Impact assessment metric:

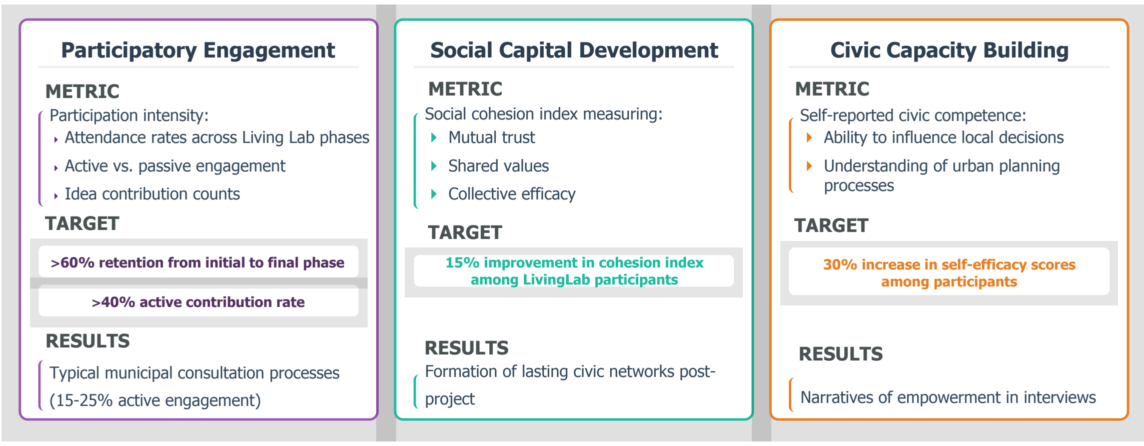


Fig.4 Community impact assessment metric

Territorial impact

The Citisense approach enhances cultural tourism experiences by enabling visitors to access personalized information and insights, such as recommendations on destinations, visiting times, and itineraries, which can be regarded as smart tourism services.

Emphasizing visitor well-being represents an advancement in both the concept and the experience of tourism, as it entails, for instance, the possibility of avoiding congestion peaks by suggesting alternative routes and visiting schedules. Ultimately, this contributes to redefining the notion of "well-being places" in relation to situational and emotional perceptions.

Such an enhanced qualitative service generates positive territorial impacts, fostering more rewarding visitor experiences and promoting economic growth for micro and small enterprises, thereby paving the way for greater economic vitality and urban regeneration.

Impact assessment metric:

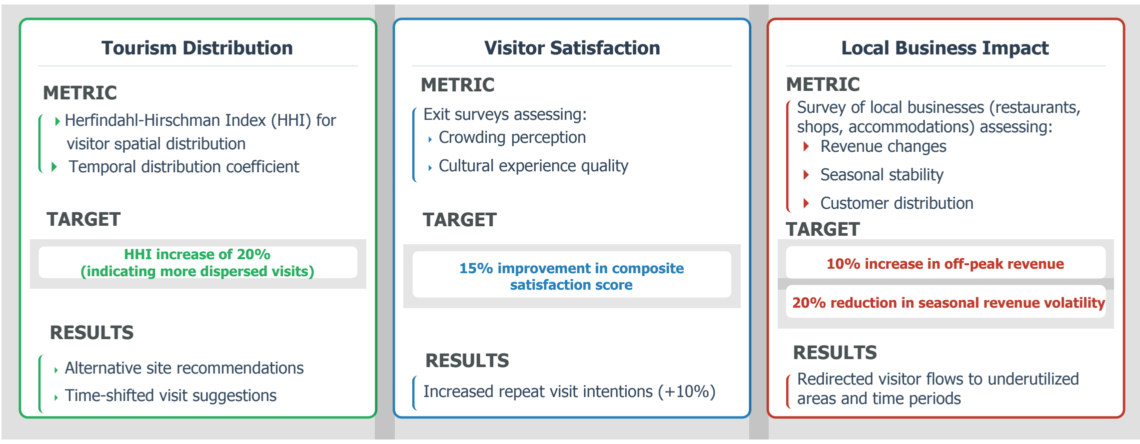


Fig.5 Territorial impact assessment metric

Public administration impact

Public authorities and stakeholders involved in the Citisense approach can derive significant benefits in terms of collective learning. First and foremost, they can obtain datasets which, when combined with an understanding of the specific characteristics, opportunities, and challenges of local territories, can effectively support the scope of public intervention.

The most crucial aspect, however, concerns resource management. Access to a comprehensive dataset serves as a key input for resource allocation, with the goal of improving the quality of smart city services and enhancing citizens' well-being. Commerce, security, public health prevention, and mobility are key dimensions of local governance. The availability of tools derived from personal devices and environmental sensors enables authorities to anticipate service demand in these areas. Consequently, this can lead to more efficient public spending and optimized resource use.

The metrics for assessing this impact should be sought in the improvement of resident and visitor satisfaction (evaluated through specific surveys) and in the wider adoption of data dashboards within public decision-making processes.

7. Conclusions and research perspectives

Technological innovation offers significant opportunities to protect, enhance, and regenerate Italy's historic centres. However, as already emerged from the expected results, the well-being of residents and the environment, as well as the quality of the landscape and cultural heritage, both tangible and intangible, cannot be the simple product of advanced technologies: these must remain tools at the service of communities, not the ultimate goal of urban policies.

The Citisense project, thanks to the combination of explainable AI (XAI), participatory design, and real-time data collection, represents a departure from the traditional Smart Cities paradigm, often criticized for its focus on technocratic and infrastructural solutions at the expense of social and cultural values. The focus on urban well-being, landscape quality, and cultural heritage enhancement is an important step towards context-sensitive and inclusive models of technological innovation.

Most national and international urban transformation/regeneration projects focus on contemporary cities with adaptable infrastructure, while greater attention should be paid to the specific challenges faced by historic centres (particularly small and medium-sized ones). These areas require a delicate balance between preserving cultural heritage and introducing cutting-edge technologies to improve urban management and citizen well-being.

The ability to collect and integrate anonymized personal data from wearable devices, smartphones, and municipal databases allows for the creation of a personalized urban experience. This user-centric approach enables dynamic real-time mapping of public spaces based on user preferences and contextual factors such as weather, safety, and crowding levels. Unlike traditional models, which focus on collecting infrastructure data via large urban sensor networks, innovative methods can be developed that use personal devices to collect information, significantly reducing the need for new sensor installations. This approach not only minimizes infrastructure costs, but also ensures that solutions are scalable and adaptable to different cities without massive investment.

Developing community-based designs with explainable AI (XAI) improves citizen trust and engagement. By involving users in the shared design process, citizens actively shape smart city solutions, ensuring that systems reflect their needs and concerns. The participatory approach of co-design encourages greater user involvement, making citizens key contributors to urban innovation and resource management.

The impacts described in the previous paragraph concern various levels: for individuals, increased perceived comfort and safety; for communities, greater social cohesion and active participation through Living Labs; for territories, more sustainable cultural tourism and new opportunities for local economies; for public administrations, innovative data-based governance tools capable of optimizing resource allocation. Although promising, these prospects also have limitations that require critical reflection:

- Local contextualization: each historic centre has physical, social, and economic characteristics that require tailor-made solutions, avoiding technological standardization that would risk compromising identity and authenticity;
- Balance between conservation and innovation: technologies must be introduced with respect for architectural and cultural heritage, avoiding invasive interventions that alter the perception of the urban landscape;
- Effective participation and transparency: the use of XAI and co-design methodologies is crucial to strengthen citizens' trust and counteract the biases inherent in algorithmic systems;
- Integrated governance and strategic vision: innovation must be part of coordinated urban plans, avoiding fragmentation and dispersion of projects that would reduce their impact.

The research perspectives emerging from Citisense include:

- The construction of conceptual frameworks that integrate cultural heritage, local identity, and digital infrastructure, overcoming the still widespread separation between Smart Cities and the protection of cultural heritage;
- The development of mixed online/offline methodologies to assess the social value of places, capable of capturing the ‘deep values’ of historic centres and guiding more inclusive decisions;
- The development of predictive and explainable AI to support urban decisions on comfort, environment, and tourism, while ensuring interpretability and social acceptability;
- The analysis of overtourism and seasonality dynamics in smaller historic centres, with models capable of suggesting visitor distribution strategies without compromising the quality of life of residents;
- The establishment of public monitoring systems for the long-term impacts of technological solutions, through shared indicators of well-being, sustainability, and heritage quality.

In conclusion, Citisense's main contribution is to show that technology, when integrated into an overall strategic vision and accompanied by participatory practices, can support urban regeneration processes that respect heritage and are oriented towards collective well-being. The biggest challenge is not only to innovate, but to do so in a coordinated manner, avoiding dispersion and fragmentation, and ensuring that innovation is always guided by the common good and long-term sustainability.

Notes

Although the paper is the result of the joint work of the authors, M. Zupi wrote sections 1, 6 and 7, D. M. Tufarelli section 2, A. Bisello section 3, P. Celani sections 4 and 5.3 and D. Sardo sections 5.1 and 5.2.

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Image Sources

Fig.1a and 1b are taken from Burc n. 90 of 22 December 2015, available at the link: https://calabriaeuropa.regione.calabria.it/wp-content/uploads/2024/05/DGR-n_490-del-27.11.2015.-Approvazione-Strategia-Regionale-per-le-Aree-Interne.pdf

Fig.2, 3, 4 and 5 are made by the authors.

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