Participation and Spatial Analysis to make Cities Resilient to Climate Change. The Historic Center of Genoa

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1. Introduction

Climate change is unequivocal and represents one of the most urgent and critical challenges of the 21st century. It results unambiguously from human activities, mainly due to anthropogenic greenhouse gases emissions, leading to a global surface temperature of 1.1C above 1850-1900 during the period 2011-2020. Many of the observed changes are unprecedented, with widespread negative impacts and associated loss and damage to both human and natural systems [IPCC, 2023], including urban areas. Cities have, over time, become a privileged

Climate change represents one of the most urgent challenges of the 21st century; Historic Centers are highly vulnerable to its effects, and, in a scenario of worsening climate regimes, it is crucial to explore innovative methods and tools to promote adaptation to climate change specific to these multi-

risk contexts. However, research in this field is still underdeveloped, especially when it comes to the active involvement of territorial stakeholders in identifying and managing multiple climate-related risks-prone areas. This research paper proposes a methodology for participatory planning processes developed within the EU-funded HERIT ADAPT project aims at analyzing the criticalities affecting Historic Centers and co-planning interventions for the multi-risk adaptation of them to climate change. The application of the methodology to the case study of the Historic Centre of Genoa is presented and first results are reported. The goal is to test and generalize the approach to make it as objective and replicable as possible, by identifying processes and technological tools, as well as categories of data that can be easily found in official databases (e.g. ISTAT data, SIT, Municipal Urban Plans, SECAPs, Emergency Plans, etc.) related to historical urban contexts.

platform for discussion and experimentation on climate change: they cause it -cities account for more than half of the world's population, consume 75 per cent of all energy consumption [UN-HABITAT, 2020] and emit over 70 per cent of greenhouse gases [Mukim et al. 2023]- and bear its impacts. The increased incidence of extreme weather events is the most evident effect of changing urban climate regimes: pluvial and river floods, droughts, heatwaves, storms, both tropical and extratropical cyclones, atmospheric rivers and compound events. Although cities are affected by the same adverse conditions as their surroundings, the coexistence of context-specific factors ends up exacerbating the negative consequences of various climate events and causing even more severe impacts. Along with increasing population density, higher concentration of productive activities, limited soil permeability, etc., the presence of urban cultural heritage also contributes to the particularly unfavorable scenario that cities are confronted with. Urban cultural heritage is to be understood as a common that contributes to the identity and continuity of urban communities. It includes intangible elements, such as traditions, social practices and collective memories, as well as the (tangible) physical features of cities including Historic districts and Centers [Sadowski et al. 2018]. The latter represents a non-renewable resource that embodies the link between the community and space; despite their intrinsic value, today Historic Centers are highly vulnerable to current and future climate-related phenomena, negatively impacting the degree of resilience of the whole city. Such vulnerability is mainly due to their urban, architectural and socio-economic characteristics:

- First, Historic Centers are generally typified by a dense layout: while certain density configurations can enhance factors positively associated with health and life quality (e.g. walkability, accessibility to services, and opportunities for social interaction) [Pont et al. 2023], these same morphologies often suffer from impervious surfaces, acute poor airflow, high thermal mass, etc. and do not allow much room for maneuver where it is necessary to intervene through comprehensive adaptation strategies, such as the re-integration of nature [Tzortzi et al. 2022]. Furthermore, excessive or poorly managed density can generate environmental stressors that can lead to climate-related mortality and morbidity [Cleland et al. 2023].
- Second, materials (generally, but not exclusively: metal, stone, glass, wood and ceramics) and structures in Historic Centers are particularly vulnerable to increased flood frequency and magnitude, as well as wind-related hazards, which initiate mechanisms of corrosion, biological growth, salt crystallization and erosion of materials and related direct impacts (e.g. decay, erosion, collapse of building, etc.); in addition, an increasingly warm and dry climate also leads, on the one hand, to the degradation of materials and, on the other, to soil desiccation and the subsidence of building foundations [Sesana et al. 2021].
- Third, Historic Centers have spatial externalities (e.g. the attractiveness of visitors and tourists, as well as residents, investors, entrepreneurs in the creative industry, etc.); however, this centripetal force concentrates a large number of local economic activities -which often work to preserve local folk traditions- in urban areas where the tension between the conservation of the past and adapting for future needs is palpable [Kourtit et al. 2014].

Against this backdrop, it is more crucial than ever to act proactively and explore innovative methods and tools for promoting multi-risk adaptation of Historic Centers to climate change, considering the context-specific characteristics of the territory in which intervention occurs. Speaking of which, Sabbioni and colleagues [Sabbioni et al. 2010] propose recommendations for planning adaptation interventions to the impacts of climate change and accompany these with management guidelines (e.g. monitoring, maintenance, preparation). More recently, Blavier et al [Blavier et al. 2023] review practical solutions for adaptation to climate change, offering a categorization of such measures into traditional (e.g. façade drips, storm rolls, etc.), adaptive technological (e.g. actively ventilated crawl spaces, seasonal insulation, spaceframe system foundation, etc.), and emerging technological (e.g. solar refrigeration technologies, active cooling systems in crawl spaces, etc.). Rosso and co-workers [Rosso et al. 2023] cluster the (Italian) historic built environment and describe for each proposed category specific combinations of interventions for multi-risk reduction. With a broader perspective, Nicolini [Nicolini, 2024] proposes urban planning strategies to tackle the climate crisis concerning the following urban sectors: energy (e.g. redeveloping public lighting, electrifying the municipal fleet, etc.), buildings (e.g. installing green roofs and walls, designing multi-purpose facilities, etc.), infrastructure and landscape (e.g. waterproofing road surfaces, maintaining and repairing infrastructure, shading public spaces, etc.), transport (e.g. providing different lanes for pedestrians and bicycles, etc.), resources (e.g. storing, filtering and recirculating rainwater, preventing waste, cultivating in urban areas, etc.). Some international organizations also provides inputs regarding soft and cross-cutting actions: ICOMOS [Wilson, 2019] identifies additional variables needed to accompany the implementation of technical adaptation measures: knowledge, understanding and the provision of sectoral leadership are some of the most crucial elements; UNESCO [UNESCO, 2023] clarifies how governance, finance and technological innovation are among the conditions facilitating climate action.

1.1. Research Gaps and Rationale for the Research

Research on multi-risk adaptation of Historic Centers to climate change remains underdeveloped, with several gaps requiring further investigation. First, a clear understanding of climate change impacts, the design of appropriate metrics and monitoring tools, and the development of methodologies that effectively balance conservation and adaptation are among the most frequently identified unexploited potentials in the literature [Orr et al. 2021]. Furthermore, some authors highlight that interdisciplinary, multidisciplinary, and transdisciplinary studies are still underrepresented, limiting the co-production of integrated and nuanced knowledge of climate change phenomena [Nguyen et al. 2023]. Most contributions to date have focused on technical approaches; the question of how to collectively engage territorial stakeholders in identifying disaster-prone areas and in managing and maintaining urban spaces affected by climate-related multi-risk scenarios remains largely unresolved [Akturk et al. 2024]. Enhanced collaboration, however, represents a significant opportunity to more effectively implement climate change adaptation strategies promoted by the international scientific community [Sesana et al. 2018], the EU [EU, 2022], and UNESCO [UNESCO, 2021]. This research paper contributes to this emerging field by proposing a transdisciplinary and participatory methodology for planning processes aimed at analyzing the criticalities affecting Historic Centers, with the goal of co-planning interventions for multi-risk climate adaptation. Furthermore, the methodology is applied within the EU-funded HERIT ADAPT project (Interreg Euro-MED) to the case study of the Historic Centers of Genoa -specifically the buffer zone defined by the UNESCO Site Management Plan "Strade Nuove and the Sistema dei Palazzi dei Rolli"- and presents first results.The rest of the research paper is structured as follows: Section 2 delves into the topic of participation in the adaptation of historic centers to climate change. Section 3 contextualizes and briefly describes the methodology used in this research. Section 4 applies the methodology to the case study. Section 5 draws the main conclusions of the research and highlights opportunities for further improvement.

2. Participation In Adaptation Of Historic Centers To Climate Change

Participation is an umbrella term that encompasses a range of forms of interaction amongst stakeholders in decision-making processes, from informing and listening through dialogue, debate and analysis, to the implementation of jointly agreed solutions [Hugel et al. 2020]. Despite its still blurry conceptual boundaries, participation is comprehensively considered as a key tool in the multi-risk adaptation of Historic Centers [UNESCO, 2017]. The latter is to be understood as the approach for both moderating or avoiding damage caused by current or projected climate, and for exploiting positive opportunities, by considering multiple climate-related hazards in a territory and their potential interactions that contribute to a social or environmental risk. Such hazards may coincide with, trigger, catalyze or hinder the occurrence of other events, etc. [Stalhandske et al. 2024]. It results from the integration between disaster risk reduction and climate change adaptation, which have been lines of research for a long time addressed by very separate scientific communities. Unlike the traditional paradigm in managing climate-related risk in Historic Centers, which is dedicated to top-down and technocratic conservation models, rooted in architectural preservation and hazard-specific mitigation, participatory planning of multi-risk adaptation to climate change is still underexplored. The origin of this approach might be traced down to Agenda21 [UNCED, 1992], which calls for a close collaboration amongst governmental and local authorities, local communities, NGOs and private business for intervening in multi-risk context. And this is further confirmed and deepened in later frameworks. But, still, between the 1990s and 2000s the theoretical and practical integration of stakeholder engagement and multi-risk approach specifically into cultural heritage climate-related planning persists slowly. Perhaps, the real turning point comes only in the 2010s when the Sendai Framework for Disaster Risk Reduction [UNDRR, 2015] provides a forward-looking and action-oriented agenda: it takes up the legacy of precedent agreements, advocates for inclusive multi-risk approaches and highlights the role of cultural heritage in promoting urban resilience to the effects of climate change. It is noteworthy that UNESCO [UNESCO, 2023]: recognizes the urgency of climate change impacts already in the early 2000s; values the role of stakeholder engagement in heritage management practices in the early 2010s; but only recently multi-risk approaches to climate change adaptation and governance are incorporating, revealing a space for experimentation and innovation.

However, scientific literature investigating participatory planning processes and stakeholder engagement in the multi-risk adaptation of Historic Centers to climate change is underrepresented. Despite this, literature plays an essential role in the paradigm shift towards participatory planning of multi-risk adaptation to climate change: it contributes to highlighting how traditional top-down practices often fail to properly deal with the challenges posed by climate change, while participatory approaches prove to enable context-specific solutions and increase the legitimacy of adaptation strategies [Holtorf, 2018]. Indeed, the inclusion of different categories of actors in the decision-making process fosters the knowledge co-production through the systematization of local knowledge and technical and scientific background; from such synergy, the possibility of developing scientifically sound and socially acceptable adaptation strategies is maximized [Fatoric et al. 2019]. According to some authors [Li et al. 2020a], literature dealing with cultural heritage (including Historic Centers) climate-related planning generally introduce local communities as "associated users", supporting functions and meaning of the sites the participatory process focuses on: local identity, sense of belonging, traditions, ownership, custodianship; conversely, Administrations, experts, economic actors and NGOs are generally presented as "facilitators" who support, guide and assist local communities in the decision-making process. To the authors' knowledge, however, no study has yet applied the Quadruple Helix Model [Cai et al. 2022] to the topic as a way of systematizing the stakeholders to engage.

Among action research techniques, questionnaires or semi-structured interviews are the most common, whereby stakeholders are directly involved, particularly in identifying the objective of the participatory process and supervising the study [Pisa et al. 2024]. Beyond consultative involvement, participatory methodologies adopted in risk management contexts are used -albeit to a lesser extent- in more collaborative and co-decision-making forms, such as local labs, scenario workshops, gamified activities often supported by digital tools. Participatory Geographic Information Systems [PGIS/PPGIS] stand out as effective tools, as they enable the mapping of both

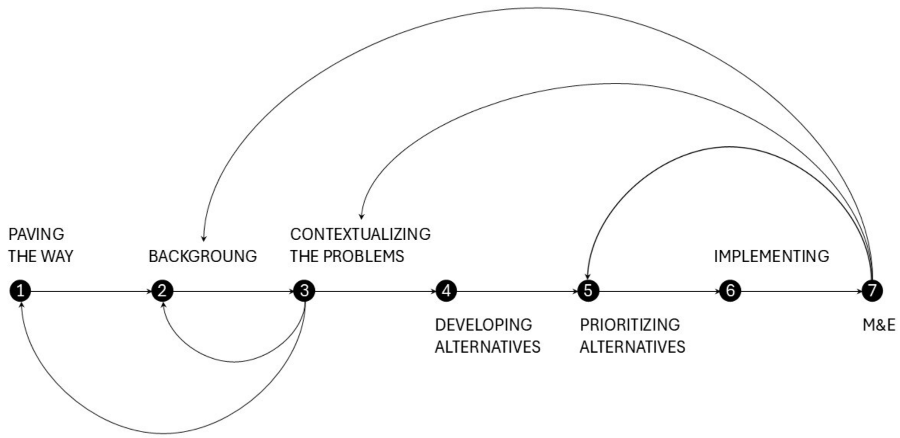
Methodological framework.
Fig. 1

scientific data (for instance, data extracted from planning tools) and local knowledge, lived experience, and perceived risk among stakeholders. In doing so, they provide a continuously updated, participatory planning and decision-support system. Barbi et al. [Barbi et al. 2020] offer a valuable example in this regard: the authors engaged residents in co-designing climate-resilient cultural routes that connected heritage value with environmental awareness, linking heritage preservation with climate adaptation goals. The ResCult project developed a 3D-GIS compliant with INSPIRE standards by combining data on hazards, vulnerability, heritage and stakeholder/user interfaces to facilitate continuous monitoring and preventive planning [Colucci et al. 2022]. Moreno et al. (2024) studied how the use of remote sensing and GIS data can predict subsidence and damage to historic fortifications due to heavy rainfall, also incorporating elements of perceived vulnerability and historical material conditions. Other scholars [Del Espino Hidalgo et al. 2023] experimented with collaborative maps in vulnerable rural areas, where citizens actively participate in building heritage knowledge and identifying environmental and infrastructural criticalities.

Clearly, several challenges remain in implementing participatory planning processes for multi-risk climate change adaptation in Historic Centers. How to effectively integrate the quantitative data typically used in disaster risk reduction and climate adaptation with local knowledge remains an open question. Moreover, there is still limited understanding of how to systematically manage the coexistence of diverse social groups characterized by varying levels of digital literacy, language barriers, and unequal access to information sources. Finally, cultural and institutional inertia continue to undermine efforts toward awareness-raising and co-creation, preventing such initiatives from fully empowering the stakeholders involved [Egusquiza et al. 2023].

3. Methodology

The research paper presents a methodology for participatory planning processes [FAO, 2003] for the analysis of spatial criticalities affecting Historic Centers, to co-planning interventions to adapt to climate change in multi-risk context (Fig.1). To address the gaps highlighted in Section 1.1, this process innovatively enhances the typical steps of heritage management [UNESCO, 2013] with the useful phases of planning urban regeneration projects [Natividade-Jesus et al. 2019], the stages of designing climate change adaptation strategies [ClimateADAPT, 2016] and the cycle of participatory action research [Cornish et al. 2023; Feekery 2024]. It is defined as a flexible yet potentially dynamic set of best practices, capable of responding to developments -often unforeseen- within the specific context of intervention.



3.1. Phase I-Paving the way

Phase I covers all those anticipatory governance actions in support of the participatory planning processes for multi-risk adaptation. It is initially necessary to set up a working group that includes the actors of the Quintuple Helix Model of Innovation -Administration, Business, Academy, Third Sector, Citizenry-thereby enabling the synergistic integration of scientific expertise, public governance, economic actors, and civil society. This approach ensures that resilience strategies address not only technical and infrastructural aspects but also social, cultural, and ecological dimensions, generating contextualized solutions that are accepted, sustainable, and resilient over the long term [Iaione et al. 2022]. High-quality participation is further indicated by engaging already well-established and active networks, provided they are complemented by other skills and actor categories to avoid participation fatigue and the repeated involvement of the "usual suspects". The formation of the working group relies on mapping local actors to determine precisely who should be involved, in what capacity, and for what purpose. Engaging local actors implies the need for careful awareness of the ethical implications of such engagement. Participation should be voluntary and conducted with full respect for the privacy, rights, and autonomy of all participants. Particular attention should be paid to avoiding the reinforcement of existing power imbalances, the marginalization of less visible groups, or the imposition of external agendas. Maintaining ethical vigilance safeguards both the integrity of the participatory process and the trust of the involved actors [OECD, 2022].

The working group is tasked with co-developing a clear work programme, as well as coordinating and monitoring its implementation. Drafting the programme requires several preliminary actions: ensuring that all members are fully informed about the framework guiding the process, i.e. the multi-risk adaptation of Historic Centers to climate change and the added value of participation; homogenizing the degree of perceived environmental risk among group members; aligning members' perceptions of environmental risk; securing political support; reaching consensus on the vision, specific objectives, and targets to be achieved, both in terms of strategic directives and the macro-categories of climate-related risks to address; conducting an ex-ante assessment of the necessary (financial, human and technical) resources; defining a timetable, thematic sub-groups, and a clear division of responsibilities. These tasks can be effectively carried out through dedicated workshops conducted in a hybrid format, combining in-person and remote participation. Hybrid settings often encounter technological barriers and imbalances in participation between online and onsite attendees. To overcome these challanges, it is essential to ensure the use of equitable and inclusive interaction tools, such as web-based platforms like Mentimeter (successfully employed within the SUSTAINadapt project) and Wooclap (effectively applied within the EU City Lab project). These platforms provide virtual environments that can be accessed without the need for login credentials, using either an alphanumeric code or a QR code, and allow participants to engage anonymously. This feature encourages immediate involvement through some of the most established participatory techniques (such as polls, brainstorming, and cognitive mapping) which can be easily managed and used by both in-person and remote participants. Furthermore, these tools offer instant and continuously updated visual representations of participants' inputs, creating a dynamic foundation for in-depth intra-group discussion. Interspersing the use of digital platforms with structured opportunities for oral discussion is essential to avoid superficial responses that overlook the complexity of the phenomena under examination and to promote deeper qualitative interaction. The latter are among the most significant limitations, in addition to potential difficulties arising from limited familiarity with the tools, which may result in initial time loss and participant frustration.

3.2. Phase II-Background

Phase II intends to collect all data necessary for the definition of strategic actions for multi-risk adaptation. In alignment with the work programme, the working group identifies and agrees upon the data generation methods that best correspond to the specific objectives of the process. Subsequently, the group undertakes the collective collection and documentation of data relevant to the case study. The first step is to consult existing planning tools and urban policies from which to extract raw data relating to socio-economic (ISTAT and Municipal Urban Plan), environmental (River Basin Plan, SECAP, Landscape Plan and other sector plans and strategies) and territorial governance dimensions; climate trends (considering hazards), the impacts of climate change and the propensity of the case study to suffer damage (calculating vulnerability), the environmental and local actors conditions (assessing vulnerability and exposure); and the adaptation measures already in place or planned (preventing maladaptation) can be consulted in the SECAP, in the Civil Protection Plan or in further plans approved ad hoc. This can be done collaboratively among the members of the working group in a brainstorming session [ISPRA, 2013], but care must be taken to prevent loss of focus or dominance by some participants, which could marginalize others' contributions. It is also essential to activate a cycle of on-site visits and participatory walks [Evans et al. 2011] to engage additional local actors - not formally part of the working group- met on the territory in an unpremeditated way [consult the ClimateGO project]. These latter are conducted by a thematic subgroup and involve the collection of qualitative and quantitative indicators selected ad hoc for the multiple risks identified in Phase I. However, systematically recording and organizing field observations can be challenging, particularly when multiple participants contribute simultaneously. The on-site visits represent the opportunity to collect photographic material to support the documentation of spatial conditions and highlight the specific characteristics of the context. Participatory walks enable the collection of contextual information that helps to fill the gaps often found in data obtainable from official public databases. They add interpretive depth to previously conducted analyses by incorporating the local knowledge and lived experiences of community members. Nevertheless, it should be acknowledged that the individuals encountered along the route represent a non-representative subset of local stakeholders. Their perceptions are also likely to be context-dependent, for instance influenced by weather or immediate environmental conditions.

3.3. Phase III-Contextualizing the problems

Phase III involves interpreting the data to identify criticalities and opportunities, which are to be addressed and leveraged, respectively, in the subsequent phase of developing alternative solutions. In participatory planning processes, it is essential to triangulate the collected data -that is, to integrate and harmonize qualitative and quantitative methods and/or data sources- to enhance the understanding of phenomena and validate interpretations [Hanson-DeFusco, 2023]. To complement technical studies on planning tools, online questionnaires are among the most widely used techniques in participatory planning processes. To administer them, it is necessary to rely on platforms for designing anonymous online questionnaires such as LimeSurvey and GoogleForm [tested in the RAINMAN and STRENCH projects, respectively]: allow questionnaires to be customized using a wide range of question types, enabling efficient data collection and analysis. Moreover, being open-source software, they offer a high degree of flexibility and adaptability to specific research needs. Although questionnaires may at times flatten the depth and nuance of the responses obtained, their use nonetheless represents one of the most efficient and scalable tools available for gathering structured information. Conducting a series of semi-structured interviews with experts in specific sectors represents a time-efficient approach to obtaining relevant information too. Despite the difficulties inherent in comparing and standardizing the collected information, such interviews substantially improve comprehension of the territory and the dynamics that shape it. Phases II and III are closely interconnected and are presented here in chronological order solely for conceptual clarity. In practice, however, participatory planning processes are highly iterative, and these phases often overlap and become indistinguishable, as stakeholder engagement frequently involves working with already processed data. To capture a snapshot of the case study, the working group members may conduct a PPGIS session in which they collaboratively create a shared map highlighting localized or areal criticalities related to the multiple macro-categories of risk defined during Phase I. Technological barriers for non-expert participants constitute a significant limitation, which can be mitigated by providing facilitator support and ensuring that the map includes reference landmarks for spatial orientation, as well as pre-processed information derived from existing planning tools and urban policies. Google-MyMaps represents an effective tool for this purpose (as already employed within URCA! and ADAPT projects). It is user-friendly even for participants whose digital literacy is limited to everyday tasks; it allows downloading data gathered via participation in formats directly importable into Geographic Information Systems [GIS], tools extremely useful at this stage of the process (and subsequently) to robustly manage datasets subjected to recurring changes, visualize through multi-level representations of a large number of spatial data for urban planning purposes and develop models to thoroughly characterize the case study. An important consideration, which also guides the subsequent selection of multi-risk adaptation alternatives in Phase IV, is the degree of elasticity inherent in the planning process. This involves identifying, a priori, the barriers imposed by key legal, regulatory, and political frameworks that influence climate change adaptation in multi-risk contexts. A practical approach to achieve this is through a participatory SWOT analysis, which can generate a structured database of strengths and weaknesses (arising from within the case study) and threats and opportunities (emerging from external factors) to guide planning strategies [Tavares et al. 2021]. It is crucial to ensure that the use of SWOT does not devolve into a superficial or overly cursory listing of factors but rather facilitates in-depth reflection and critical discussion.

3.4. Phase IV-Developing alternatives

Phase IV entails the compilation of a catalogue of relevant adaptation options, building on the insights generated in Phases II and III. To this end, the working group collaboratively collects good practices, which may be sourced from scientific and grey literature, emerge from innovative combinations of traditional actions, or consist of original and novel interventions (consult the ADRISEISMIC project). Each participant enters in a shared spreadsheet the good practices of his knowledge, categorized by: typology (plans and strategies, processes, technologies, other); objectives and expected results; applicability and adaptability to the case study. It is then possible to set up a shared spreadsheet in which each participant -within a workshop or autonomously- can enter good practices, categorized by type (plans and strategies, processes, technologies, others); objectives and expected results; applicability and adaptability to the case study. In this context, GoogleSheets (a platform not previously employed in participatory planning workshops) can be effectively utilized, as it demonstrates many of the advantages of GoogleMyMaps (see subsection 3.3). A key factor for the success of these methods, particularly when collaborating with stakeholders during regular office hours, is to make access links to the shared map and spreadsheet available for a flexible period. This approach allows data to be integrated at a later stage, including contributions from absentees or collaborators who join subsequently. This flexibility, while beneficial, may lead to unintentional alterations or data loss, and therefore requires careful oversight and clearly established guidelines.

3.5. Phase V-Prioritizing alternatives

Phase V encompasses all assessments carried out to propose a hierarchy of multi-risk adaptation alternatives, indicating their recommended sequence of implementation. From a multi-risk perspective, it is essential to examine the interrelationships among the pool of good practices, the macro-categories of climate-related risks identified in Phase I, and other projects already approved by public authorities. The objective is to ensure that the implementation of any specific action does not undermine the effectiveness of other policies or projects, contribute to maladaptation, or exacerbate the vulnerability of Historic Centers to additional risks. These aspects can be explored in a brainstorming session facilitated through Miro platform (used as part of the Climatactions project) which provides participants with a versatile and collaborative digital workspace. Its whiteboard enables real-time interaction, fosters visual thinking, and improves coordination among geographically distributed teams. The use of pre-structured templates, clearly defined roles and timelines, and a final synthesis phase with all participants helps mitigate risks of data dispersion

a) national level: Italy;
b) regional level: Liguria;
c) municipal level: Genoa;
d) the case study perimeter (buffer zone).
Fig. 1

or loss. At this stage of the process, the participants can implement a territorialization of the proposed alternatives on a shared map; in this PPGIS activity, the marked points may represent specific interventions, and the polygons may be broader infrastructural or social policies, programmes or interventions. Comparing solutions through environmental, social and economic benefit-cost analysis is ultimately the responsibility of Public Administration and other actors contributing to financing multi-risk adaptation action. In this case, you can consult the experience developed within the BASE project.

3.6. Phase VI-Implementing

Phase VI corresponds to the operational phase, which involves drafting, reviewing, and approving a clear Action Plan to be integrated into urban policies and planning tools.

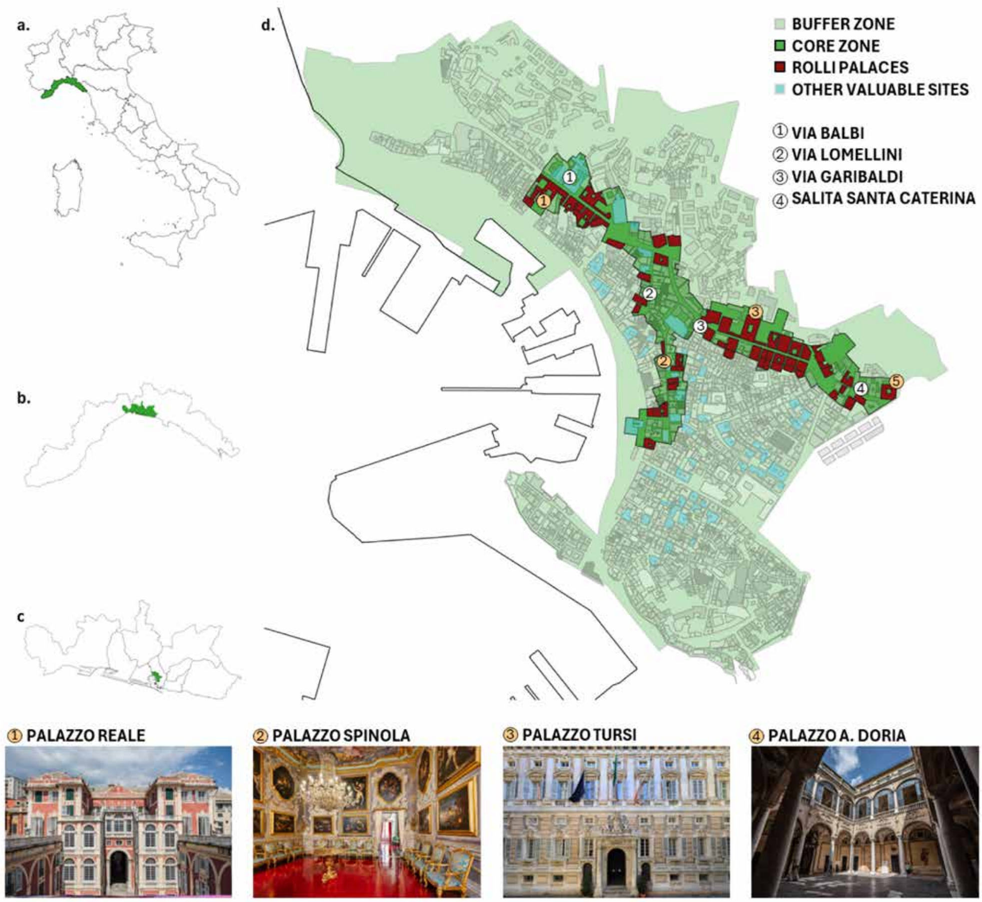
3.7. Phase VII-Monitoring and Evaluation

Phase VII involves the development of a monitoring and evaluation approach, the use of maintenance mechanisms, process improvement and continuous learning. The monitoring and evaluation of co-planned multi-risk adaptation actions can be carried out through the participatory application of a system of qualitative and quantitative indicators, which encompass process indicators (tracking the implementation of adaptation measures), outcome indicators (assessing the direct effects of these measures), and impact indicators (evaluating long-term changes in urban resilience), thereby combining local knowledge with scientific assessments to ensure relevance and effectiveness [Feldmeyer et al. 2019]. Establishing a shared data collection platform, digital or physical, for working group members and partially for public access, is desirable to promote transparency and ensure the traceability of information. This phase also encompasses the transparent dissemination of project results through both institutional and informal channels of the working group members. It includes identifying public meetings and press conferences during which intermediate results of the process can be communicated.

4. Application

4.1. Case Study: Strade Nuove and the Sistema dei Palazzi dei Rolli

The selected case study is the Historic Center of Genoa and, more specifically, the buffer zone defined by the Management Plan of the UNESCO Site "Strade Nuove and the Sistema dei Palazzi dei Rolli". Genoa is a medium-sized city (24,013 ha) located in northern Italy and 2022 data state that it hosts a population of almost 566,410 thousand (density of 94 inhabitants/ha in urban areas) (Fig.2a-b) [ISTAT, 2023]. According to the Kopper-Geiger climate classification, the city belongs to the Mediter-



ranean CSA zone, characterized by a temperate climate with hot and dry summers (total annual rainfall and maximum daily temperature are: 1340 mm; 19 °C on average). In 2024 Genoa is the second major Italian city most affected by the climate change effects while Liguria is the first region for number of extreme events recorded per km^2, i.e. 1/319 km^2 [Legambiente, 2024]. Due to its morphology, Genoa is mainly subjected to: floods, where soil sealing is high and urban development interferes with the characteristics of watercourses; heatwaves, where most of the elderly population is concentrated; windstorms, in correspondence with built environments undergoing maintenance, with decorations, overhangs, etc.; storm surges, especially in correspondence with urbanized coastlines; wildfires near peri-urban forests, Mediterranean scrub and cultivated fields [SECAP, 2020]. As far as the urban environment is concerned, the Historic Center of Genoa represents a hotspot and an interesting urban lab for experimenting with multi-risk approaches: the city has an old age index -i.e. the ratio between the population aged 65 or over and the 0-14 age group- equal to 249, 84 units higher than the national average and the population over65 is concentrated mainly in densely populated areas, including the Historic Center; the city hosts 40% of the foreign population of the entire region who live predominantly in the Historic Center and

Participatory planning process for multi-risk adaptation.

Tab. 1

in a few other border neighborhoods; tourism is one of the municipal driving economic sectors and the Historic Center is a gathering area for various tourist flows; among the various elements on exposure, the Historic Center also has tangible cultural heritage to be adequately conserved in light of the increasingly pressing effects of climate change.

The Historic Center of Genoa is one of the largest medieval centers in Europe (about 198 ha) and is made up of the districts Prè-Molo-Maddalena (about 113 ha) and the historic port area (85 ha), for a total of about 23,000 inhabitants (Fig.2c). It is characterized by a predominant medieval settlement structure (12th-13th century), still recognizable in the pace of the building parcels and in the architectural features of the buildings, which leads to a high density with an overall volume of approximately 10,000,000 m^3. Yet, the Historic Center shows a certain degree of urban heterogeneity, given the local custom of building on already existing structures, the numerous architectural modifications carried out during periods of economic prosperity and growth of the city, the interventions on the road network, the reconstructions following the bombings by the French fleet in 1684; the repression carried out by the Savoy of the independence movements of 1849; the attacks by the allies in the Second World War. A more recent notable transformation -dating back to the last three decades- takes place since the redevelopment of the waterfront in 1992 (International Exhibition) with the consequent repurpose of buildings originally intended for port warehouses and the enhancement of both the piers and the surrounding public spaces. This revitalization is mainly dictated by the contraction of employment in the port sector and the crisis of maritime passenger transport, with consequent depopulation of the urban area (in favor of public housing in the hilly neighborhoods) and an increase in social, building, architectural and urban degradation. The urban planning strategy is to guide the city in the dismantling-delocalization of industrial activities and promote a new tourist vocation. In doing so, the Historic Center is suffering from the gentrification of some areas and the consequent social exclusion of the weakest and most marginal groups; therefore, in addition to a certain climatic vulnerability and urban complexity, the Historic Center also shows a certain degree of social complexity, both in terms of residential and fruition [PUC, 2015].

In line with the revitalization of the Historic Center (1990s-the early 2000s), the reorganization of cultural circuits and the valorization of the tangible cultural heritage also take place. including the inscription of the Site "Strade Nuove and the Sistema dei Palazzi dei Rolli" on the World Heritage List in 2006. The Site represents the first example in Europe of an urban development project parceled out by a public authority in a unitary framework and

Method	Setting	Goals	Techniques	Tools	Actors
I Workshop	In presence	Co-designing the adaptation process	Presentations	Power Point	Quintuple Heix Model
			Polls	Wooclap	
			Brainstorming	Wooclap	
II Workshop	Remotely	Background and contextualizing	Presentations	Power Point	Quintuple Heix Model
			Community mapping	Google MyMaps	
			Good practices	Google Sheet	
I Interview	Remotely	Contextualizing	Semi-structured interview	Microsoft Teams	Local Administration Academia
II Interview	Remotely	Contextualizing	Semi-structured interview	Microsoft Teams	Academia
On-site visits	In presence	Contextualizing	Indicator-based site inspection	Photographic support	Academia
Survey	Remotely	Contextualizing	Participatory SWOT	LimeSurvey	Quintuple Heix Model
III Workshop	Remotely	Planning and prioritizing alternatives	Presentations	Power Point	Quintuple Heix Model
			Brainstorming	Miro	
			PPGIS	Google MyMaps	

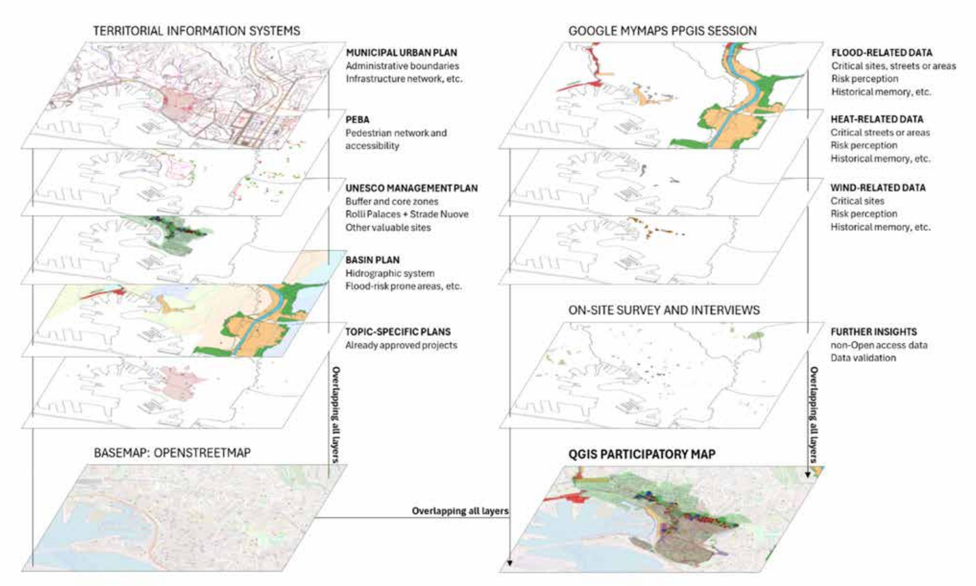
associated with a particular network of private residences intended to host state visits: these residences (accommodation of the most powerful aristocratic families of the then Republic of Genoa), according to a decree of 1576, are in fact classified by the value of the land and the quality of the building and divided into three categories; each of them corresponds to a different degree of dignity of the visitors, including ambassadors, dignitaries, sovereign princes, popes and emperors. The Site includes 42 Renaissance and Baroque palaces -Rolli- along the streets with the highest concentration of noble residences, namely Via Garibaldi, Via Balbi, Via Lomellini and Salita Santa Caterina (Fig.2d). The buildings, generally three or four floors high, are characterized by spectacular staircases, courtyards and loggias overlooking gardens, built on different levels in a relatively small space. The buildings offer an extraordinary variety of different solutions and achieve universal value by adapting to the peculiar characteristics of the Historic Center of Genoa and to the needs of a specific social and economic organization.

In this context, the EU-funded project HERIT ADAPT aims at strengthening the resilience of tourist destinations in the Euro-Mediterranean area, increasing the capacity to adapt and mitigate the risks of urban natural and cultural heritage related to tourist overflow and climate change.

4.2. The Participatory Planning Process for Multi-Risk Adaptation

The research was carried out by activating a participatory process and applying specific engagement techniques for participatory spatial analysis to make cities -and Historic Centers- resilient to climate change (Tab.1).

A 1st Workshop was organized to pave the way (Phase I). The established working group included the following categories of stakeholders: local, regional and national administrators; the local Chamber of Commerce; trade associations; private businesses; the University; foundations and cultural associations operating in the territory; representatives of the citizens. The composition of the group aligned with the Quintuple Helix model of Innovation



and drew on the Management Committee of the UNESCO Site of Genoa, a formalized body previously tested and subsequently expanded within this participatory planning process for multi-risk adaptation of the Historic Center, encompassing the following profiles: technical experts in sustainable tourism management and/or climate change adaptation; and professionals in urban planning and facilitation of participatory planning processes. The University of Genoa took on the role of facilitator of the process; Administrations, public bodies and private companies that of supporters and financiers; Third Sector bodies and citizenry that of gatekeepers and end users. An instant poll conducted via Wooclap to assess participants' perceptions of the case study's resilience to climate change revealed a lack of consensus: 50% of working group members considered the territory already resilient. The direct poll was introduced briefly and subsequently served as a starting point for more in-depth reflections, thereby overcoming the potential limitation of oversimplifying complex issues. From these reflections, the need to organize capacity-building activities and to engage specialized expertise in climate change adaptation emerged. Subsequently, the group identified the most widespread hazards in the territory, categorizing them into three macro-groups: hydraulic, wind-related, and heat-island risks. This task was addressed during a brainstorming session, in which the risks of topic dispersion or dominance by certain participants were mitigated through several measures: setting a maximum time for individual interventions and encouraging contributions grounded in information available from existing planning tools. Notably, the outcomes of this session were consistent with the municipal Action Plan for urban resilience. Finally, the group planned several information dissemination actions, including the preparation of targeted press releases for distribution through the official websites of participating stakeholders and participation in relevant international events.

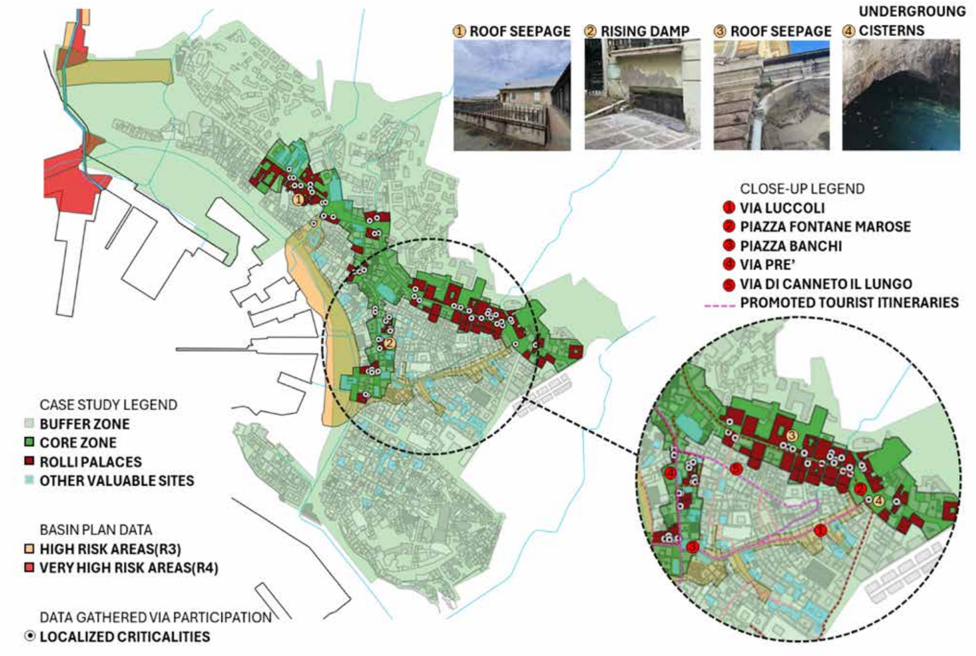
A 2nd Workshop was held (Phase II and III),

The co-mapping procedure. As outlined in the text, this figure conceptually depicts the overlap within the GIS environment of data obtained from technical sources as well as non-technical sources.
Fig. 3

and a capacity building activity was provided regarding the adaptation of Historic Centers to multiple risks through brief presentations by ad hoc experts. Based on the new knowledge acquired, the members of the working group co-produced a participatory map of the localized and areal criticalities related to hydraulic, wind-related and heat-island risks. As described in Section 3.3, the PPGIS activity was implemented using the GoogleMyMaps platform. No technological barriers or usability issues were reported by non-expert participants. In some cases, participants experienced cognitive fatigue and a temporary loss of attention. To address this, the link to the shared map was kept available for a pre-agreed period, allowing all workshop participants to contribute data at a later stage.

Subsequently, the georeferenced information collected during the workshop was downloaded from GoogleMyMaps and as shown in Figure 3, integrated with other datasets in QGIS.

As shown in Figure 3, OpenStreetMap was set as the base map in QGIS. The datasets derived from existing planning tools -as reported directly by the working group during a brainstorming session (1st Workshop)- were then added. These included, for example, the Municipal Urban Plan, the Plan for the Elimination of Architectural Barriers (PEBA), the UNESCO Management Plan, the Basin Plan, and several sectoral plans. Up to this stage, the mapping process reflected the current state of affairs, based on the knowledge already held by the Public Administration. Subsequently, the layers produced during from the PPGIS activity with GoogleMyMaps were incorporated. Participants identified critical sites, roads, and areas, but more importantly, they spatialized their perceptions of risk and historical memory. This information was then integrated with findings from on-site visits, participatory walks and interviews. During the on-site visits, photographic material was collected to validate data obtained from other sources. In the participatory walks, non-preselected local stakeholders accompanied the technical team through the study area, jointly reflecting on past events and on bottom-up self-protection strategies. Interviews were conducted remotely in a semi-structured format. Two experts on the Historic Center of Genoa were involved: one senior official from the public administration and one researcher from the local university. These profiles were selected based on internal discussions within the working group and according to their specific expertise (convenience sampling). The interviewer prepared only two guiding questions: Which places are the most critical in terms of hydraulic, wind-related and heat-island risks, and why? and What are the reasons for these criticalities, and how has action already been taken or is planned to be taken? After initial transcription, the data were georeferenced and incorporated directly into the GIS environment.

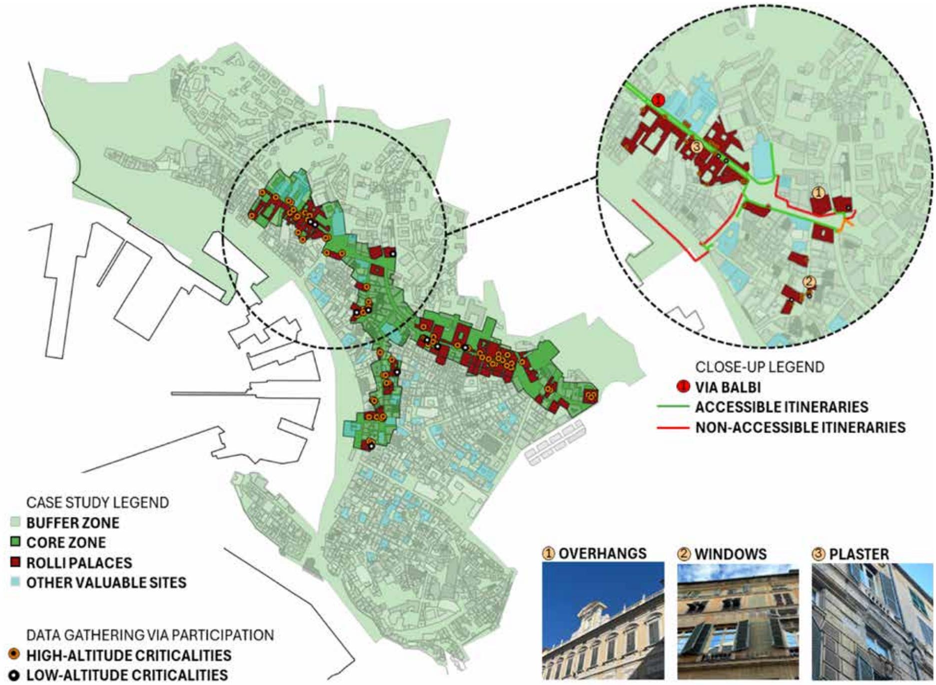


Georeferenced participatory map of criticalities concerning hydraulic risk.
Fig. 4

In terms of hydraulic risk, the areas identified as critical were Via Luccoli, Piazza Fontane Marose, Piazza Banchi, Via Prè, and Via di Canneto il Lungo, primarily due to rainwater flow, aligning with the risk areas highlighted in the Basin Plan. A notable concern is that these areas intersect pedestrian tourist routes promoted by the Municipality of Genoa, increasing exposure during peak tourist seasons. Localized criticalities were especially evident near the Palazzi dei Rolli and historic villas, which feature exposed lower floors, deteriorating roofs, blocked drains, and impermeable surrounding pavements. Figure 4 illustrates the georeferenced participatory map of hydraulic risk criticalities.

Regarding wind-related risk, mapped critical elements included overhanging features above roofs and balconies, severely degraded window and door frames, and detached or raised slabs in relief decorations, plasters, or stone coverings. Via Balbi was identified as one of the most critical areas, experiencing high pedestrian traffic from residents and tourists due to its role as a key intermodal transport corridor near the central station and multiple bus, metro, and vertical lift stops. It is also one of the few streets currently recognized by PEBA as accessible to people with psychomotor limitations. Figure 5 shows the georeferenced participatory map of these criticalities.

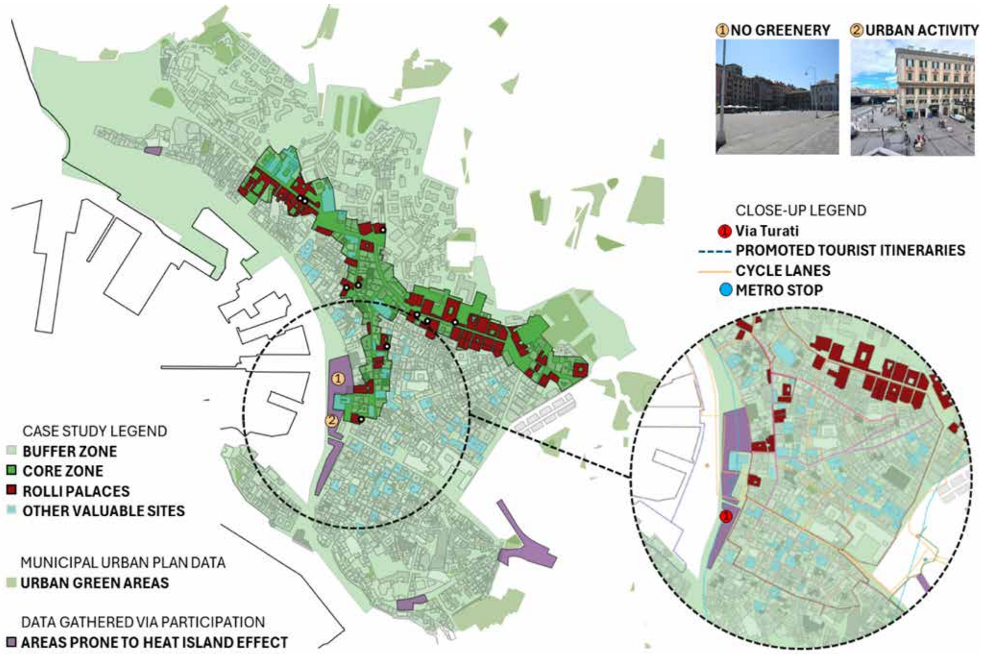
For the macro-categories of risk "heat-islands", areas such as Piazza della Commenda, Piazza Caricamento, Via Turati, Piazza Sarzano, and Via Dante were mapped as particularly prone to elevated summer temperatures. Via Turati



Georeferenced participatory map of criticalities concerning wind-related risk.
Fig. 5

warranted special attention due to heavy vehicle traffic, impermeable surfaces, and the absence of shading (neither natural nor artificial), despite its importance for residential, commercial, and tourist activities, as well as its cultural heritage and role in the city's soft mobility network. Figure 6 shows the georeferenced participatory map of criticalities concerning heat-island risk.

Best practices (Phase IV) were determined based on territorial analysis, resulting in participatory maps (Figs. 4, 5, 6) and further elaborated during brainstorming sessions in the 2nd Workshop with GoogleSheets and the 3rd Workshop with Miro. The use of these platforms involved a significant initial learning curve. Reliability of the data was maintained through effective facilitation and by keeping platform access links active for a pre-determined period, enabling participants to contribute as needed. The most frequently suggested categories of alternatives of solution were: 1_Awareness and training of stakeholders, beginning with commercial operators and non-technical staff, focused on the main criticalities (such as impermeable roads, exposed ground floors, and commercial activities) and on adaptation and self-protection measures; 2_Scheduled maintenance of interventions, including the use of innovative technological tools such as periodic photographic monitoring and reality-based 3D modelling, with shorter intervals between maintenance cycles; 3_Climate-proofing of road surfaces in compliance with historical and monumental heritage, aiming to reduce surface runoff and heat-islands



Georeferenced participatory map of criticalities concerning heat-island risk.
Fig. 6

while improving accessibility. At the strategic level, priorities included seeking external (national or international) funding, ensuring coherence with existing planning tools, and creating synergies with ongoing projects.

Prioritization of solution alternatives (Phase V) was carried out primarily according to the following criteria: focusing on the areas of the case study most affected by criticalities identified in Phase IV; considering projects and policies already approved or under implementation; evaluating environmental, social, and economic cost-benefits; and taking into account the constraints imposed by planning tools and urban policies. As a first solution, the working group agreed to focus on the Museo d'Arte Orientale E. Chiossone—one of the most important collections of Oriental art in Europe—located in Villetta Di Negro, on the western side of the UNESCO buffer zone in Genoa. The group decided to enhance the visibility of the museum and Villetta through the installation of vertical and horizontal signage along the most congested and adjacent historic streets, and by integrating recommended accessible routes on official public websites, thereby providing populations exposed to heat-island risk with usable alternatives to the most critical areas (see Fig.6). The working group further decided to improve the museum's climatic adaptation, addressing the absence of an air-conditioning system that adversely affected artefact conservation and visitor experience. Measures included installing climate control systems in showcases containing the most vulnerable artefacts and engaging start-ups to create digital scans and digital twins for 3D modelling.

5. Conclusions And Future Prospects

This research paper presents a methodology grounded in technological tools and processes, utilizing data readily available from official sources. In the coming months, multi-risk climate adaptation measures will be implemented in the Historic Center of Genoa and their effectiveness systematically assessed. The research will additionally examine the participatory planning process as a driver of innovation and collaborative resilience in Historic Urban Centers.

Overall, the main limitations of the participatory process included cognitive fatigue and attentional lapses, especially during remote sessions. Although activities were clearly introduced, rules were explained, digital and verbal interactions were alternated, and techniques were diversified, engagement was not always maintained. Workshops conducted during working hours may have exacerbated this issue, as participants were subject to workplace distractions. Additionally, map development relied on currently available data and did not integrate novel scenario analyses. Future research could explore cross-referencing the generated maps (Figs. 4–6) with data from initiatives such as the SEAGUL platform, addressing social inclusiveness and economic development, and the ReMED platform, focused on climate adaptation measures in Genoa.

Author Contributions

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